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Environmental Assessment

Davis Canyon Site, Utah

Volume I

May 1986

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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FOREWORD

The Nuclear Waste Policy Act of 1982 (the Act) established a process for the selection of sites for the disposal of spent nuclear fuel and high-level radioactive waste in geologic repositories. The first steps in this process were the identification of potentially acceptable sites and the development of general guidelines for siting repositories. In February 1983, the DOE identified nine sites in six States as potentially acceptable for the first repository. The Davis Canyon site in San Juan County, Utah, was identified as one of those sites. The general guidelines were issued in November 1984 as Title 10 of the Code of Federal Regulations, Part 960. The DOE is now proceeding with the next step in the site-selection process for the first repository: the nomination of at least five of the nine potentially acceptable sites as suitable for site characterization, which is a program of detailed studies.

The Act requires that site nomination be accompanied by an environmental assessment (EA). The DOE has prepared EAs for the nominated sites through a process that provided opportunity for public input. Public hearings were held during March, April, and May 1983 to obtain recommendations on the issues to be addressed in an EA. All such recommendations were considered in preparing the EAs. The DOE issued draft EAs for public review and comment in December 1984 and conducted a series of public hearings in February and March 1985. The issues raised in the comment letters and hearings were considered in preparing the final EAs. These issues are addressed in a comment-response document appended to the final EAs (Appendix C).

The information presented in the EAs is derived from hundreds of technical reports containing more-detailed data and analyses. All of these reference documents are available to the public in various libraries and reading rooms; a listing of their locations is given in Appendix B.

After the nomination, the Secretary is required by the Act to recommend to the President not fewer than three of the nominated sites for characterization as candidate sites for the first repository. This recommendation will be submitted and documented in a separate report that is being issued separately from this environmental assessment. After submittal, the Act provides the President 60 days to approve or disapprove the candidate sites. The President may delay his decision for up to six months if he determines that the information supplied with the recommendation of the Secretary is insufficient to permit a decision within the 60-day period. If the President does not approve, disapprove, or delay the decision, the candidate sites shall be considered approved. After the President approves the candidate sites, the DOE will start site characterization.

ABSTRACT

In February 1983, the U.S. Department of Energy (DOE) identified the Davis Canyon site in Utah as one of the nine potentially acceptable sites for a mined geologic repository for spent nuclear fuel and high-level radioactive waste. To determine their suitability, the Davis Canyon site and the eight other potentially acceptable sites have been evaluated in accordance with the DOE's General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. These evaluations were reported in draft environmental assessments (EAs), which were issued for public review and comment. After considering the comments received on the draft EAs, the DOE prepared the final EA.

The Davis Canyon site is in the Paradox Basin, which is one of five distinct geohydrologic settings considered for the first repository. This setting contains one other potentially acceptable site--the Lavender Canyon site. Although the Lavender Canyon site is suitable for site characterization, the DOE has concluded that the Davis Canyon site is the preferred site in the Paradox Basin. On the basis of the evaluations reported in this EA, the DOE has found that the Davis Canyon site is not disqualified under the guidelines.

Futhermore, the DOE has found that the site is suitable for site characterization because the evidence does not support a conclusion that the site will not be able to meet each of the qualifying conditions specified in the guidelines. On the basis of these findings, the DOE is nominating the Davis Canyon site as one of five sites suitable for characterization.

TABLE OF CONTENTS

	Page
FOREWORD	iii
ABSTRACT	v
EXECUTIVE SUMMARY	1
1 PROCESS FOR SELECTING FOR SITES GEOLOGIC REPOSITORIES	1-1
1.1 Introduction	1-1
1.1.1 The geologic repository concept	1-1
1.1.2 The Nuclear Waste Policy Act of 1982	1-2
1.1.3 The environmental assessment	1-3
1.2 Summary of the overall decision process	1-5
1.2.1 Site screening	1-5
1.2.2 Salt sites	1-7
1.2.2.1 Salt domes in the Gulf Coast Salt dome basin of Mississippi and Louisiana	1-8
1.2.2.2 Bedded salt in Davis Canyon and Lavender Canyon, Utah	1-9
1.2.2.3 Bedded salt in Deaf Smith and Swisher Counties, Texas	1-10
1.2.3 Sites in Basalt and Tuff	1-11
1.2.3.1 Basalt lava in the Pasco Basin, Washington	1-11
1.2.3.2 Tuff in the Southern Great Basin, Nevada	1-12
1.2.4 Nomination of sites for characterization	1-14
1.2.5 Final steps in the site-selection process	1-15
1.3 Evaluation of potentially acceptable sites against the disqualifying conditions of the guidelines and grouping into geohydrologic settings	1-16
1.3.1 Evaluation against the disqualifying conditions	1-16
1.3.2 Diversity of geohydrologic settings and types of host rock	1-16
1.3.2.1 Geohydrologic classification system	1-17
1.3.2.2 Distinct differences among the geohydrologic settings and host rocks	1-19
References for Chapter 1	1-22
2 SITE SELECTION PROCESS - PARADOX BASIN	2-1
2.1 Geohydrologic setting	2-1
2.2 Identification of potentially acceptable sites	2-4
2.2.1 Region-to-area screening	2-4
2.2.2 Area-to-location screening	2-7
2.2.3 Identification of potentially acceptable sites in the Gibson Dome location screening	2-11
2.3 Disqualification evaluation of the potentially acceptable sites	2-14
2.4 Comparative evaluation of potentially acceptable sites within the Paradox Basin geohydrologic setting, and selection of the preferred Paradox Basin site	2-14

TABLE OF CONTENTS (Continued)

Page

2.4.1 Evaluation of Paradox Basin postclosure distinguishing site characteristics and discriminating Technical Guidelines 2-22
2.4.2 Evaluation of Paradox Basin preclosure discriminating Technical Guidelines 2-22
2.4.2.1 Preclosure radiological safety guideline group 2-22
2.4.2.2 Environmental, socioeconomic, and transportation guideline group 2-24
2.4.2.3 Ease and cost of siting, construction, operation, and closure guideline group 2-26
2.4.3 Preferred Paradox Basin site 2-27
2.5 Chapter 2 references 2-29
2.5.1 References listed by author 2-29
2.5.2 Federal regulations and statutes 2-30

3 THE SITE 3-1
3.1 Location, general appearance and terrain, and present uses . . 3-1
3.2 Geologic conditions 3-5
3.2.1 Regional geology 3-5
3.2.2 Geomorphology 3-7
3.2.2.1 Physiography 3-7
3.2.2.2 Erosion processes 3-7
3.2.2.3 Influence of joints on drainage pattern 3-22
3.2.2.4 Paleoclimate 3-23
3.2.3 Stratigraphy 3-25
3.2.3.1 Regional stratigraphic history of the Paradox Basin 3-25
3.2.3.2 Site-specific stratigraphy 3-32
3.2.3.3 Thickness, lateral extent, and characteristics of the host rock 3-40
3.2.4 Paleontology 3-48
3.2.5 Structure and tectonics 3-48
3.2.5.1 Faulting 3-56
3.2.5.2 Seismicity 3-62
3.2.5.3 Igneous activity 3-66
3.2.5.4 Uplift, subsidence, and folding 3-66
3.2.5.5 Salt flow and diapir development 3-68
3.2.5.6 Dissolution 3-71
3.2.5.7 Jointing 3-73
3.2.6 Rock characteristics 3-79
3.2.6.1 Geomechanical properties 3-79
3.2.6.2 Thermal properties 3-98
3.2.6.3 Natural radiation 3-98
3.2.7 Geochemistry 3-98
3.2.7.1 Host rock chemical properties 3-98
3.2.7.2 Hydrochemistry 3-103

TABLE OF CONTENTS (Continued)

	Page
3.2.8 Mineral resources	3-104
3.2.8.1 Hydrocarbon resources	3-107
3.2.8.2 Other resources	3-132
3.2.8.3 Leasing activity	3-152
3.2.9 Soils	3-152
3.3 Hydrologic conditions	3-155
3.3.1 Surface water	3-155
3.3.1.1 Hydrologic setting	3-155
3.3.1.2 Streamflow characteristics	3-159
3.3.1.3 Water quality	3-159
3.3.1.4 Flooding	3-159
3.3.1.5 Water availability and demand	3-167
3.3.2 Ground water	3-171
3.3.2.1 Hydrology and modeling	3-171
3.3.2.2 Ground-water quality	3-212
3.3.3 Ground-water supply	3-212
3.3.3.1 Shallow wells and springs	3-212
3.3.3.2 Deep wells	3-212
3.4 Environmental setting	3-213
3.4.1 Land use	3-213
3.4.1.1 Land ownership	3-213
3.4.1.2 Land-use plans and controls	3-213
3.4.1.3 Land-use patterns	3-215
3.4.2 Terrestrial and aquatic ecosystems	3-223
3.4.2.1 Terrestrial ecosystems	3-223
3.4.2.2 Aquatic ecosystems	3-228
3.4.2.3 Threatened and endangered, and other special status species	3-228
3.4.2.4 Recreationally and commercially important species	3-233
3.4.3 Air quality and climatology	3-233
3.4.3.1 Existing air quality	3-233
3.4.3.2 Climate	3-234
3.4.3.3 Severe weather	3-237
3.4.3.4 Atmospheric transport and diffusion	3-237
3.4.4 Noise	3-241
3.4.5 Aesthetic resources	3-241
3.4.6 Cultural resources	3-245
3.4.6.1 Previous work	3-247
3.4.6.2 Davis Canyon site and vicinity	3-248
3.4.7 Background radiation	3-252
3.5 Transportation and utilities	3-252
3.5.1 Roads	3-252
3.5.2 Railroads	3-257
3.5.3 Airports	3-259
3.5.4 Waterways	3-259
3.5.5 Utilities	3-259

TABLE OF CONTENTS (Continued)

Page

3.6 Socioeconomic conditions 3-263
3.6.1 Population density and distribution 3-263
3.6.1.1 Population density 3-263
3.6.1.2 Population distribution 3-263
3.6.1.3 Population projections 3-266
3.6.1.4 Population characteristics and temporary population 3-266
3.6.2 Economic conditions 3-269
3.6.2.1 Employment by sector 3-269
3.6.2.2 Unemployment 3-269
3.6.2.3 Per capita income trends 3-271
3.6.2.4 Tourism 3-271
3.6.3 Community services 3-279
3.6.3.1 Housing 3-279
3.6.3.2 Education 3-281
3.6.3.3 Health services 3-281
3.6.3.4 Recreation 3-281
3.6.3.5 Protective services 3-284
3.6.3.6 Water supply and treatment 3-284
3.6.3.7 Sewage treatment and solid waste disposal . . . 3-286
3.6.3.8 Community transportation and utilities 3-286
3.6.4 Social conditions 3-288
3.6.4.1 Social history and life-style differences . . . 3-288
3.6.4.2 Attitudes toward growth and the project 3-288
3.6.4.3 Social services 3-289
3.6.4.4 Social problems 3-290
3.6.5 Fiscal conditions and government structure 3-290
3.6.5.1 Fiscal conditions 3-290
3.6.5.2 Government structure 3-292
3.7 Chapter 3 references 3-293
3.7.1 References listed by author 3-293
3.7.2 Federal regulations and statutes 3-318
3.7.3 State of Utah laws 3-318

4 EXPECTED EFFECTS OF SITE CHARACTERIZATION ACTIVITIES 4-1
4.1 Site characterization activities 4-1
4.1.1 Geotechnical field studies 4-2
4.1.1.1 Basic geotechnical and hydrologic studies . . . 4-2
4.1.1.2 Geophysical studies 4-19
4.1.1.3 Geologic mapping 4-22
4.1.1.4 Access route topographic mapping 4-22
4.1.1.5 Pre-waste-emplacement geochemical conditions 4-23
4.1.2 Exploratory shaft facility (ESF) 4-23
4.1.2.1 Land requirements 4-26
4.1.2.2 Construction 4-26
4.1.2.3 Testing 4-50
4.1.2.4 Final disposition 4-56
4.1.2.5 Required permits and approvals 4-63
4.1.2.6 Detailed discussion of ESF waste management . . 4-63

TABLE OF CONTENTS (Continued)

Page

4.1.3 Other activities 4-67
4.1.3.1 Environmental field studies 4-68
4.1.3.2 Socioeconomics 4-82
4.1.3.3 Land acquisition 4-85
4.2 Expected effects of site characterization 4-86
4.2.1 Expected effects on the natural environment 4-86
4.2.1.1 Effects on land use and mineral resources 4-86
4.2.1.2 Effects on terrestrial and aquatic ecosystems 4-90
4.2.1.3 Air quality effects 4-96
4.2.1.4 Water quality effects 4-109
4.2.1.5 Effects on soils, geology, and paleontology 4-112
4.2.1.6 Noise effects 4-114
4.2.1.7 Effects on aesthetic resources 4-127
4.2.1.8 Effects on archaeological, cultural, and historical resources 4-150
4.2.1.9 Effects on radiological levels 4-156
4.2.1.10 Effects on transportation and utilities 4-157
4.2.1.11 Effects of salt management and disposal 4-164
4.2.2 Expected socioeconomic effects 4-169
4.3 Alternative site characterization activities 4-179
4.3.1 Alternative exploratory shaft locations 4-179
4.3.2 Single exploratory shaft alternative 4-180
4.3.3 Alternative water supply 4-180
4.3.4 Alternative waste disposal 4-181
4.3.4.1 Combustible refuse 4-181
4.3.4.2 Disposal of excess salt 4-181
4.3.5 Alternative access improvements 4-183
4.4 Summary of site characterization impacts at Davis Canyon site 4-188
4.4.1 Cumulative site characterization impacts on Canyonlands National Park including tourism and recreation 4-189
4.4.1.1 Approach 4-189
4.4.1.2 Site characterization activities 4-189
4.4.1.3 Impacts due to site characterization 4-189
4.4.1.4 Discussion of cumulative impacts resulting from site characterization 4-203
4.4.2 Summary of site characterization impacts 4-204
4.5 Chapter 4 References 4-212
4.5.1 References listed by author 4-212
4.5.2 Federal regulations and statutes, U.S. Department of Energy orders, and executive orders 4-220
4.5.3 State laws 4-221

TABLE OF CONTENTS (Continued)

	Page
5 REGIONAL AND LOCAL EFFECTS OF LOCATING A REPOSITORY AT THE SITE	5-1
5.1 The repository	5-1
5.1.1 General description	5-19
5.1.1.1 Repository site layout	5-19
5.1.1.2 Waste receiving, handling, and packaging facilities	5-23
5.1.1.3 Repository shafts	5-27
5.1.1.4 Repository subsurface facilities	5-27
5.1.1.5 Repository land acquisition	5-31
5.1.2 Repository construction activities	5-31
5.1.2.1 Construction schedule and personnel	5-31
5.1.2.2 Offsite development	5-33
5.1.2.3 Onsite development	5-36
5.1.2.4 Shafts and facilities development	5-40
5.1.2.5 Subsurface development	5-40
5.1.3 Repository operation activities	5-42
5.1.3.1 Surface waste-handling and packaging operations	5-44
5.1.3.2 Subsurface waste-handling operations	5-47
5.1.3.3 Retrievability	5-47
5.1.3.4 Salt disposal	5-48
5.1.3.5 Treatment and disposal of other repository-generated wastes	5-50
5.1.4 Decommissioning and decontamination	5-51
5.1.4.1 Surface activities	5-51
5.1.4.2 Subsurface activities	5-51
5.1.4.3 Salt and nonnuclear waste disposal	5-54
5.1.4.4 Labor force	5-54
5.1.5 Postclosure activities	5-54
5.1.5.1 Active prevention	5-54
5.1.5.2 Passive prevention	5-54
5.1.5.3 Active monitoring	5-56
5.2 Expected effects on the physical environment	5-56
5.2.1 Geologic conditions	5-56
5.2.1.1 Soils	5-59
5.2.1.2 Mineral resources	5-61
5.2.2 Hydrology	5-61
5.2.2.1 Surface water	5-61
5.2.2.2 Ground water	5-64
5.2.3 Land use	5-66
5.2.3.1 Construction	5-67
5.2.3.2 Operation	5-69
5.2.3.3 Decommissioning	5-70
5.2.3.4 Mitigation	5-70
5.2.3.5 Cumulative and long-term impacts	5-71
5.2.4 Terrestrial and aquatic ecosystems	5-71
5.2.4.1 Terrestrial biota	5-71
5.2.4.2 Aquatic biota	5-74
5.2.4.3 Threatened and endangered species	5-76

TABLE OF CONTENTS (Continued)

	Page
5.2.5 Air quality	5-77
5.2.5.1 Activities and emissions	5-77
5.2.5.2 Methodology	5-80
5.2.5.3 Air quality impacts	5-82
5.2.6 Aesthetic conditions	5-87
5.2.6.1 Construction	5-87
5.2.6.2 Operation	5-87
5.2.6.3 Decommissioning and closure	5-108
5.2.6.4 Mitigation techniques	5-108
5.2.6.5 Summary	5-110
5.2.7 Noise	5-111
5.2.7.1 Noise criteria	5-112
5.2.7.2 Methodology	5-112
5.2.7.3 Noise impacts	5-113
5.2.7.4 Impact mitigation	5-121
5.2.8 Cultural resources	5-121
5.2.8.1 Construction	5-122
5.2.8.2 Operation	5-123
5.2.8.3 Decommissioning and closure	5-123
5.2.9 Radiological	5-123
5.2.10 Impacts of salt management and disposal	5-123
5.2.10.1 Salt management and control	5-124
5.2.10.2 Impacts of salt management	5-126
5.2.10.3 Salt disposal and impacts	5-128
5.3 Expected effects of transportation and utilities	5-130
5.3.1 Nuclear waste transportation	5-130
5.3.1.1 Waste transportation activities	5-131
5.3.1.2 Radiological and nonradiological effects associated with nuclear waste transport	5-134
5.3.1.3 Mode of transport and access routes	5-136
5.3.1.4 Additional regional concerns	5-144
5.3.2 Environmental effects of improvements to transportation corridors	5-147
5.3.2.1 Roadways	5-147
5.3.2.2 Railroads	5-152
5.3.2.3 Airports	5-154
5.3.2.4 Waterways	5-154
5.3.3 Effects on transportation infrastructure in the area	5-154
5.3.3.1 Roadways	5-155
5.3.3.2 Railroads	5-158
5.3.3.3 Airports	5-159
5.3.3.4 Waterways	5-160
5.3.4 Utilities	5-160
5.4 Expected effects on socioeconomic conditions	5-160
5.4.1 Population distribution and displacement	5-166
5.4.1.1 Construction	5-166
5.4.1.2 Operation	5-169
5.4.1.3 Decommissioning and closure	5-169
5.4.1.4 Population displacement	5-169

TABLE OF CONTENTS (Continued)

Page

5.4.2 Economic conditions 5-169
5.4.2.1 Employment 5-169
5.4.2.2 Economic activity 5-172
5.4.2.3 Displacement of economic activity 5-174
5.4.3 Community services 5-174
5.4.3.1 Housing 5-174
5.4.3.2 Education 5-176
5.4.3.3 Protective services 5-176
5.4.3.4 Health services 5-177
5.4.3.5 Water supply 5-177
5.4.3.6 Sewage and solid waste disposal 5-177
5.4.3.7 Recreation facilities 5-178
5.4.4 Social conditions 5-178
5.4.5 Fiscal conditions and government structure 5-179
5.4.5.1 Fiscal conditions 5-180
5.4.5.2 Government structure 5-181
5.5 Summary of repository impacts at Davis Canyon site 5-182
5.5.1 Cumulative repository impacts on Canyonlands National Park including tourism and recreation 5-182
5.5.1.1 Approach 5-182
5.5.1.2 Physical environmental impacts 5-182
5.5.1.3 Summary of the cumulative impacts on Canyonlands National Park and its users 5-204
5.5.2 Summary of repository impacts on the Davis Canyon site 5-206
5.6 Chapter 5 references 5-221
5.6.1 References listed by author 5-221
5.6.2 Federal regulations and statutes and Executive Orders . 5-230
5.6.3 State of Utah laws 5-231

6 SUITABILITY OF THE DAVIS CANYON SITE FOR SITE CHARACTERIZATION AND FOR DEVELOPMENT AS A REPOSITORY 6-1

6.1 The DOE siting guidelines 6-1
6.1.1 Format and structure of the guidelines 6-1
6.1.2 Use of the siting guidelines in evaluating site suitability 6-2
6.1.3 Division of the guidelines into categories 6-3
6.1.4 Formats for the presentation of site evaluations 6-4
6.2 Suitability of the Davis Canyon site for development as a repository under guidelines not requiring site characterization 6-4
6.2.1 Technical guidelines 6-6
6.2.1.1 Site ownership and control (postclosure), guideline 10 CFR 960.4-2-8-2 6-6
6.2.1.2 Population density and distribution, guideline 10 CFR 960.5-2-1 6-18
6.2.1.3 Site ownership and control (preclosure), guideline 10 CFR 960.5-2-2 6-21

TABLE OF CONTENTS (Continued)

Page

6.2.1.4 Meteorology, guideline 10 CFR 960.5-2-3 6-23
6.2.1.5 Offsite installations and operations, guideline 10 CFR 960.5-2-4 6-26
6.2.1.6 Environmental quality, Technical Guideline 10 CFR 960.5-2-5 6-30
6.2.1.7 Socioeconomic impacts, guideline 10 CFR 960.5-2-6 6-69
6.2.1.8 Transportation, guideline 10 CFR 960.5-2-7 6-74
6.2.2 Preclosure system guidelines 6-83
6.2.2.1 Preclosure radiological safety, guideline 10 CFR 960.5-1 6-84
6.2.2.2 Environment, socioeconomics, and transportation, guideline 10 CFR 960.5(a)(2). 6-89
6.2.3 Conclusion for the qualifying condition regarding suitability of the site for development as a repository under guidelines not requiring site characterization . . 6-93
6.3 Suitability of the Davis Canyon site for site characterization: evaluation against guidelines that do require site characterization 6-93
6.3.1 Postclosure technical guidelines, 10 CFR 960.4-2 6-94
6.3.1.1 Geohydrology, guideline 10 CFR 960.4-2-1 6-94
6.3.1.2 Geochemistry, guideline 10 CFR 960.4-2-2 6-103
6.3.1.3 Rock characteristics, guideline 10 CFR 960.4-2-3 6-134
6.3.1.4 Climatic changes, guideline 10 CFR 960.4-2-4 6-141
6.3.1.5 Erosion, guideline 10 CFR 960.4-2-5 6-148
6.3.1.6 Dissolution, guideline 10 CFR 960.4-2-6 6-155
6.3.1.7 Tectonics, guideline 10 CFR 960.4-2-7 6-160
6.3.1.8 Human interference and natural resources, guideline 10 CFR 960.4-2-8-1 6-167
6.3.2 Postclosure system guideline, 10 CFR 960.4-1 6-174
6.3.2.1 Statement of qualifying condition 6-174
6.3.2.2 Evaluation process 6-175
6.3.2.3 Engineered barrier system 6-175
6.3.2.4 Geologic setting 6-176
6.3.2.5 Conclusion 6-178
6.3.3 Preclosure technical guidelines, 10 CFR 960.5-2 6-178
6.3.3.1 Surface characteristics, guideline 10 CFR 960.5-2-8 6-178

TABLE OF CONTENTS (Continued)

Page

6.3.3.2 Rock characteristics, guideline 10 CFR 960.5-2-9 6-186
6.3.3.3 Hydrology, guideline 10 CFR 960.5-2-10 6-194
6.3.3.4 Tectonics, guideline 10 CFR 960.5-2-11 6-196
6.3.4 Preclosure system guidelines 10 CFR 960.5-1(a)(3) . . . 6-200
6.3.4.1 Statement of qualifying condition 6-200
6.3.4.2 Evaluation process 6-200
6.3.4.3 Analysis 6-202
6.3.4.4 Conclusion 6-202
6.3.5 Conclusion regarding the suitability of the site for site characterization 6-206
6.4 Performance assessments 6-206
6.4.1 Preclosure radiological assessment for Davis Canyon 6-206
6.4.1.1 Guideline requirements 6-206
6.4.1.2 10 CFR Part 20 calculation 6-207
6.4.1.3 40 CFR Part 191 calculation 6-210
6.4.1.4 Accident calculations 6-210
6.4.2 Preliminary postclosure performance assessment 6-213
6.4.2.1 Scope and objective 6-220
6.4.2.2 Subsystem descriptions 6-220
6.4.2.3 Preliminary subsystem performance assessment . 6-228
6.4.2.4 Preliminary system performance assessment . . . 6-276
6.4.2.5 Comparison with regulatory criteria 6-281
6.4.2.6 Effects of potentially disruptive events and processes 6-281
6.4.2.7 Conclusions 6-286
6.5 Chapter 6 references 6-288
6.5.1 References listed by author 6-288
6.5.2 Federal regulations and statutes, and executive and DOE orders 6-308
6.5.3 State of Utah laws 6-313

APPENDIX 6-A Estimation of the extent of the disturbed zone 6-A1

7 COMPARATIVE EVALUATION OF NOMINATED SITES 7-1

7.1 Introduction 7-1
7.1.1 Purpose and requirements 7-1
7.1.2 Approach and organization 7-1

7.2 Comparison of the sites on the basis of the postclosure guidelines 7-3
7.2.1 Technical guidelines 7-4
7.2.1.1 Geohydrology (postclosure) 7-4
7.2.1.2 Geochemistry 7-16

TABLE OF CONTENTS (Continued)

Page

7.2.1.3 Rock characteristics 7-24
7.2.1.4 Climatic changes 7-29
7.2.1.5 Erosion 7-33
7.2.1.6 Dissolution 7-36
7.2.1.7 Tectonics (postclosure) 7-40
7.2.1.8 Human interference 7-44
7.2.1.8.1 Natural resources 7-45
7.2.2 Postclosure system guidelines 7-51

7.3 Comparison of sites on the basis of preclosure guidelines . . . 7-52
7.3.1 Preclosure radiological safety 7-54
7.3.1.1 Technical guidelines 7-54
7.3.1.1.1 Population density and distribution . 7-55
7.3.1.1.2 Site ownership and control 7-59
7.3.1.1.3 Meteorology 7-62
7.3.1.1.4 Offsite installation and operations . 7-66
7.3.1.2 Preclosure system guidelines for radiological safety 7-70
7.3.2 Environment, socioeconomics, and transportation 7-72
7.3.2.1 Technical guidelines 7-72
7.3.2.1.1 Environmental quality 7-72
7.3.2.1.2 Socioeconomic impacts 7-79
7.3.2.1.3 Transportation 7-89
7.3.2.2 System guidelines on environment, socioeconomics, and transportation 7-100

7.3.3 Ease and cost of siting, construction, operation, and closure 7-106
7.3.3.1 Technical guidelines 7-106
7.3.3.1.1 Surface characteristics 7-106
7.3.3.1.2 Rock characteristics (preclosure) . . 7-110
7.3.3.1.3 Hydrology 7-117
7.3.3.1.4 Tectonics (preclosure) 7-121
7.3.3.2 System guidelines on the ease and cost of siting, construction, operation, and closure 7-127

GLOSSARY, LIST OF ACRONYMS AND ABBREVIATIONS G-1

APPENDIX A TRANSPORTATION A-1

APPENDIX B AVAILABILITY OF REFERENCES B-1

APPENDIX C COMMENT-RESPONSE DOCUMENT C-1

LIST OF FIGURES

Figure	Title	Page
1	Potentially acceptable sites for the first repository	2
2	Davis and Lavender Canyon sites	7
3	Geologic cross section of the Davis Canyon site	8
1-1	Potentially acceptable sites for the first repository	1-4
1-2	Geohydrologic regions of the contiguous United States	1-18
2-1	Location of Davis Canyon and Lavender Canyon sites, San Juan County, Utah	2-2
2-2	Paradox Basin region, Colorado Plateau physiographic province	2-3
2-3	Generalized composite stratigraphic column and hydrostratigraphic units, Paradox Basin	2-5
2-4	Paradox Basin screening process	2-6
2-5	Identified areas and Gibson Dome location in the Paradox Basin	2-9
2-6	Designated Gibson Dome location	2-13
3-1	Paradox Basin region	3-2
3-2	Preliminary facility location within the site	3-3
3-3	Colorado Plateau physiographic province and Paradox Basin region	3-4
3-4	Regional tectonic features	3-6
3-5	Physiographic subprovince and section in site vicinity	3-8
3-6	Map of the Needles Fault zone and Monument upwarp	3-21
3-7	Generalized composite stratigraphic column, Paradox Basin	3-26
3-8	Diagrammatic cross section showing Pennsylvanian stratigraphic nomenclature	3-28
3-9	Diagrammatic cross section of the Paradox Basin showing three salt geometries	3-29
3-10	Davis Canyon site and vicinity geologic map	3-33
3-11	Surface geologic exploration in the site vicinity	3-34
3-12	Locations of boreholes with available geophysical logs within the candidate area	3-35
3-13	East-west computer-generated cross section	3-37
3-14	Stratigraphic column of the Davis Canyon site	3-38
3-15	Portion of the Gibson Dome No. 1 (GD-1) lithologic log	3-41
3-16	Isopach map of the Paradox Formation	3-42
3-17	Isopach, top of Paradox Formation to top of Salt Cycle 6	3-44
3-18	Depth to Salt Cycle 6, Davis Canyon site vicinity	3-45
3-19	Isopach of Salt Cycle 6	3-46
3-20	Structure contours, top of Paradox Formation	3-47
3-21	Isopach map of carnallite marker in Salt Cycle 6 as interpreted from geophysical logs	3-49
3-22	Portion of gamma ray geophysical log of the GD-1 borehole showing carnallite marker	3-50
3-23	Map showing estimated concentration of carnallite in carnallite marker of Salt Cycle 6	3-51
3-24	Principal tectonic elements	3-53
3-25	Mapped faults	3-54
3-26	Locations of geophysical survey	3-55

LIST OF FIGURES (Continued)

Figure	Title	Page
3-27	Reflection time contours, top of Mississippian	3-57
3-28	Needles Fault zone, schematic subsurface configuration and graben evolution	3-59
3-29	Seismicity of the Colorado Plateau, 1962 to 1982	3-64
3-30	Seismicity of the Paradox Basin, July 1979 to July 1984	3-65
3-31	Folded structures related to salt flow	3-70
3-32	Concentrations of total dissolved solids, lower hydrostratigraphic unit	3-74
3-33	Predominant joint trends and density in the site vicinity	3-75
3-34	Representative jointing associated with the Gibson Dome structure	3-76
3-35	Example of prominent northeast-trending joints in the southwestern quarter of site vicinity	3-77
3-36	Example of curvilinear jointing pattern in southwestern corner of the site vicinity	3-78
3-37	Surface/near surface mineral resource localities, candidate area	3-105
3-38	Subsurface resources, candidate area	3-106
3-39	Oil and gas fields in Utah part of Paradox Basin	3-108
3-40	Deep boreholes, candidate area	3-109
3-41	Deep boreholes, site and vicinity	3-110
3-42	Structure contours, top of Paradox Formation, and significant hydrocarbon shows	3-126
3-43	Structure contours, top of Leadville Limestone	3-127
3-44	Isopach of potash zone in Paradox Salt Cycle 13	3-146
3-45	Isopach of potash zone in Paradox Salt Cycle 18	3-147
3-46	Soils, Davis Canyon site and vicinity	3-153
3-47	Davis Canyon geologic repository operations area soils	3-154
3-48	Water resource regions of the United States	3-156
3-49	Regional drainage pattern	3-157
3-50	Water quality and stream gaging stations, candidate area	3-160
3-51	Davis Canyon probable maximum and 100-year floodplains	3-166
3-52	Utah's ten hydrologic areas	3-168
3-53	Permeability values for the western Paradox Basin region, upper and lower hydrostratigraphic units	3-174
3-54	Water wells and springs, candidate area	3-194
3-55	Frequency plot showing total dissolved solids in wells and springs in the candidate area -- Cedar Mesa and Cutler Formations	3-195
3-56	Comparison of hydraulic conductivity data in the GD-1 borehole -- Elephant Canyon and Honaker Trail Formations	3-196
3-57	Frequency plot showing total dissolved solids in wells and springs in the candidate area -- Elephant Canyon Formation and Leadville Limestone	3-198
3-58	Comparison of hydraulic conductivity data in the GD-1 borehole -- Paradox Formation and Leadville Limestone	3-199

LIST OF FIGURES (Continued)

Figure	Title	Page
3-59	Frequency plot showing distribution of permeability data in the Leadville Limestone from tests in the candidate area	3-201
3-60	Potentiometric level data from the GD-1 borehole	3-203
3-61	Static reservoir pressure data from the GD-1 borehole	3-205
3-62	Preliminary map of potentiometric surface, upper hydrostratigraphic unit	3-206
3-63	Preliminary map of potentiometric surface, lower hydrostratigraphic unit, candidate area	3-207
3-64	Preliminary map of potentiometric surface, Ismay substage, candidate area	3-209
3-65	Existing recreational uses	3-216
3-66	Golden circle of parks	3-217
3-67	Canyonlands National Park	3-220
3-68	Vegetation communities in Davis Canyon	3-224
3-69	Birds, fish, and small mammals	3-229
3-70	Big game ranges	3-230
3-71	Seasonal baseline visibilities in Canyonlands National Park, Island-in-the-Sky District	3-236
3-72	Annual wind rose, Salt Wash, Utah	3-239
3-73	Visual resource management classifications	3-244
3-74	Locations of the survey area surrounding Davis Canyon	3-249
3-75	Locations of survey areas near Indian Creek	3-250
3-76	Regional highway network, Davis Canyon area	3-254
3-77	Highways and railroads, Davis Canyon area	3-255
3-78	Regional highway network traffic counts, annual average daily traffic	3-256
3-79	Area airports	3-260
3-80	Utilities	3-262
3-81	Population distribution for radiological analysis for Davis Canyon study area	3-264
3-82	Percentage of visitors to total park within selected areas of the Needles District of Canyonlands National Park	3-273
3-83	Percentage of visitors to total park within selected areas of the Island-in-the-Sky District of Canyonlands National Park	3-274
4-1	Schedule of proposed geotechnical field activities, Davis Canyon site	4-6
4-2	Proposed location of drilling activities, Davis Canyon site	4-7
4-3	Proposed field activities in the Davis Canyon candidate area	4-8
4-4	Typical drill site layout	4-11
4-5	Seismographic stations in the Paradox Basin microseismic network	4-21
4-6	Exploratory shaft facility area plan, Davis Canyon	4-24
4-7	Exploratory shaft facility isometric view, Davis Canyon	4-25

LIST OF FIGURES (Continued)

Figure	Title	Page
4-8	Exploratory shaft facility construction/testing schedule, Davis Canyon	4-28
4-9	Exploratory shaft facility drill and blast method of shaft sinking, Davis Canyon	4-38
4-10	Exploratory shaft facility, typical seal system, Davis Canyon	4-41
4-11	Exploratory shaft facility, exploratory shaft profile, Davis Canyon	4-42
4-12	Exploratory shaft facility, subsurface plan - initial underground excavation, Davis Canyon	4-51
4-13	Exploratory shaft facility, subsurface plan - underground excavation, Davis Canyon	4-54
4-14	Exploratory shaft facility schedule for reclamation of exploratory shaft site, Davis Canyon	4-60
4-15	Relationship of environmental field program to geotechnical and exploratory shaft programs, Davis Canyon	4-68
4-16	Proposed locations (approximate) for environmental study sampling: land use and transportation, Davis Canyon	4-70
4-17	Proposed locations (approximate) for environmental study sampling: biota/ecosystems	4-72
4-18	Proposed locations (approximate) for environmental study sampling: soils, radiological, meteorological/air quality, and salt impacts	4-75
4-19	Proposed atmospheric monitoring stations, Davis Canyon	4-76
4-20	Proposed locations (approximate) for environmental study sampling: water resources, Davis Canyon	4-77
4-21	Proposed locations (approximate) for environmental study sampling: sound levels, Davis Canyon	4-79
4-22	Potentially wet areas containing wetlands, Davis Canyon site	4-94
4-23	Monthly particulate emission rates due to ESF construction and underground testing activities at the Davis Canyon site	4-100
4-24	Running 12-month total particulate emission rates due to ESF construction and underground testing activities at the Davis Canyon site	4-101
4-25	Running 12-month NO_x emissions due to drilling rig operations and mobile sources at the Davis Canyon site	4-103
4-26	Schedule and relative sound level, site characterization	4-119
4-27	Davis Canyon, site characterization, audibility contours	4-123
4-28	Davis Canyon, site characterization, day/night sound level	4-124
4-29	Key observation points and visual resource management classes, Davis Canyon study area	4-128
4-30	Composite viewshed: service and production headframes	4-139
4-31	Viewshed: salt stockpile	4-140
4-32	Viewshed: exploratory shaft facility ground level activities	4-141
4-33	Viewshed: 60-meter meteorological tower	4-146

LIST OF FIGURES (Continued)

Figure	Title	Page
4-34	Composite viewshed: Davis Canyon and Lavender Canyon 10-meter meteorological tower	4-147
4-35	Davis Canyon site characterization vehicular traffic	4-148
4-36	Salt management flow diagram	4-165
4-37	Cumulative site characterization work force	4-170
4-38	Proposed Utah State highway 211 Newspaper Rock bypass plan, Davis Canyon location	4-185
4-39	Detectable physical site characterization phase environmental impacts to Canyonlands National Park	4-198
4-40	Significant physical site characterization phase environmental impacts to Canyonlands National Park	4-199
5-1	Nuclear waste repository facility concept	5-20
5-2	Preliminary facility location within the site	5-22
5-3	Repository site layout plan, Davis Canyon	5-24
5-4	Waste handling and packaging facility layout, Davis Canyon	5-25
5-5	Waste handling and packaging facility - overall functional schematic, Davis Canyon	5-26
5-6	Repository underground layout, Davis Canyon	5-28
5-7	Schedule summary bar chart, Davis Canyon	5-32
5-8	Construction personnel requirements, Davis Canyon	5-34
5-9	Alternative railroad and highway routes to Paradox Basin repository site	5-35
5-10	Offsite development - Davis Canyon proposed utility connections to repository site	5-38
5-11	Underground activities, initial development phase, Davis Canyon	5-41
5-12	Input to packaging facility, Davis Canyon	5-46
5-13	Repository sealing system schematic, Paradox Basin repository	5-52
5-14	Schematic layout for shaft seals, Paradox Basin	5-53
5-15	Schematic design for sealing vertical boreholes in the Paradox Basin	5-55
5-16	Key observation points and visual management classifications, repository and corridors	5-89
5-17	Composite viewshed: service and waste shaft headframes	5-91
5-18	Viewshed: waste packaging facility	5-92
5-19	Viewshed: salt stockpile	5-93
5-20	Viewshed: repository ground level activities	5-94
5-21	Viewshed: Dead Horse Point Overlook (KOP No. 1)	5-95
5-22	Viewshed: Needles Overlook (KOP No. 8)	5-96
5-23	Davis Canyon, repository construction, audibility contours	5-114
5-24	Davis Canyon, repository construction, day/night sound level	5-115
5-25	Davis Canyon, repository operation, audibility contours	5-118
5-26	Davis Canyon, repository operation, day/night sound level	5-119
5-27	Salt management flow diagram	5-125

LIST OF FIGURES (Continued)

Figure	Title	Page
5-28	Repository work force requirements	5-161
5-29	In-migration model logic of calculations	5-163
5-30	Construction phase - detectable physical environmental impacts to Canyonlands National Park	5-194
5-31	Construction phase - significant physical environmental impacts to Canyonlands National Park	5-195
6-1	TEMPV5 temperatures versus time at salt-overpack interface for Davis Canyon	6-121
6-2	Temperatures around CHLW waste package at Davis Canyon	6-122
6-3	Temperatures around SFPWR waste package at Davis Canyon	6-123
6-4	Configuration of emplaced waste package	6-224
6-5	Repository high-level waste storage placement	6-226
6-6	System analyses for assessment of performance of engineered barriers	6-229
6-7	Brine accumulation at waste package with time and threshold gradient of 0.125° C/cm for Davis Canyon	6-233
6-8	Brine accumulation at waste package with time and zero threshold gradient for Davis Canyon	6-234
6-9	Brine migration inflow rates per canister	6-236
6-10	Radiation fields at waste package-material interface	6-238
6-11	Radiation fields at waste form container interface	6-239
6-12	Radiation fields at container crushed salt interface	6-240
6-13	Effect of radiation field on corrosion rates of low carbon steel container in brines	6-241
6-14	Stress boundary conditions at waste package midplane	6-243
6-15	Comparison of corrosion with transient failure thickness of container	6-245
6-16	Effect of brine rate on corrosion of the container	6-246
6-17	Corrosion and failure of waste package in low-magnesium brine	6-248
6-18	Net accumulated brine during corrosion of the waste package	6-251
6-19	Evaporite, interbed and adjacent strata used for ground-water analysis, Davis Canyon	6-262
6-20	Relative frequency of ground-water travel times for likely conditions of porous media flow, Davis Canyon	6-267
6-21	Complementary cumulative frequency of ground-water travel times for likely conditions of porous media, Davis Canyon	6-268
6-22	Relative frequency of ground-water travel times for unlikely conditions of porous and fractured media flow, Davis Canyon	6-272
6-23	Complementary cumulative frequency for ground-water travel times for unlikely conditions of porous and fractured media flow, Davis Canyon	6-273
6-24	Schematic of repository as infinite plane source	6-279
6-25	Travel distances with time at Davis Canyon for most soluble radionuclides, iodine-129 and cesium-135	6-280
7-1	Sites selected for nomination	7-2

LIST OF TABLES

Table	Title	Page
1	Rankings of sites for each technical guideline in the postclosure set	19
2	Rankings of sites for each technical guideline in the preclosure set	20
3	Ranking of sites for the set of postclosure guidelines	21
4	Ranking of sites for preclosure groups of guidelines	22
5	Overall ranking of sites obtained by three aggregation methods	24
2-1	Paradox Basin region-to-area screening criteria	2-8
2-2	Highest priority Paradox Basin area-to-location screening criteria	2-10
2-3	Principal differentiating factors for Gibson Dome and Elk Ridge locations	2-12
2-4	Summary of rationale for not disqualifying the potentially acceptable Paradox Basin salt sites	2-15
2-5	10 CFR Part 960 general guidelines for recommendation of sites for nuclear waste repositories and comparative evaluation procedure descriptors	2-18
2-6	Summary of descriptors within technical guidelines which provide the basis for possible discrimination among the potentially acceptable Paradox Basin sites	2-20
2-7	Summary of findings based on discriminating guidelines between the potentially acceptable Paradox Basin sites	2-28
3-1	Relative erodibility of rock units in the Paradox Basin	3-9
3-2	Long-term incision rates	3-12
3-3	Denudation rates for watersheds in the Colorado Plateau	3-18
3-4	Average rates of scarp retreat on the Colorado Plateau, based on geomorphic interpretations	3-20
3-5	Summary of rock characteristics	3-80
3-6	Summary of thermal properties of Paradox Cycle 6 Salt	3-99
3-7	Paradox Cycle 6 brine-content calculations for Davis Canyon Canyon Site	3-101
3-8	Summary of hydrocarbon shows in candidate area boreholes	3-111
3-9	Hydrocarbon shows in drill stem tests	3-116
3-10	Hydrocarbon shows in cores and samples	3-123
3-11	Summary of favorable hydrocarbon conditions	3-129
3-12	Mineral resources in the Davis Canyon candidate area	3-133
3-13	Potash resource data, Paradox Basin	3-149
3-14	Streamflow data, Gibson Dome	3-161
3-15	Mean monthly streamflows, Indian Creek	3-161
3-16	Colorado River flow and water quality at Cisco, Utah--water years 1977 and 1983	3-162
3-17	Indian Creek water quality at Kelly Ranch	3-163
3-18	Indian Creek water quality at selected locations downstream from Kelly Ranch	3-164
3-19	Comparison of Kelly Ranch sample water quality with downstream locations for like sample dates	3-165
3-20	Water requirements for offstream uses, Colorado-Gunnison subregion	3-169

LIST OF TABLES (Continued)

Table	Title	Page
3-21	Water requirements for offstream uses, Colorado-San Juan subregion	3-170
3-22	Davis Canyon hydrostratigraphic column	3-172
3-23	Gibson Dome No. 1 hydraulic test results summary	3-175
3-24	Available data on water wells and springs, Davis Canyon area	3-178
3-25	Analytical results of salt sample	3-211
3-26	Land ownership: San Juan County	3-214
3-27	Visits to Needles District of Canyonlands National Park, 1983	3-222
3-28	Galleta-shadscale community	3-225
3-29	Flora list for Canyonlands National Park	3-226
3-30	Rare plants known to occur in Grand and San Juan Counties, Utah and their Federal status	3-231
3-31	Endangered animal species, for which there is favorable habitat, near the Davis Canyon Site	3-232
3-32	National and Utah State ambient air quality standards	3-235
3-33	Atmospheric stability distribution for Salt Wash	3-240
3-34	Sound-level measures and assumed ambient noise levels	3-242
3-35	Dose equivalent rates from background radiation, Monticello, Utah	3-253
3-36	Accident history, area highways	3-258
3-37	Description of airports in Paradox Basin area	3-261
3-38	Persons per square mile, Grand and San Juan Counties	3-265
3-39	Population projections: counties and incorporated communities	3-267
3-40	Populations of study area counties and incorporated communities	3-267
3-41	1980 population characteristics, Davis Canyon area	3-268
3-42	Economic characteristics of Grand and San Juan Counties, 1970-1984	3-270
3-43	Unemployment rate estimates in uranium industry in Grand and San Juan Counties	3-272
3-44	Transient room tax, Grand and San Juan Counties	3-272
3-45	Visits to Canyonlands and Arches National Parks and Natural Bridges National Monument, 1978 to 1983	3-278
3-46	Number of housing units in Grand and San Juan Counties, 1980	3-280
3-47	Enrollment, capacity, and student-teacher ratio for socioeconomic study area schools (1984-1985 school year)	3-282
3-48	Health services	3-283
3-49	Community recreational facilities	3-283
3-50	Protective services, 1980	3-285
3-51	Municipal water supply	3-285
3-52	Community wastewater system capacities, present and planned	3-287
3-53	Fiscal structure of study area counties and cities, 1982	3-291
4-1	Geotechnical field activities to be performed during site characterization, Davis Canyon	4-3

LIST OF TABLES (Continued)

Table	Title	Page
4-2	Summary of geotechnical field activity requirements, Davis Canyon	4-4
4-3	Exploratory shaft project characteristics, two 12 foot conventionally mined shafts	4-27
4-4	Estimated personnel requirements by ESF phase, Davis Canyon	4-29
4-5	Concurrent construction activities, Davis Canyon ESF site	4-30
4-6	Equipment for construction of access road and site preparation	4-32
4-7	Estimated resources consumed during exploratory shaft facility activities, Davis Canyon	4-33
4-8	Access roadway design criteria	4-35
4-9	Estimated vehicular traffic during ESF construction and testing, Davis Canyon	4-37
4-10	Equipment for shaft and surface facility construction stage	4-47
4-11	Equipment for initial underground excavation stage	4-52
4-12	Equipment for shaft outfitting stages	4-53
4-13	Equipment for expanded underground excavation stage	4-55
4-14	Proposed in-situ test program	4-57
4-15	Equipment for testing stage	4-58
4-16	Equipment for the final disposition stage	4-64
4-17	Description of wastes and estimated quantities relating to disposal, Davis Canyon	4-66
4-18	National and Utah state ambient air quality standards	4-98
4-19	Emissions from geologic field studies and exploratory shaft construction	4-99
4-20	Air quality impacts during site characterization, Davis Canyon	4-108
4-21	Acceptable levels above threshold of audibility for various recreational opportunities	4-116
4-22	Individual response to noise	4-117
4-23	Noise impacts to sensitive receptors - Davis Canyon, site characterization	4-125
4-24	Summary of VRM inventory data for geologic field activities, ESF, and other activities	4-129
4-25	Requirements used to determine significance of visual impact	4-132
4-26	Geologic field studies visibility summary	4-134
4-27	Summary of VRM impacts of geologic field activities, ESF, and other activities	4-135
4-28	Key observation points, Davis Canyon study area	4-138
4-29	Potential visibility of exploratory shaft facilities and other activities from KOPs	4-143
4-30	Potential visibility by area	4-144
4-31	Potential visibility from Utah 211	4-145
4-32	Archaeological studies conducted for the Davis Canyon site	4-152
4-33	Traffic increases during shaft construction and testing, Davis Canyon	4-159

Table	Title	Page
4-34	National motor vehicle accident and fatality rates, 1983	4-161
4-35	Projected accident increases on U.S. 191 during project activities	4-161
4-36	Comparison of levels of service	4-163
4-37	Inputs for the population in-migration model for site characterization	4-172
4-38	Peak site characterization in-migration distribution to Moab, Monticello, and Blanding	4-173
4-39	Additional baseline growth present at the peak of in-migration for Moab, Monticello, and Blanding (1984-1987)	4-174
4-40	Projected baseline and project-related service requirements for the peak of site characterization activities, Davis Canyon	4-176
4-41	Characteristics of improvements to Utah State Highway 211	4-184
4-42	Impacts to Newspaper Rock visitors from improvements to Utah 211	4-187
4-43	Summary of physical environmental impacts to Canyonlands National Park (CNP)	4-191
4-44	Detectable physical environmental impacts to Canyonlands National Park as a result of site characterization activities	4-194
4-45	Significant physical environmental impacts to Canyonlands National Park as a result of site characterization activities	4-195
4-46	Significance of physical environmental impacts on in-park activities	4-200
4-47	Summary of site characterization impacts at the Davis Canyon site	4-205
5-1	Comparison of alternative repository design concepts, Davis Canyon site	5-2
5-2	Average annual repository personnel requirements, Davis Canyon	5-21
5-3	Approximate waste storage room quantities	5-30
5-4	Paradox Basin access route comparative table, Davis Canyon site	5-37
5-5	Summary of excavation quantities	5-43
5-6	Typical vehicular traffic volume during repository operations	5-43
5-7	Atomic energy commission injury and fatality incidence rates: 1943-1975	5-45
5-8	Maximum repository particulate emission rates	5-78
5-9	Maximum repository NO_x emission rates	5-79
5-10	Air quality impacts during repository construction and operation, Davis Canyon	5-85
5-11	Summary of VRM inventory data for railroad route alternatives from Potash, Davis Canyon site	5-88
5-12	Potential visibility of repository facility from key observation points	5-97

LIST OF TABLES (Continued)

Table	Title	Page
5-13	Potential visibility by area	5-98
5-14	Potential visibility from Utah 211	5-100
5-15	Potentially visible miles of access road by distance zone from key observation points	5-100
5-16	Potentially visible miles of rail line by distance zone from key observation points - Colorado River Canyon route "A"	5-102
5-17	Potentially visible miles of rail line by distance zone from key observation points - Colorado River Canyon route "B"	5-103
5-18	Potentially visible miles of rail line by distance zone from key observation points - Kane Springs Canyon route	5-104
5-19	Potentially visible miles of rail line by distance zone from key observation points - Spanish Valley route	5-105
5-20	Potential visibility summary of rail route alternatives by distance zone from key observation points	5-106
5-21	Summary of visual resource contrast rating results for railroad route alternatives as seen from key observation points	5-109
5-22	Noise impacts to sensitive receptors - Davis Canyon, repository construction	5-116
5-23	Noise impacts to sensitive receptors - Davis Canyon, repository operation	5-120
5-24	Lifetime nuclear waste shipment requirements to repository, Davis Canyon	5-133
5-25	Total life cycle nuclear waste transport cost	5-135
5-26	Total risk of nuclear waste transport to Davis Canyon during the operational period	5-137
5-27	Average daily waste receipts	5-138
5-28	Regional risk calculation (highway), Davis Canyon	5-141
5-29	Regional risk calculation (rail), Davis Canyon	5-143
5-30	Estimated radiological exposures to an individual in the public sector from a single shipment under normal conditions of transport	5-145
5-31	Estimated radiological exposures to an individual worker from a single shipment during selected activities under normal conditions of transport	5-146
5-32	Maximum individual radiation dose estimates for a rail cask accident involving release to the atmosphere	5-148
5-33	50-year population dose estimates for a rail cask accident involving land contamination	5-149
5-34	50-year population radiation exposure from a drinking-water reservoir contamination from a rail cask accident	5-150
5-35	Traffic increases on area highways during construction	5-156
5-36	Traffic increases during repository operation	5-157
5-37	Davis Canyon inputs and multipliers for the ONWI in-migration computer model	5-164
5-38	Definitions - population in-migration model, Davis Canyon	5-165
5-39	In-migration population location results during construction, Davis Canyon	5-167

Table	Title	Page
5-40	In-migration population location results during operation, Davis Canyon	5-168
5-41	Estimated yearly increment of direct, indirect, and total in-migration during repository construction	5-170
5-42	Estimated peak of direct, indirect, and total in-migration during repository operation	5-170
5-43	Estimated yearly increment of employment generated by repository construction, Davis Canyon	5-171
5-44	Peak employment generated by repository operation, Davis Canyon	5-173
5-45	Projected baseline and project-related service requirements - peak project construction and operation, Davis Canyon	5-175
5-46	Summary of cumulative environmental impacts to Canyonlands National Park for a nuclear waste repository	5-183
5-47	Detectable physical environmental impacts to Canyonlands National Park	5-191
5-48	Significant environmental impacts to Canyonlands National Park	5-192
5-49	Construction phase - significance of physical environmental impacts on in-park activities	5-197
5-50	Operations phase - significance of physical environmental impacts on in-park activities	5-202
5-51	Summary of repository impacts	5-207
6-1	Categorization of guidelines and findings based on application of the disqualifying and qualifying conditions	6-5
6-2	Preclosure and postclosure technical guidelines not requiring site characterization for the Davis Canyon site	6-7
6-3	Environmental statutory and regulatory authorities and requirements, Davis Canyon site.	6-32
6-4	Nonfederally derived State and local statutory and regulatory authorities, Davis Canyon	6-55
6-5	Measures to control potential adverse environmental impacts - Davis Canyon	6-57
6-6	Site transportation data, Davis Canyon	6-76
6-7	Davis Canyon railway system interchanges	6-79
6-8	Preclosure system guidelines not requiring site characterization, Davis Canyon	6-86
6-9	Particle exit layer distributions for 1,000 realizations of Davis Canyon local ground-water system, 5-kilometer accessible environment, including fracture-controlled pathways	6-99
6-10	Postclosure technical guidelines requiring site characterization, Davis Canyon site	6-105
6-11	Compositions of simulated salt brines used in corrosion tests	6-119
6-12	Davis Canyon CHLW package. Comparison of package release rates to saturate incoming brine at the waste package boundary with NRC engineered system release rate limits in 10 CFR Part 60	6-128

EXECUTIVE SUMMARY

1. INTRODUCTION

By the end of this century, the United States plans to begin operating the first geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste. Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site, and constructing, operating, closing, and decommissioning the repository. Congress approved geologic disposal by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" [Section 111(b)(1)].

A geologic repository can be viewed as a large underground mine with a complex of tunnels occupying roughly 2,000 acres at a depth between 1,000 and 4,000 feet. To handle the waste received for disposal, surface facilities will be developed which will occupy about 400 acres. The repository will be operational for about 25 to 30 years. After the repository is closed and sealed, waste isolation will be achieved by a system of multiple barriers, both natural and engineered, that will act together to contain and isolate the waste as required by regulations. The natural barriers include the geologic, hydrologic, and geochemical environment of the site. The engineered barriers consist of the waste package and the underground facility. The waste package includes the waste form, the waste disposal container, and materials placed over and around the containers. The underground facility consists of underground openings and backfill materials, not associated with the waste package, that are used to further limit ground-water circulation around the waste packages and to impede the subsequent transport of radionuclides into the environment.

In February 1983, the DOE carried out the first requirement of the Act by formally identifying nine sites in the following locations as potentially acceptable sites for the first repository (the host rock of each site is noted in parentheses):

1. Vacherie dome, Louisiana (domal salt)
2. Cypress Creek dome, Mississippi (domal salt)
3. Richton dome, Mississippi (domal salt)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows).

The locations of these sites are shown in Figure 1.

Figure 1. Potentially acceptable sites for the first repository.

After identifying these potentially acceptable sites, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (the guidelines) in accordance with the Act. The draft guidelines were revised in response to extensive comments and received the concurrence of the Nuclear Regulatory Commission (NRC) in June 1984. Final guidelines were published in December 1984 as 10 CFR Part 960.

The Act requires the DOE to nominate at least five sites as suitable for site characterization--a formal information-gathering process that will include the sinking of one or more shafts at the site and a series of experiments and studies underground. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. After site characterization is completed, one of the characterized sites will be recommended for development as a repository.

The Act also requires the DOE to prepare environmental assessments (EAs) to serve as the basis for site-nomination decisions. These EAs contain the following information and evaluations consistent with the requirements of Section 112 of the Act:

- A description of the decision process by which the site is being considered for nomination (EA chapters 1 and 2).
- A description of the site and its surroundings (EA Chapter 3).
- An evaluation of the effects of site characterization activities on public health and safety and the environment and a discussion of alternative activities that may be taken to avoid such effects (EA Chapter 4).
- An assessment of the regional and local effects of locating the proposed repository at the site (EA Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (EA Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (EA Chapter 6).
- A reasonable comparative evaluation of the site with other sites that have been considered (EA Chapter 7).

This executive summary highlights the important information and evaluations found in the accompanying EA. Section 2 of this executive summary presents a summary of the decision process and findings leading to the nomination of the Davis Canyon site. Sections 3 through 7 summarize the results of evaluations contained in corresponding chapters of the EA.

2. DECISION PROCESS AND PRELIMINARY CONCLUSIONS

2.1 DECISION PROCESS

The guidelines require the DOE to implement the following seven-part evaluation and decision process for nominating and recommending sites for characterization:

1. Evaluate the potentially acceptable sites against the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation, under each guideline, of the sites proposed for nomination.

7. Consider an order of preference of the nominated sites as recommended sites and, on the basis of this order of preference, recommend not fewer than three sites for characterization to the President.

The DOE prepared a draft EA for each of the nine potentially acceptable sites to give all interested parties an opportunity to review the full evaluation of all sites considered. In preparing the final EAs for the five nominated site, the DOE has considered all comments that were received.

The final EAs will accompany the formal nomination of at least five sites as suitable for characterization. The Secretary of Energy will then recommend not fewer than three of these sites to the President as candidate sites for characterization. After the President approves the Secretary's recommendation, characterization activities will begin at those sites. After characterization is completed, the DOE will again evaluate each site against the guidelines and, after completing an environmental impact statement will recommend one site to the President for the first repository. The President may then recommend the site to Congress. At this point, the host State may issue a notice of disapproval that can be overridden only by a joint resolution of both Houses of U.S. Congress. If the notice of disapproval is

not overridden, the President must submit another repository site recommendation within 12 months. If no notice of disapproval is submitted, or if Congress overrides the notice of disapproval, then the site designation is effective, and the DOE will file an application with the NRC to obtain a construction authorization for a repository at that site.

2.2 FINDINGS AND DETERMINATIONS

The DOE's findings and determinations that apply to the Davis Canyon site are summarized below.

2.2.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

The evidence does not support the disqualification of the Davis Canyon site under the guidelines, nor are any of the other eight potentially acceptable sites found to be disqualified.

2.2.2 GROUPING OF SITES BY GEOHYDROLOGIC SETTING

The nine potentially acceptable sites are contained within five distinct geohydrologic settings as defined by the U.S. Geological Survey. The sites are grouped by the DOE's geohydrologic designations as follows:

Geohydrologic Setting	Site
Columbia Plateau	Reference repository location, Hanford Site, Washington
Great Basin	Yucca Mountain, Nevada
Permian Basin	Deaf Smith County and Swisher County, Texas
Paradox Basin	Lavender Canyon and Davis Canyon, Utah
Gulf Interior Region of the Gulf Coastal Plain	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi.

The distinctions among the geohydrologic settings and the host rock are clear not only among basalt, salt, and tuff, but also among the three basins in salt. The bedded salt of the Paradox and Permian Basin are distinct from the dome salt of the Gulf Interior Region in terms of their structure, rock properties, and the relationship of the host rock to the aquifers in the

geohydrologic environment; the Paradox Basin is also distinct from the bedded salt in the Permian Basin in terms of stratigraphic sequence, regional hydrologic setting, history of deposition, and physiography.

2.2.3 SELECTION OF A PREFERRED SITE IN THE PARADOX BASIN

On the basis of the information and evaluations reported in this EA and, in particular, a comparison of the Davis Canyon and the Lavender Canyon sites in the Paradox Basin, the DOE has identified the Davis Canyon site as the preferred site in the Paradox Basin.

The Davis Canyon site was identified as the preferred site primarily because of land-acquisition uncertainties. Both the Davis and the Lavender Canyon sites are located on public lands managed by the Bureau of Land Management (BLM) as well as some private and State-owned land. Part of the Lavender Canyon site, however, extends into the Bridger Jack Mesa Wilderness Study Area, an area under review for possible inclusion in the National Wilderness System. Therefore, the Lavender Canyon site would require, in addition to the Congressional action needed to permanently withdraw public land, a Congressional determination of the status of the Wilderness Study Area. The time frame for such Congressional action is not scheduled and could potentially delay site characterization and other program activities. As a result of the uncertainties associated with this land transfer, the Davis Canyon site is considered to be more favorable than the Lavender Canyon site.

Because the Davis Canyon site is only 2.4 kilometers (1.5 meters) from the Lavender Canyon site, differences between the two sites tend to be minor. While the Lavender Canyon site is closer than the Davis Canyon site to a known geologic fault, a known dissolution feature, and a population center, these differences are considered insignificant. Similarly, estimated differences in the potential impacts on the Canyonlands National Park are not distinguishable between the two sites.

2.2.4 SUITABILITY OF THE DAVIS CANYON SITE FOR DEVELOPMENT AS A REPOSITORY

Section 112(b) of the requires the DOE to evaluate the suitability of a site for development as a repository under each guideline that does not require site characterization as a prerequisite for the application of the guidelines. The intent is to preclude the investment of money and effort in sites that could be disqualified under those guidelines for which substantial information is available for site evaluation. The guidelines that do not require characterization primarily relate to those characteristics of a site that are related to the effects of a repository on public health and safety, the quality of the environment, and socioeconomic conditions before the repository is closed and sealed.

For a site to be suitable for repository development under each of those guidelines that do not require site characterization, no disqualifying conditions can be present, and each of the qualifying conditions under those guidelines must be met. A final determination of suitability for repository

development cannot be made until site characterization is complete. However, at this stage, the evidence does not support a finding that the Davis Canyon site is disqualified. Furthermore, the evidence does not support a finding that the Davis Canyon site is not likely to meet all the qualifying conditions under the guidelines that do not require site characterization.

2.2.5 SUITABILITY OF THE DAVIS CANYON SITE FOR CHARACTERIZATION

To determine whether a site is suitable for characterization, the DOE must evaluate the site against all of the guidelines, including those that require site characterization. In order to judge that a site is suitable, the DOE must then conclude that the evidence does not support a finding that the site is not likely to meet all of the guidelines. As a result of the evaluations reported in Chapter 6, the DOE has found that the Davis Canyon site is suitable for characterization.

2.2.6 DECISION ON NOMINATION

Having made the above findings, the DOE has decided to nominate the Davis Canyon site as suitable for site characterization. The other potentially acceptable sites selected for nomination are Deaf Smith County, Texas; the reference repository location at the Hanford site, Washington; the Richton Dome, Mississippi; and Yucca Mountain, Nevada.

3. THE SITE

The Davis Canyon site is in northern San Juan County, Utah, in a sparsely populated southeastern portion of the State (Figure 2). The site is located in a semiarid setting and is in an area of rugged terrain. Davis Canyon is a relatively flat valley surrounded by nearly vertical cliffs and long, narrow mesas. The 2,331-hectare (5,760-acre) Davis Canyon site is composed of 92 percent public lands managed by the BLM, 4 percent State lands, and 4 percent private lands. The nearest communities are Monticello, 44 miles by road (23 air miles) to the south, and Moab, 69 miles by road (33 air miles) to the north. The community of Blanding is 74 miles by road (34 air miles) to the south. The nearest regional highway is U.S. Highway 191, which is 47 kilometers (29 miles) from the site via Utah State Highway 211 (Utah 211), its National Park Service extension, and a short unimproved road. The nearest rail line to the site is the Kane Creek branch of the Denver & Rio Grand Western Railroad (D&RGW). This 57.5-kilometer (35.7-mile) line extends south from the D&RGW main line at Crescent Junction, Utah, to Potash, on the north bank of the Colorado River west of Moab.

The Davis Canyon site is within the area in San Juan County managed under the BLM Indian Creek-Dry Valley management plan. The management plan provides for multiple uses including livestock grazing, mining, oil and gas development, recreational vehicle use, and dispersed recreation (The BLM is currently preparing a new resource management master plan). The area's

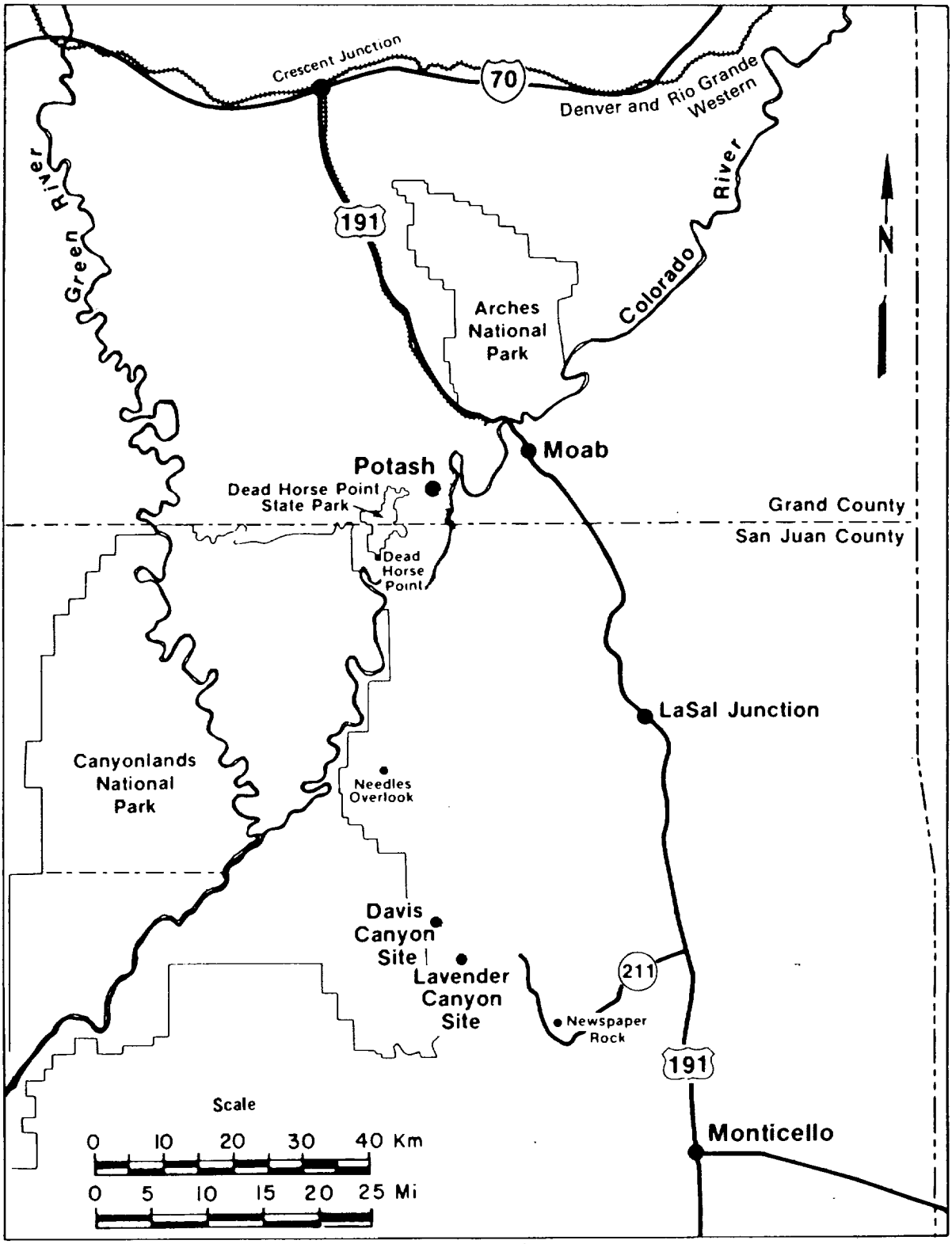

Figure 2. Davis and Lavender Canyon Sites.

primary uses are agriculture (principally cattle grazing) and recreation. Important recreation resources include Canyonlands National Park, Manti-La Sal National Forest, Newspaper Rock State Historical Monument, Canyon Rims Recreation Area, Beef Basin, and three wilderness study areas.

The southeastern district of Canyonlands National Park (the Needles district) is within 0.3 kilometer (0.2 mile) of the Davis Canyon site. This district is accessible by Utah 211, the road which also provides access to Davis Canyon. The Needles district is characterized by colorful stone spires and numerous arches. Its recreational uses include hiking, camping, backpacking, and nature study. Canyonlands National Park, including the Needles district, is open to visitors throughout the year.

The Davis Canyon site is in the southwest part of the Paradox Basin (Figure 3). The rocks beneath the site consist of siltstones, sandstones, salt, and limestones that overlie a basement complex of crystalline rock. The host rock under consideration is a salt bed that is approximately 61 meters (200 feet) thick and lies about 884 meters (2,900 feet) underground. The bed is one of the 29 evaporite layers comprising the Paradox Formation. Although faults have been identified 16 kilometers (10 miles) west of the Davis Canyon site, none have been identified within the site. Known salt-dissolution features occur at the Lockhart and Beef Basins, 19 kilometers (12 miles) north and 23 kilometers (14 miles) southwest of the site, respectively. Salt dissolution is also possible in the vicinity of the two fault areas. There is no evidence of igneous or volcanic activity in the site area in the last 25 million years.

Davis Canyon is a tributary of Indian Creek, which ultimately drains into the Colorado River. The canyon includes a small ephemeral wash, flowing only during, and immediately after, intense summer storms. The 100-year floodplain in Davis Canyon encroaches on a portion of the land needed for the repository. The quality of the surface water in the region is typified by high salinity as well as high concentrations of other dissolved solids. The major use of surface water in this area is irrigation.

The ground-water system of the western Paradox Basin is divided into three hydrostratigraphic units. The first is an upper hydrostratigraphic water-bearing unit that overlies the second unit, which is an aquitard consisting of the salt beds of the basin, including the host salt. The third, or lower, hydrostratigraphic unit underlies the salt beds. Ground-water discharge from the upper hydrostratigraphic unit in the Davis Canyon area is from springs and subriver-level seeps into the Colorado River. There are several small-capacity livestock and domestic wells; five wells supplying Canyonlands National Park in the Needles area can produce from 4 to 60 gallons of water per minute. There is apparently no significant discharge from the middle or lower hydrostratigraphic units. Potentiometric levels for tests in the upper hydrostratigraphic unit are generally higher than those for tests in the lower hydrostratigraphic unit. This suggests a downward hydraulic gradient from the upper to the lower aquifer. Fluid pressure and potentiometric levels on the middle hydrostratigraphic unit have an anomalous trend (i.e., they do not decrease uniformly). This could suggest that the

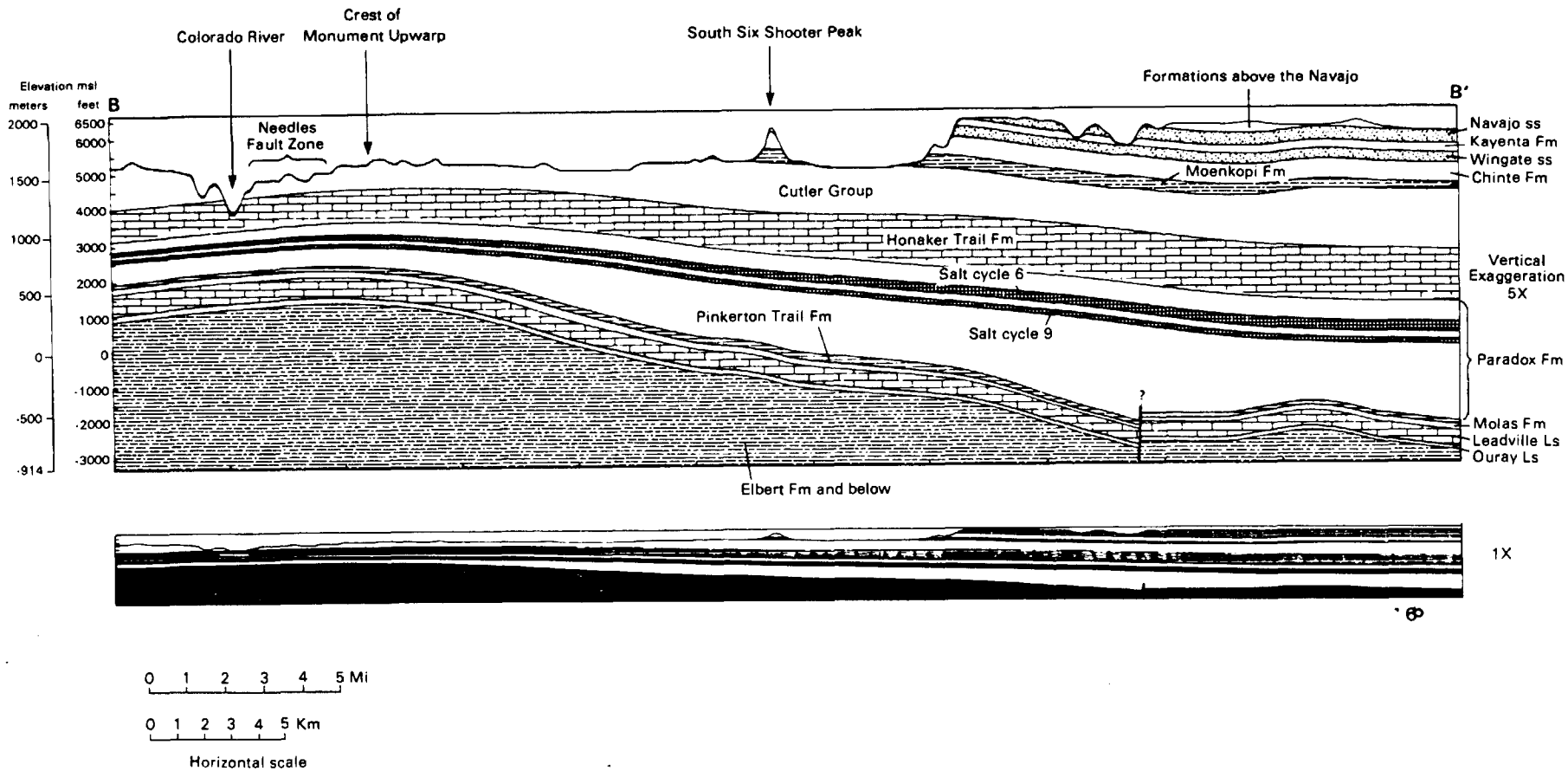

Figure 3. Geologic cross section of Davis and Lavendar Canyon sites.

upper and lower hydrostratigraphic units are not connected. Ground-water flow for the upper unit is predominately to the north, toward the Colorado River; ground-water flow in the lower unit is west-southwest.

Mineral resources at the Davis Canyon site consist primarily of uranium and vanadium as well as potash, with minor deposits of copper, manganese, quartz, iron oxide, sand and gravel, and dimension stone. The vicinity of the site contains only four documented localities of uranium and vanadium production. There are also potential oil and gas resources within the area; however, there is no record of hydrocarbon production at the site, and the area is classified as "undiscovered speculative resources" by the Bureau of Mines and the USGS.

The major vegetation types in the site area are the Great Basin desert shrub and pinyon pine-juniper woodland communities. Much of the Davis Canyon site is a native pasture supporting open-range livestock operations. Overgrazing and other human activities have altered the natural vegetation. There are no aquatic ecosystems on the site.

The generally low diversity and productivity of the natural vegetation in this area results in a corresponding low abundance and diversity in wildlife populations. Two threatened or endangered and 21 rare plant species are known to occur in San Juan and Grand Counties. The only such species that occurs near the site is the Monument Valley milkvetch, a species recommended for threatened status. Conditions are favorable in the site area for eight animal species listed as endangered or under review for such status. In winter, bald eagles roost along the Colorado River, and there are active peregrine falcon eyries within 16 kilometers (10 miles) of the site. The Davis Canyon site is not known to contain any critical or unique habitats. No existing or proposed units of the National Wildlife Refuge System occur within 80 kilometers (50 miles) of the Davis Canyon site.

The climate in southeastern Utah is predominantly semiarid. The annual precipitation averages about 20.8 centimeters (8.2 inches) at Moab and 35.1 centimeters (13.8 inches) at Monticello. Tornadoes are very infrequent. Flash floods from summer thunderstorms may cause localized flooding in Davis Canyon.

The Davis Canyon site is located in a prevention of significant deterioration (PSD) Class II area that meets all air-quality standards for that designation. Because of the site's proximity to the Canyonlands National Park, a PSD Class I area begins 0.3 kilometers (0.2 miles) west of the site. The nearest major source of emissions (the town of Moab) is 33 air miles north of the site. The sources of pollution in the site area are vehicular traffic and dust from sparsely vegetated rangeland, roads, and trails. Conditions in the site area are generally conducive to the dispersion of pollutants. However, the dispersion of emissions can be hampered by the area's mountain-and-valley terrain; local inversions can cause the air to be trapped in a valley.

The Davis Canyon vicinity contains abundant cultural artifacts, dominated by the remains of the Mesa Verde Anasazi Indians. It also includes several historical sites associated with the area's livestock frontier and earlier mining ventures. Two sites on the National Register of Historic Places are

near Davis Canyon: the Newspaper Rock State Historical Monument and the Salt Creek Archaeological District in Canyonlands National Park, which includes hundreds of recorded archaeological sites.

The scenic character of the Davis Canyon area is one of open spaces with unusual rock formations and color contrasts. The landscape includes broad basins, prominent cliffs, isolated buttes, mesas, spires, and deeply entrenched meandering canyons. The numerous scenic attractions that are nearby include the Canyonlands National Park, the Needles Overlook in the Canyon Rims Recreation Area, and the Newspaper Rock State Historical Monument.

The average population density in the 80-kilometer (50-mile) radius around the site is 3.8 persons per square mile. The towns in this region, and their 1980 populations, are as follows: Moab, 7,173 (including Spanish Valley); Monticello, 1,929; and Blanding, 3,118. Population estimates for 1984 show an 8-percent decrease for Moab and no significant changes for Monticello and Blanding. Projections for the year 2006 show substantial increases for all three communities over their 1984 levels.

The Indian reservations in the region include a part of the Unitah and Ouray Reservation in northeastern Grand County, which belongs to the Ute tribe, and a part of the Navajo tribal lands in southern San Juan County.

The economy of the study area is generally tied to natural resources, in terms of energy-related activities. Mining (primarily uranium), trade, and government have been the major employers in Grand and San Juan Counties. The economy of the two Counties has been declining over recent years, consistent with a decline in the uranium industry. In 1984, Grand County and San Juan County experienced unemployment rates of 16.0 and 10.7 percent, respectively.

Mayor-council municipal governments exist in Monticello, Blanding, and Moab. Monticello and Blanding also have city managers. Monticello is the county seat of San Juan County, and Moab is the county seat of Grand County. Both communities also are the centers of county-wide school systems which are at or below capacity. In 1984, Monticello, Blanding, and Moab had approximately 400 vacant housing units available, including units for rent or sale and mobile home spaces.

4. EFFECTS OF SITE CHARACTERIZATION

This section describes the site-characterization activities that would be performed if the Davis Canyon site were selected for site characterization.

To obtain the information necessary for evaluating the suitability of the Davis Canyon site for a repository, the DOE would conduct a site-characterization program of underground testing. To carry out this program, the DOE would construct two shafts down to the level of the repository (one shaft for removing salt and other materials and lowering test apparatus into the shaft facility, and one for services and emergency egress), excavate drifts at the proposed repository depth, construct support structures on the surface, and construct an access road to the site. In addition to the

tests performed underground and in the exploratory shaft facility (ESF), geologic field studies would be conducted to characterize underground conditions.

At the same time, the DOE would study the environment of the site and its vicinity, including weather conditions, air quality, noise, plant and animal communities, and archaeological and cultural resources. Socioeconomic conditions would also be investigated in the nine-county area expected to be affected by the repository.

The site-characterization program would last several years. At the end of this period, if the Davis Canyon site is found unsuitable for a repository, the shafts would be filled and sealed, and the site would be reclaimed.

Site characterization will entail some adverse effects. Current land uses in parts of the site will be disrupted. Approximately 24 hectares (59 acres) of public land will be required for constructing the ESF, and an additional 14 hectares (35 acres) of land will be needed for a 7.7-kilometer (4.8-mile) access road, connecting with the National Park Service extension of Utah 211. The DOE will obtain access to public land by entering into a cooperative agreement with the BLM. State-owned and private land needed to conduct field studies will be purchased or leased.

Protection of land approximating the controlled area around a geologic repository site will be necessary. This area, to be protected during characterization, consists of approximately 2,331 hectares (5,760 acres). Public land would be acquired for protection by filing a withdrawal application with the BLM. State and private lands would be purchased or leased.

The excavation of salt from the underground test area would create a surface stockpile of approximately 222,345 cubic meters (170,000 cubic yards), covering an area of about 2 hectares (6 acres). An impermeable liner would be placed beneath the salt pile and ponds would be used to control surface-water runoff so as to minimize the potential for surface- and ground-water contamination. During salt-handling operations, some windblown salt would be deposited on nearby ground. The DOE has successfully managed salt excavation and stockpiling on a similar scale at two different sites. This experience has shown that salt emissions during excavation would not be significant. Waste salt and residues would be removed to an offsite licensed landfill.

Wildlife would be removed from the immediate area of surface structure development, while wildlife in the surrounding areas could be disturbed by site-characterization activities. The measures that can be taken to mitigate these effects include minimizing land clearing and making provisions for revegetation after site characterization. Because the site and its immediate surroundings do not support any ecologically unique communities, and the area to be cleared is very small in comparison with the surrounding undisturbed area, the ecological effects are expected to be minimal.

Air-quality effects would result mainly from fugitive dust (a contributor to particulate emissions) and the gases emitted by equipment and vehicle engines. When total suspended particulate (TSP) concentrations from site characterization are added to background concentrations, the peak

concentration may exceed secondary National Ambient Air Quality Standards (NAAQS) at the immediate site boundary but not at the Park boundary. This excess would be limited to small areas. Examples of measures to mitigate air-quality effects include the spraying of disturbed areas with water or chemicals, soil stabilization, and the management of the salt and spoils piles.

Some structures and the night lighting needed for site-characterization activities would be visible from a stretch of Utah 211 and a small area in the Canyonlands National Park. The degree of visual intrusion would be reduced by such measures as orienting and painting buildings and other structures to blend with the surrounding environment. Site characterization would also temporarily elevate noise in offsite areas. Possible mitigation measures include the scheduling of noise-generating activities and the use of physical sound barriers.

The Canyonlands National Park and other recreational areas in the vicinity of the site could lose some tourists who would come to the area to seek a wilderness experience. The greatest effect would occur during the drilling of test wells and the construction of shafts. A small percentage of users of the Canyonlands National Park would be affected by noise and visual intrusion. These effects would be mitigated as discussed above.

The Needles district of Canyonlands National Park (adjacent to the Davis Canyon site) is managed by the National Park Service to provide a range of interpretive and recreational activities to hikers and users of four-wheel-drive vehicles. Access to this district is by Utah 211, the road which also provides access to Davis Canyon. Current traffic along this road is approximately 45 vehicles per day; however, over 1,000 vehicles per day travel this road on peak visitation days at the Park. During site characterization, traffic volume associated with the project would average approximately 300 vehicles per day, with a peak volume increase of 600 vehicles per day. This peak volume would last 3 months. Improvements could be made to minimize traffic flow problems on this highway.

Potential indirect impacts on cultural and archaeological resources are possible because the access route to Davis canyon (Utah 211) passes Newspaper Rock State Historical Monument and because the Salt Creek Archaeological District in Canyonlands National Park is near the proposed location of the ESF. To minimize these and any other effects, the DOE would conduct site surveys before disturbing any land and make every effort to design project activities to avoid damage to historic or archaeological properties. A worker awareness and education program would be implemented to stress the need for resource conservation.

There would not be any major disturbances of residents located near the site, and no relocation of any residents is expected. Nor is any significant displacement of economic activity expected in the area. Approximately 439 of the 488 workers needed for site characterization would move to the area, with the total number of in-migrating people estimated at 953. Local communities may experience some social effects in accommodating in-migrants. Population increases may place a housing burden on Blanding and Monticello. The mitigation measures that could be undertaken to reduce local effects would

include hiring as many local residents as possible and attempting to influence the settlement patterns of in-migrants toward communities with the best capacity to accommodate new residents.

Site characterization at Davis Canyon would cost $250 million for ESF construction and $225 million for other (primarily geologic) activities. Seventy percent of this amount would be for materials and 30 percent for wages. Although only a portion of these funds would be spent locally, it could result in considerable economic activity. The site characterization project would be the biggest single employer in southeastern Utah.

5. REGIONAL AND LOCAL EFFECTS OF REPOSITORY DEVELOPMENT

To determine the effect of developing a repository at the site, three phases of repository development were examined: construction, operation, and closure and decommissioning. During the construction phase, which will last approximately 7 years, the DOE would construct surface and support structures, construct access shafts, excavate and prepare underground tunnels and waste-disposal rooms, and improve access roads and utility services. During the first few years of the operation phase, the repository would receive small amounts of waste-about 400 metric tons (441 tons) per year - while the surface and underground facilities are completed. After construction is completed, the rate of waste receipt would increase to a maximum of 3,000 metric tons (3,300 tons) of radioactive waste per year. During the operation phase, underground development would continue concurrently with waste emplacement until the required area is excavated. This full-operation phase is estimated to last some 25 to 30 years; it would be followed by a "caretaker" period because the U.S. Nuclear Regulatory Commission (NRC) requires the DOE to preserve the option of retrieving the waste for 50 years after the initial emplacement. During closure and decommissioning the underground repository would be backfilled, shafts and boreholes would be closed and sealed, land-use controls would be instituted, the surface facilities would be decontaminated and decommissioned, and permanent markers or monuments would be erected at the site to warn future generations about the presence of the underground repository.

Both adverse and beneficial effects would result from developing a repository at the Davis Canyon site. A 189-hectare (467-acre) surface site would be used for repository facilities, and an additional 2,142 hectares (5,293 acres) would be needed for the controlled zone.

While the removal of a total of 2,331 hectares (5,760 acres) of land would result in closing almost all of the land in Davis Canyon accessible to cattle, it may be feasible to continue to allow grazing on land outside the surface site. Grazing would also be lost from the lands developed as access and utility corridors. The corridors could have the additional effects of changing grazing patterns and blocking livestock access to water. These effects would be addressed when the specific corridors are identified.

Recreational use of Davis Canyon will be affected during the construction and (to a lesser extent) operation of a repository. Direct impacts will be characterized by impaired access to Canyonlands National Park and Newspaper Rock State Historical Monument. Indirect impacts will be created by a change in the status of the land to a single-purpose repository site. If an exclusive-use repository access road is built, there will be only temporary construction-traffic impacts along Utah 211. This new access road, or an improved Utah 211, will bypass Newspaper Rock State Historical Monument.

Approximately 3.3 million tons of excavated salt would be stored at the site to be used for backfilling the repository. The salt-storage pile would cover about 20 hectares (50 acres) and reach a height of about 11 meters (35 feet). Although a hard crust would form over the salt pile, some windblown salt is likely to be deposited in the immediate vicinity of the site during salt-transfer operations. An impermeable liner would be used under the pile to minimize effects on ground water. Collection ponds would be constructed to contain any runoff from the salt pile. It is not expected that the windblown salt from salt-handling activities or from the salt pile would have a significant effect on local soils. It is estimated that about 10 million tons of excess salt would require removal and offsite disposal. Excess salt can be disposed of by several methods, including placement in an offsite mine; no method of salt disposal has yet been selected.

The ecological effects of repository development would be largely confined to the site and would be similar to those experienced during site characterization (see 4). Transportation and utility corridors may serve as behavioral barriers to some area wildlife. Land clearing and route selection would take into account measures to reduce ecological impacts.

Air-quality effects would result from fugitive dust and gases emitted by equipment and vehicle engines; these effects would be greatest during site preparation. The 24-hour National Ambient Air Quality Standards (NAAQS) for total suspended particulates (TSP) and the annual average NAAQS for TSP and nitrous oxides (NO_x) will be met during repository construction, operations, and decommissioning and closure. Visibility impacts at Davis Canyon (atmospheric discoloration) probably would be imperceptible.

Individual repository activities would be potentially visible from limited areas within Canyonlands National Park (including the end of Davis Canyon). These areas have no designated hiking or jeep trails for park visitors. The repository facility is potentially visible from Utah 211 at South Six-Shooter Peak, Davis Canyon jeep trail, and Bridger Jack Mesa. The proposed access road from U.S. Utah 191 to the repository is visible from several observation points. All four of the rail route alternatives to the repository potentially can be seen from the Island-in-the-Sky district of the National Park, but none can be seen from jeep and hiking trails in the Needles district of the park. The siting and construction of support facilities would take into account measures to reduce visibility and the degree of contrast with local conditions.

During repository and rail route construction, short duration noise levels from intermittent blasting may be audible over 24 kilometers (15 miles) from the site for the initial period of construction (approximately 2 weeks) under typical conditions. During operation, machinery noise would be heard in

the park, and the noise made by the trains hauling waste may be audible up to 12.1 kilometers (7.5 miles) into the park for short periods of time. Possible mitigation measures include the proper scheduling of activities and the use of physical sound barriers.

The effects on local tourism during repository construction would be similar to those experienced during site characterization (see 4). Some reduced tourism could continue during operation because of the negative perception of the repository.

A potential exists for indirect impacts resulting from increased human intrusion into the area during construction and operation of the repository. Increased vandalism and unintentional destruction of cultural resources could occur because there would be more people at and near the repository site. The effects could be mitigated by restricting offsite and off-road vehicle use and through educational programs.

Because runoff from the site would be controlled, only minor siltation and salt addition to surface and underground waters are projected. All significant contaminants will be controlled in lined ponds. Shaft sinking will employ seals to prevent ground-water contamination and degradation of aquifer quality. Water for repository construction and operation could be supplied from a variety of sources. Data indicate that sufficient water would be available for the repository.

During the peak of repository construction, about 2,070 direct and indirect jobs would be created in the region, and approximately 4,690 persons (workers and their families) are expected to in-migrate. During the peak of operation, also about 2,070 direct and indirect jobs would be created (although there would be a smaller proportion of direct jobs than during construction), and a maximum of 3,730 persons are expected to in-migrate. The maximum project-related increase in the population of the Grand and San Juan Counties in the year 1997 is estimated to be 20 percent over the 1977 baseline population projection. This level of in-migration would necessitate increased housing and increases in community services. The area may also experience some stress-related social problems associated with boomtown conditions.

Local business activity would increase. During the 8-year construction period, an estimated $43 million would be spent for materials purchased locally. Wages and salaries available to be spent locally would approximate $141 million during the construction phase. During the 26 year period of repository operations, an estimated $93 million would be spent locally for materials. Wages and salaries to be spent locally would amount to about $530 million. Potentially adverse socioeconomic effects should be offset by the increased tax base, by grants-equal-to taxes, and financial assistance provided by the DOE. It is not expected that any households would be displaced because of land requirements for the repository or for transportation and utility corridors.

Two highway routes are being studied for access to Davis Canyon. One would involve upgrading Utah 211 to the 7.7-kilometer (4.8-mile) access road into the repository. The other would be a 40-kilometer (25-mile) repository highway from U.S. 191 (including a 1.9 kilometer [1.2-mile] tunnel). Four feasible railroad access routes are under study. Three of the routes extend

Another important factor in the site's ability to isolate wastes is the potential for human intrusion through exploration for natural resources. As described above in the section, The Site, potential resources such as uranium and vanadium are present at Davis Canyon, and exploration for oil and gas has occurred in the surrounding area. However, there has not been any oil and gas production in the immediate site area that would have created pathways between the repository horizon and the accessible environment. Moreover, the site is considered to have a low economic potential in comparison with the rest of the region, which indicates that there is little likelihood of human intrusion into the repository horizon.

With regard to the performance of engineered barriers at the site, the NRC standards specify that the waste package is to contain the waste for 300 to 1,000 years and that the rate of radionuclide release beyond this period of containment is not to exceed 1 part in 100,000 per year. Current information on the corrosion of metals like those used for the waste canisters suggests that at the Davis Canyon site the lifetime of the waste package is expected to exceed 10,000 years. The potential for corrosion will be addressed further during site characterization. The DOE estimates that the release rate beyond the period of containment will not only meet the regulatory limits, it may be much lower. Preliminary assessments of engineered-barrier performance under realistic but conservative assumptions indicate that the EPA's limit on the release rate to the accessible environment would be met at the Davis Canyon site.

6.3 SUMMARY OF SITE EVALUATIONS AGAINST THE PRECLOSURE GUIDELINES

The evaluation of the Davis Canyon site against the three groups of preclosure guidelines are summarized below.

6.3.1 RADIOLOGICAL SAFETY

Preliminary assessments of preclosure performance for the Davis Canyon site do not indicate that any releases of radioactive material from the repository would exceed any applicable radiation standards during repository operation and closure. In addition, the site was evaluated against the following Technical Guidelines that are concerned with the radiological effects of repository operation on public health and safety: population density and distribution, site ownership and control, meteorology, and offsite installations and operations.

No people are residing within the boundaries of the Davis Canyon site, and the population density in the region is low (3.8 persons per square mile). The closest highly populated areas are Moab, 33 air miles away with a 1980 population of 5,333 (1,772 persons per square mile), and Blanding, 34 miles away with a 1980 population of 3,118 (1,973 persons per square mile). Monticello, 23 air miles from the site, had a 1980 population of 1,929. The Davis Canyon site is located on land for which the DOE can obtain ownership and control access.

The meteorological characteristics are not favorable, according to the Technical Guidelines. The inversions that can occur at the site may decrease the dispersion of pollutants, and the region experiences such potentially disruptive events as flooding, heavy fog, and snowstorms. Also, the City of Moab is 53 kilometers (33 miles) downwind of the site. Nevertheless, preliminary assessments indicate that the radiation-exposure limits of 10 CFR Part 20 and 40 CFR Part 191 would not be exceeded.

There are no nearby industrial, transportation, or military installations or operations so close to the site that they would significantly affect the safety of the repository. There are three uranium mills within 80 kilometers (50 miles) of the site; the closest is in Moab, 53 kilometers (33 miles) away. However, there is no evidence that regulatory standards would be exceeded when the releases from the mills are added to the conservative values calculated for the repository.

6.3.2 ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

Three Technical Guidelines address the environmental, socioeconomic, and transportation effects of a repository before closure. These effects, which would be both beneficial and adverse, are summarized above. Preliminary analyses indicate that the expected adverse effects can be mitigated to an acceptable level.

With respect to the System Guideline on the environment, socioeconomics, and transportation, the evidence does not support a finding that the Davis Canyon site is not likely to meet the qualifying conditions of protecting the public and the environment from the potential hazards associated with waste disposal.

6.3.3 EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

Four Technical Guidelines address the ease and cost of siting, construction, operation, and closure; they are concerned with surface characteristics, rock characteristics, hydrology, and the tectonic stability of the site. The surface facilities of the repository would be located within a generally flat, well-drained area surrounded by rugged terrain. Part of the site is within the floodplain of the 100-year flood, but this potential for flooding can be mitigated by fill placement to elevate the area out of the floodplain. There are no man-made surface impoundments in the area that could interfere with the repository.

The host rock at the Davis Canyon site affords significant flexibility in repository locations. Minimal artificial support would be required to maintain underground openings; however, salt creep would necessitate regular maintenance, including scaling, to keep passageways open. If waste retrieval is necessary, it could be adversely affected by thermal cracking or by radiation effects on the mechanical behavior of the adjacent rock. Creep around, and the stresses induced on, the overpack could pose difficulties in

retrieval, as could brine migration toward the canister. There is a potential for brine or gas pockets in the repository horizon, but the associated hazards can be mitigated.

The Elephant Canyon Formation, which lies between the host rock and the land surface, yields a small quantity of ground water. As stated above, there is a potential for surface flooding, which can be mitigated. Sufficient water is currently available for repository construction and operation. Overall, the surface- and ground-water systems are compatible with the activities associated with a repository.

Active faults (Shay Graben, 16.1 kilometers [10 miles] to the south) do occur in the area, and conservative estimates of ground motion are not significantly lower than those generally allowed at nuclear power plants. However, the Davis Canyon area is unlikely to experience earthquakes or man-induced seismicity that could pose serious design or operational-safety problems.

Preliminary evaluations indicate that the repository can be constructed and operated with reasonably available technology, and the costs would be comparable to those of a repository at any of the other potentially acceptable sites. Therefore, the evidence does not support a finding that the Davis Canyon site is not likely to meet the qualifying condition of the System Guideline on the ease and cost of siting, construction, operation, and closure.

7. COMPARATIVE EVALUATION OF NOMINATED SITES

7.1 PURPOSE AND REQUIREMENTS

Chapter 7 presents a comparative evaluation of the five sites nominated as suitable for site characterization: Davis Canyon, Deaf Smith County, Hanford, Richton Dome, and Yucca Mountain. Each site is a preferred site within a geohydrologic setting: Davis Canyon is in the bedded salt of the Paradox Basin in Utah; Deaf Smith County is in the bedded salt of the Permian Basin in Texas; Hanford is in basalt in the Columbia Plateau in Washington; Richton is a salt dome in Mississippi; and Yucca Mountain is in tuff in the Southern Great Basin in Nevada.

The purpose of this chapter is to present a comparative evaluation of the nominated sites in order to satisfy the following:

1. Section 112(b)(1)(E)(iv) of the Nuclear Waste Policy Act of 1982, which requires that a "reasonable comparative evaluation" be included in the environmental assessments that accompany site nomination, and

2. Section 960.3-2-2-3 of the DOE's siting guidelines (10 CFR Part 960), which requires that a reasonable comparative evaluation be made and that a summary of evaluations with respect to the qualifying condition for each guideline be provided to "allow comparisons to be made among sites on the basis of each guideline."

This comparative evaluation is intended to allow the reader to compare the more detailed suitability evaluations of the individual sites that are presented in Chapter 6 of each environmental assessment. The comparison should assist the reader in understanding the basis for the nomination of five sites as suitable for characterization [112(b)(1)(A)]; it is not intended to directly support the subsequent recommendation of three sites for characterization as candidate sites.

7.2 APPROACH AND ORGANIZATION

This comparative evaluation of the five nominated sites is based on the postclosure and preclosure guidelines (10 CFR Part 960, Subparts B and C, respectively). The evaluation presented in this chapter includes the system guidelines and the technical guidelines. The approach used to compare the sites with respect to each system and technical guideline in summarized below.

7.2.1 TECHNICAL GUIDELINES

Major considerations that could be used to compare the sites on the basis of the qualifying condition of each technical guideline were derived by identifying the favorable, potentially adverse, and disqualifying conditions that deal with the same general topic. Contributing factors that represent the characteristics of the site that are potentially important in evaluating the sites with respect to each major consideration were also identified. The relative importance of the major considerations was determined primarily by the degree to which they contribute to the qualifying condition; that is, the stronger the tie between the consideration and the qualifying condition, the greater the importance of the consideration.

The purpose of identifying major considerations for each guidelines is to combine closely related site conditions so that the balance of the favorable and potentially adverse conditions can be considered directly. Most guidelines that contain a disqualifying condition have one or more potentially adverse conditions that relate to the disqualifying condition. Since these potentially adverse conditions are considered in the formulation of a major consideration, the important aspects of the disqualifying conditions indirectly enter the comparative evaluation. Where a major consideration that is needed to evaluate the qualifying condition does not have a related favorable or potentially adverse condition, the consideration is derived directly from the qualifying or disqualifying condition.

The comparative evaluation of the sites with respect to each guideline, using the approach described above, is summarized in Sections 7.2 and 7.3 for the postclosure and preclosure guidelines, respectively.* These sections are organized in the following manner:

1. For each guideline, the major consideration(s) and associated contributing factors are identified.

2. The evaluation of each site on the basis of each major consideration is then summarized. The evaluation of each site with respect to each major consideration is presented in alphabetical order, by site.

3. The sites are then compared on the basis of the qualifying condition. This comparative evaluation describes the sites with the most favorable combination of characteristics first and those with a less favorable combination of characteristics last in order to allow easier comparison of the suitability evaluation of the site presented in Chapter 6 with sites having other combinations of characteristics.

7.2.2 SYSTEM GUIDELINES

The comparison of sites on the basis of the individual technical guidelines uses the major considerations to incorporate the favorable and potentially adverse conditions in an evaluation of a site's standing on the qualifying conditions for each technical guideline. It is not appropriate, however, to use this approach for a comparative evaluation of sites on the basis of the system guidelines. The qualifying conditions for the system guidelines do not lend themselves to the identification of major considerations in the way that the qualifying conditions for the technical guidelines do. The system guidelines for postclosure repository performance and preclosure radiological safety are stated in terms of regulatory requirements of the NRC and EPA. The evaluations of these two system guidelines are based on preliminary performance assessments that consider the associated technical guidelines as the elements of the system. These evaluations are summarized directly from Sections 6.3.2 and 6.2.2.1 of each environmental assessment.

The system guidelines for environment, socioeconomics, and transportation, and for ease and cost of repository construction, operation, and closure are not stated as regulatory standards, and they cannot be evaluated by a performance assessment as are the other two system guidelines.

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*Since the comparative evaluations in Section 7.2 and 7.3 are already a summary of information in Chapter 6, this executive summary does not attempt to further abstract the substance of the comparative evaluation. The DOE believes that a further synopsis of Section 7.2 and 7.3 for the purpose of this executive summary would distort the information and possibly mislead the reader.

Instead, they are evaluated by considering the individual guidelines that make up these two system guidelines collectively to determine whether each site meets the qualifying condition of the relevant system guidelines. The evaluation of these system guidelines is summarized from Section 6.2.2.2 and 6.3.4, in each environmental assessment.

Chapter 1

PROCESS FOR SELECTING SITES FOR GEOLOGIC REPOSITORIES

1.1 INTRODUCTION

By the end of this century, the United States plans to begin the operation of a geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste.* Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site and assigns to the U.S. Department of Energy (DOE) the responsibility for siting, constructing, operating, closing, and decommissioning the repository.

A number of alternative methods for disposing of spent nuclear fuel and high-level radioactive waste have been studied during the past 10 years (DOE, 1980a; EPA, 1979; Interagency Review Group, 1979; Schneider and Platt, 1974). After an extensive evaluation of these alternatives, as documented in the final environmental impact statement on the management of commercially generated radioactive waste (DOE, 1980a), the DOE chose disposal in mined geologic repositories as the preferred method and documented this decision in a notice published in the Federal Register (Vol. 46, p. 2667, May 14, 1981). Congress endorsed this preference by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" (Section 111(b)(1)).

1.1.1 THE GEOLOGIC REPOSITORY CONCEPT

A geologic repository will be developed much like a large mine. Shafts will be constructed to allow for the removal of excavated material and to permit the construction of tunnels and disposal rooms at depths between 1,000 and 4,000 feet underground. Other shafts will be constructed to allow for the transfer of waste. Surface facilities will be provided for receiving and

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*High-level radioactive waste means (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations, and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, determines by rule requires permanent isolation. The terms "radioactive waste" and "waste" are used for both spent fuel and high-level radioactive waste.

preparing the waste for emplacement underground. The surface and underground facilities will occupy about 400 and 2,000 acres of land, respectively. When the repository has been filled to capacity and its performance has been shown to be satisfactory, the surface facilities will be decommissioned and all shafts and boreholes will be backfilled and permanently sealed. A more detailed description of a conceptual design for a repository is presented in Section 5.1.

A repository can be viewed as a system of multiple barriers, both natural and engineered, that act together to contain and safely isolate the waste. The engineered barriers will include the waste package, the underground facility, and shaft and tunnel backfill materials. The waste package will consist of the waste form, either spent nuclear fuel or solidified high-level waste, a metal container, and specially designed backfill material to separate the waste container from the host rock. The waste package will contribute to long-term isolation by delaying eventual contact between the waste and the geologic environment. The underground facility will consist of underground openings and backfill materials not associated with the waste package. These barriers will further limit any ground-water circulation around the waste packages and impede the subsequent transport of radionuclides into the environment.

The geologic, hydrologic, and geochemical features of the site constitute natural barriers to the long-term movement of radionuclides to the accessible environment. These natural barriers will provide waste isolation by impeding radionuclide transport through the ground-water system to the accessible environment and will possess characteristics that will reduce the potential for human interference in the future.

Although the DOE plans to use engineered barriers--as required by both the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60 and the Environmental Protection Agency (EPA) in 40 CFR Part 191--the DOE places primary reliance on the natural barriers for waste isolation. Therefore, in evaluating the suitability of sites, the use of an engineered-barrier system will be considered to the extent necessary to meet the performance requirements specified by the NRC and the EPA but will not be relied on to compensate for deficiencies in the natural barriers.

1.1.2 THE NUCLEAR WASTE POLICY ACT OF 1982

The search for suitable repository sites has been under way for about 10 years, although preliminary screening began in the mid-1950s. With the passage of the Act, a specific process for siting and licensing repositories was established. Through provisions for consultation and cooperation as well as financial assistance, the Act also established a prominent role in the siting process for potential host States, affected Indian Tribes, and the public. To pay the costs of geologic disposal, the Act provides for a Nuclear Waste Fund through which commercial electric utility companies are charged a fee that is based on the amount of electricity they produce in nuclear power plants. The DOE's strategy for implementing the Act is discussed in detail in the Mission Plan for the Civilian Radioactive Waste Management Program (DOE, 1985).

In February 1983, the DOE carried out the first requirement of the Act by formally identifying potentially acceptable sites in the following locations (the host rock of each site is shown in parentheses):

1. Vacherie Dome, Louisiana (salt dome)
2. Cypress Creek Dome, Mississippi (salt dome)
3. Richton Dome, Mississippi (salt dome)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows)

The location of these sites in their host States is shown in Figure 1-1.*

The Act further requires the DOE to issue general guidelines to be used in determining the suitability of sites. In February 1983, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (DOE, 1983). The DOE revised the guidelines after receiving extensive comments from the NRC, the States, Indian Tribes, other Federal agencies, and the public. The NRC concurred with the revised guidelines in June 1984, and the final guidelines were promulgated in December 1984 (DOE, 1984a).

The Act requires that, after the guidelines are issued, the DOE nominate at least five sites as suitable for site characterization. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. During site characterization, the DOE will construct exploratory shafts for underground testing to determine whether geologic conditions will allow the construction of a repository that will safely isolate radioactive waste. The Act requires the DOE to prepare site-characterization plans for review by the NRC, States, Indian Tribes, and the public. After site characterization and an environmental impact statement are completed, the DOE will recommend one of the characterized sites for development as the first repository.

1.1.3 THE ENVIRONMENTAL ASSESSMENT

The Act requires the DOE to prepare environmental assessments to serve as the basis for site nominations. Although not required by the Act, draft environmental assessments were prepared for each of the nine potentially acceptable sites and issued for comment by the NRC and other Federal agencies, the States, affected Indian Tribes, and the public. The DOE has considered

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*In Texas, the DOE first identified two locations that were up to 300 square miles in area. These were subsequently narrowed to 9 square miles. The other potentially acceptable sites identified in February 1983 were on the order of tens of square miles.

Figure 1-1. Potentially acceptable sites for the first repository.

the comments received on these drafts before making final decisions about nomination and recommendation. The issues raised by the comments and the DOE's responses are presented in Appendix C.

The final environmental assessments contain the following kinds of information and evaluations to meet the requirements of Section 112 of the Act:

- A description of the decision process by which the site being considered for nomination was selected (Chapter 2).
- A description of the site and its surroundings (Chapter 3).
- An evaluation of the effects of site characterization on the health and safety of the public and the environment as well as a discussion of alternative activities that may be taken to avoid such impacts (Chapter 4).
- An assessment of the regional and local impacts of locating the proposed repository at the site (Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (Chapter 6).
- A reasonable comparative evaluation of the five nominated sites (Chapter 7).

1.2 SUMMARY OF THE OVERALL DECISION PROCESS

In seeking sites for geologic repositories, the DOE divides the siting process into the following phases: (1) screening, (2) site nomination, (3) recommendation for characterization, (4) site characterization, and (5) site selection (recommendation for development as a repository). This section describes the site-screening process that led to the identification of the nine potentially acceptable sites listed in Section 1.1 and reviews how the process of site nomination is implemented under the guidelines.

1.2.1 SITE SCREENING

During the screening phase, the DOE identified potentially acceptable sites for characterization. This phase provided the information needed for judging which of these sites appear to justify the investment in characterizing them. Screening consisted of as many as four stages, each of which progressively narrowed the study area to a smaller land unit. These stages were as follows:

1. A survey of the nation or geologic provinces, narrowing to regions. Regions are generally smaller than provinces but may extend across several States and occupy tens of thousands of square miles.

2. A survey of the regions, narrowing to areas, which encompass hundreds to thousands of square miles. For the salt sites, the regional screening phase was completed with the publication of regional characterization reports and area-recommendation reports.

3. A survey of the areas, narrowing to locations, which usually occupy an area smaller than 100 square miles. This phase was completed with the publication of location-recommendation reports for bedded salt and site-recommendation reports for salt domes.

4. A survey of the locations, narrowing to sites, which are generally smaller than 10 square miles. Although a location may be large enough to contain several sites, only one or two potential sites were usually identified in a particular location.

During each screening phase for the first repository, the DOE identified as many potentially suitable land units as were judged to be necessary for an adequate sample to be studied in the next stage. Only the regions and areas believed most likely to contain suitable sites received further study; the evaluation of all others was deferred.

Data for comparing regions, areas, and locations became increasingly detailed as progressively smaller land units were considered and as exploration and testing were concentrated on them. National, province, and regional surveys were based on the distribution of potential host rocks, published geologic maps, maps of earthquake epicenters, land use, available geohydrologic information, and other information available in the open literature. Area and location surveys required more-thorough investigations that included field exploration and testing and drilling of boreholes to investigate subsurface hydrologic, stratigraphic, and geochemical conditions. The field studies were supported by laboratory studies that focused on the waste-isolation and the engineering characteristics of potential host rocks.

The bedded-salt sites under consideration in Texas and Utah were identified by the general siting process described above, beginning with national surveys and progressively narrowing to areas, locations, and sites. The salt domes were selected by a screening that began with more than 200 domes and ended with the one site being nominated.

The screening of sites in basalt and tuff was initiated when the DOE began to search for suitable repository sites on some Federal lands where radioactive materials were already present. This approach was recommended by the Comptroller General of the United States (1979). Although land use was the beginning basis for this screening of Federal lands, the subsequent progression to smaller land units was based primarily on evaluations of geologic and hydrologic suitability. These studies began at roughly the area stage.

The technical factors used to guide site-screening decisions have evolved throughout the screening phase and are specified in a number of published documents (Brunton and McClain, 1977; DOE, 1981; DOE, 1982a; International Atomic Energy Agency, 1977; NAS-NRC, 1978).

The sections that follow summarize how the DOE applied the screening process outlined above to determine that the nine sites listed in Section 1.1.2 are potentially acceptable. Section 2.2 of each environmental assessment discusses in detail how the DOE conducted site screening in specific geohydrologic settings.

1.2.2 SALT SITES

Salt was first recommended as a potentially suitable host rock for waste disposal in 1955, after the National Academy of Sciences-National Research Council evaluated many options (NAS-NRC, 1957). This recommendation was reaffirmed in subsequent reports (e.g., American Physical Society, 1978; NAS-NRC, 1970). Rock salt, which occurs both as bedded salt and in salt domes, has several characteristics that are favorable for isolating radioactive waste, including the following:

- Salt deposits that are sufficiently deep, thick, and laterally extensive to accommodate a repository are widespread in the United States and generally occur in areas of low seismic and tectonic activity.
- Many salt bodies have remained undisturbed and water-free in comparison with other rock types for tens of millions to several hundred million years.
- Because of its high thermal conductivity, rock salt can dissipate the heat that will be generated by the waste.
- Since salt is relatively plastic under high confining pressure, the fractures that might develop at repository depth would tend to close and seal themselves.
- Rock salt undergoes only minor, highly local change as a result of exposure to radiation.
- Rock salt has excellent radiation-shielding properties.

Screening of the entire United States in the 1960s and 1970s resulted in the identification of four large regions that are underlain by rock salt of sufficient depth and thickness to accommodate a repository and represent diverse geohydrologic conditions (Johnson and Gonzales, 1978; Pierce and Rich, 1962). The four regions are as follows:

- Bedded salt in the Michigan and the Appalachian Basins of southern Michigan, northeastern Ohio, western Pennsylvania, and western New York (also called the "Salina Basin").
- Salt domes within a large part of the Gulf Coastal Plain in Texas, Louisiana, and Mississippi.
- Bedded salt in the Permian Basin of southwestern Kansas, western Oklahoma, northwestern Texas, and eastern New Mexico.

- Bedded salt in the Paradox Basin of southeastern Utah, southwestern Colorado, and northernmost Arizona and New Mexico.

This screening at the national level served as the basis for all subsequent screening in salt. After proceeding to the area phase, further screening of the salt deposits in the Salina Basin was deferred. The studies of the Salina region were not specific enough to judge that any part of the region was suitable or unsuitable for a repository. They did reveal a number of unfavorable characteristics, including a high population density associated with the concentration of urban areas in Ohio, Michigan, and New York, and an abundance of natural resources, especially oil and gas. In view of these unfavorable conditions, the DOE decided to concentrate its siting efforts on more-promising areas in the remaining three regions.

1.2.2.1 Salt domes in the Gulf Coast salt-dome basin of Mississippi and Louisiana

There are more than 500 salt domes in the Gulf Coast salt-dome basin of Texas, Louisiana, Mississippi, and areas offshore from these States. An initial screening by the U.S. Geological Survey (USGS) eliminated all offshore domes because siting a repository under water would probably not be feasible. The application of this criterion eliminated about half the domes. The USGS also evaluated the remaining 263 onshore domes (i.e., Gulf interior domes) and identified 36 as being potentially acceptable for a repository and another 89 that were worthy of further study (Anderson et al., 1973). The USGS screening factors were the depth to the top of the dome and present use for gas storage or hydrocarbon production.

The DOE and its predecessor agencies conducted regional studies of the 125 salt domes identified in the above-mentioned USGS screening. All but 11 of the domes were eliminated on the basis of three screening factors: the depth to the salt, the lateral extent of the dome, and the history of use for hydrocarbon production or storage (NUS, 1978; BNI and LETCO, 1980). Three of the 11 domes were removed from consideration on the basis of environmental factors, and a fourth was eliminated because solution mining at the site contributed to a collapse of strata above the dome.

Area-characterization studies were completed for the seven remaining dome areas: Rayburn's and Vacherie Domes in Louisiana; Cypress Creek, Lampton, and Richton Domes in Mississippi; and Keechi and Oakwood Domes in Texas. The geologic field work conducted during this phase included the drilling of deep holes to collect rock cores from the aquifers and other strata for laboratory tests of their properties and geophysical surveys to determine the underlying rock structures. The area environmental studies included descriptions of the plant and animal communities, surface- and ground-water systems, weather conditions, land use, and socioeconomic characteristics. An evaluation of the seven domes on the basis of the DOE's criteria is summarized in a location-recommendation report (ONWI, 1982a).

In the area-characterization studies, the DOE chose a repository-size criterion that was more restrictive than the one used in earlier screening studies. The application of this stricter criterion resulted in the

elimination of Keechi, Rayburn's, and Lampton Domes (ONWI, 1982a). Thus, at the conclusion of area characterization, the Vacherie, Richton, Oakwood, and Cypress Creek Domes were recommended for further screening. After further review of the area-characterization studies, the Oakwood Dome was deferred from further consideration because of uncertainties raised by large-scale petroleum exploration.

In accordance with the Act, the DOE identified the Cypress Creek, Richton, and Vacherie Domes as potentially acceptable sites in February 1983.

1.2.2.2 Bedded salt in Davis Canyon and Lavender Canyon, Utah

Screening criteria were developed for the bedded salt of the Paradox Basin, which the USGS had identified as worthy of further investigation (Pierce and Rich, 1962). The following factors were applied to identify areas for further investigation (Brunton and McClain, 1977; DOE, 1981): the depth to, and the thickness of, the salt; mapped faults; surface igneous features; hydrocarbon and mineral resources, and potential for flooding. The results of this screening were integrated with the results of screening for environmental and socioeconomic factors, such as proximity to urban areas and the presence of certain dedicated lands. On the basis of this regional screening, four areas were recommended for further study: Gibson Dome, Elk Ridge, Lisbon Valley, and Salt Valley (ONWI, 1982b).

The primary screening factors used to identify potentially favorable locations within the four areas were the depth to the salt, the thickness of the salt, proximity to faults and boreholes, and proximity to the boundaries of dedicated lands (ONWI, 1982c). These screening factors were judged to have the strongest potential for differentiating possible locations within the areas.

Salt Valley and Lisbon Valley were both deferred from further consideration because all areas with an adequate depth to the salt were too close to zones of mapped surface faults and, for Lisbon Valley, existing boreholes (ONWI, 1982c).

Application of the screening factors to the Gibson Dome showed a location of 57 square miles near the center of the area that contained appropriately deep and thick salt deposits and was sufficiently far from faults or exploration boreholes that would make a site unsuitable. It was also outside the boundaries of the Canyonlands National Park. This location is referred to as the Gibson Dome location (ONWI, 1982c). The Elk Ridge area contained one location of about 6 square miles and several smaller ones, each less than 3 square miles, that met the screening criteria (ONWI, 1982c). The smaller locations were not large enough for a repository and were therefore excluded from further consideration. The larger location was designated the Elk Ridge location.

Further comparisons of the Gibson Dome and the Elk Ridge locations were made on the basis of more-refined criteria that discriminated between them. The thickness of the salt, the thickness of the shale above and below the depth of a repository, and the minimum distance to salt-dissolution features

were considered the most critical geologic discriminators. Archaeological sensitivity and site accessibility were considered the most important environmental factors. The Gibson Dome location was judged to be superior to the Elk Ridge location in terms of the number and relative importance of favorable factors and was selected as the preferred location (ONWI, 1982c).

During 1982 and 1983 three sites were identified for further evaluation: Davis Canyon, Lavender Canyon, and Harts Draw. Since much of the intrinsic value of southeastern Utah stems from its scenic and aesthetic character, a study of visual aesthetics was performed to evaluate the three sites (Bechtel Group Inc., 1984). Harts Draw was found to be less desirable than the sites at Davis Canyon and Lavender Canyon because it affords a greater total area of visibility, and it was eliminated from further consideration. In February 1983, Davis Canyon and Lavender Canyon were identified as potentially acceptable sites.

1.2.2.3 Bedded salt in Deaf Smith and Swisher Counties, Texas

In 1976, the Permian bedded-salt deposits in the Texas Panhandle and western Oklahoma that had been identified in the USGS study (Pierce and Rich, 1962) were evaluated to determine whether they contained any areas that might be suitable for waste disposal (Johnson, 1976). This screening focused on five subbasins: the Anadarko, Palo Duro, Dalhart, Midland, and Delaware Basins. The primary screening factors were the depth to, and the thickness of, the salt; faults; seismic activity; salt dissolution; boreholes; underground mines; proximity to aquifers; mineral resources; and conflicting land uses, such as historical sites and State or national parks. All the subbasins contain salt beds of adequate thickness and depth. The Palo Duro and the Dalhart Basins had far less potential for oil and gas production and have not been penetrated as extensively by drilling as have the Anadarko, the Delaware, and the Midland Basins. Therefore, the Palo Duro and the Dalhart Basins were judged to be preferable to the other three and were recommended for further studies at the area stage (ONWI, 1983a). These two basins rated higher on six major screening factors: the depth to, and the thickness of, the salt; seismicity; known oil and gas deposits; the presence of exploratory boreholes; and evidence of salt dissolution.

More-detailed geologic and environmental studies of the Palo Duro and the Dalhart Basins began in 1977, and screening criteria were developed to define locations with favorable characteristics. The screening criteria that were most useful in the area-to-location screening were the following: salt depth and thickness, salt purity, existing and abandoned oil and gas fields, flooding, urban areas, and conflicting land use. Six locations in parts of Deaf Smith, Swisher, Oldham, Briscoe, Armstrong, Randall, and Potter Counties, Texas, met the screening criteria. A second set of criteria was then applied to further differentiate among the six locations: distance from the margins of the Southern High Plains, distance from known oil and gas fields, more than one potential repository horizon, depth of salt, number of boreholes that penetrate the repository horizon, a large geographic area, low population densities, and potential land-use conflicts. After applying these criteria, the DOE decided to focus on the two locations that had the greatest likelihood of containing a suitable site, one in northeastern Deaf Smith and southeastern

Oldham Counties and one in northcentral Swisher County. All other locations in the Palo Duro Basin were deferred from further consideration (ONWI, 1983b). In February 1983, the DOE identified parts of Deaf Smith County and Swisher County as potentially acceptable sites and subsequently narrowed the size of the two sites to be considered at each location to 9 square miles each (DOE, 1984b).

1.2.3 SITES IN BASALT AND TUFF

In 1977, the waste-disposal program was expanded to consider previous land use as an alternative basis for site screening. This approach considered the advantages of locating a repository on land already withdrawn from public use and committed to long-term institutional control. Because both the Hanford Site and the Nevada Test Site are dedicated to nuclear operations, will remain under Federal control, have a large geographic area, and are underlain by potentially suitable rocks, screening was initiated in these two areas.

1.2.3.1 Basalt lava in the Pasco Basin, Washington

The DOE and its predecessor agencies have investigated the geologic and hydrologic characteristics of the Pasco Basin since 1977 as a continuation of studies conducted for the defense-waste management program between 1968 and 1972 (Gephart et al., 1979; Myers et al., 1979). These investigations showed that the thick formations of basalt lava in the Pasco Basin are suitable for further investigation as a geologic repository for the following reasons:

- Several basalt flows more than 2,100 feet below ground apparently are thick enough to accommodate a geologic repository.
- The slow rate of deformation of the basalt ensures the long-term integrity of a repository at the Hanford Site. Also, there are synclines where structural deformation appears to be limited.
- The potential for renewed volcanism at the Hanford Site is very low.
- The likely geochemical reactions between the basalt rock, ground water, and the materials that would be emplaced in the repository are favorable for long-term isolation.

The Pasco Basin was selected for screening to provide a broader scope from which to study processes that might affect the Hanford Site and to determine whether there are any obviously superior sites in the natural region outside, but contiguous with, the Hanford Site (Woodward-Clyde Consultants, 1980, 1981).

The first step in screening was to define the candidate area. The screening factors used at this step were fault rupture, ground motion, aircraft traffic, ground transportation, operational radiation releases from nuclear facilities at the Hanford Site, protected ecological areas, culturally

important areas, and site-preparation costs. The DOE identified a candidate area that included the central part of the Hanford Site and adjacent land east of the Hanford Site.

The second step in the screening was to define subareas (locations). The siting factors used in this step were fault rupture, flooding, ground failure, erosion, the presence of hazardous facilities, induced seismicity, and site-preparation costs. This step eliminated approximately half the candidate area.

Locations were identified through an evaluation of the subareas inside and adjacent to the Hanford Site. On the basis of land use, hydrologic conditions, and bedrock dip, subareas outside the Hanford Site were eliminated because they were not obviously superior to those found within the Hanford Site. After these subareas were eliminated, five locations were identified within the boundaries of the Hanford Site.

The identification of sites from among the five locations was based on an evaluation of 23 parameters (Rockwell, 1980). Nine sites were identified, seven of which lay in the Cold Creek Syncline, a major structural feature of the Pasco Basin. This syncline was selected partly because it is not as extensively deformed as nearby anticlines and is underlain by relatively horizontal strata. Since the other two sites were not technically superior to those in the Cold Creek Syncline and were closer to the Columbia River, they were removed from further study. To avoid some geophysical anomalies of uncertain source, the DOE identified three other sites that were largely superimposed on parts of the original seven sites in the Cold Creek Syncline (Myers and Price, 1981).

Since preliminary evaluations of the resulting 10 partly overlapping sites indicated that the sites were too closely matched to be differentiated by routine ranking, a formal decision analysis was used to identify the best site (Rockwell, 1980). Decision criteria were derived from the following siting factors: bedrock fractures and faults, lineaments, potential earthquake sources, ground-water travel times, contaminated soil, surface facilities, the thickness of the proposed repository horizon, the repetitive occurrence of columnar-jointed zones (colonnades) within the host flow, natural vegetative communities, unique microhabitats, and special species. The analysis showed that two approximately coincident sites rated higher than the other sites. These two sites were combined and designated the reference repository location. In February 1983, the DOE identified the reference repository location as a potentially acceptable site.

1.2.3.2 Tuff in the southern Great Basin, Nevada

At the same time that the DOE was considering the Nevada Test Site (NTS) on the basis of land use, the USGS proposed that the NTS be considered for investigation as a potential repository site for a variety of geotechnical reasons, including the following:

- Southern Nevada is characterized by closed hydrologic basins. This means that ground water does not discharge into rivers that flow to major bodies of surface water.

- Long flow paths occur between potential repository locations and ground-water discharge points.

- Many of the rocks occurring at the NTS have geochemical characteristics that are favorable for waste isolation.

- The NTS is located in an arid region (6 to 8 inches per year of rainfall). With the very low rate of recharge, the amount of moving ground water is also low, especially in the unsaturated zone.

In 1977, the geologic medium of prime interest at the NTS was argillite (a clay-rich rock), which occurs under the Syncline Ridge, near the center of the NTS. Geologic investigations and exploratory drilling there revealed a complex geologic structure in the center of the area being considered (Hoover and Morrison, 1980; Ponce and Hanna, 1982). It was decided in July 1978 that the geologic complexity of the area would make characterization prohibitively difficult, and further evaluation was deferred.

A question then arose concerning the compatibility of a repository with the testing of nuclear weapons--the primary purpose of the NTS. A task group formed to evaluate this issue determined in 1978 that a repository located in other than the southwest portion of the NTS might be incompatible with weapons testing. At that time the program refocused on the area in and around the southwestern corner of the NTS, which subsequently was named the Nevada Research and Development Area (NRDA). The entire area then being evaluated included land controlled by the Bureau of Land Management west and south of the NRDA and a portion of the Nellis Air Force Range west of the NRDA.

In August 1978, a preliminary list of potential sites in and near the southwestern part of the NTS was compiled. The areas initially considered were Calico Hills, Skull Mountain, Wahmonie, Yucca Mountain, and Jackass Flats. Of these five areas, Calico Hills, Wahmonie, and Yucca Mountain were considered the most attractive locations for preliminary borings and geophysical testing.

The Calico Hills location was known to contain argillite. It was of particular interest because a geophysical survey showed that granite might occur approximately 1,600 feet below the surface. The first exploratory hole for waste-disposal studies at the NRDA was drilled in 1978 in an attempt to confirm the existence of granite beneath the Calico Hills. Drilling was discontinued at a depth of 3,000 feet without reaching granite (Maldonado et al., 1979). Additional geophysical surveys indicated that the argillite at Calico Hills is probably very complex structurally, comparable with that at Syncline Ridge (Hoover et al., 1982). Because the granite was considered too deep and the argillite appeared too complex, further consideration of the Calico Hills was suspended in the spring of 1979.

Concurrent with drilling at Calico Hills, geophysical studies and surface mapping conducted at Wahmonie indicated that the granite there may not be large enough for a repository, that any granite within reasonable depths may contain deposits of precious metals, and that faults in the rock may allow vertical movement of ground water (Hoover et al., 1982; Smith et al., 1981). For these reasons, Wahmonie was eliminated from consideration in the spring of 1979.

Surface mapping of Yucca Mountain indicated the existence of a generally undisturbed structural block large enough for a repository. In 1978, the first exploratory hole drilled at Yucca Mountain confirmed the presence of thick, highly sorptive units of tuff (Spengler et al., 1979). Because tuff previously had not been considered as a potential host rock for a repository, a presentation was made to the National Academy of Sciences (NAS) Committee for Radioactive Waste Management in September 1978 to solicit its views on the potential advantages and disadvantages of tuff as a repository host rock. The NAS committee supported the concept of investigating tuff as a potential host rock, and the USGS subsequently pointed out the considerable advantages of locating a repository in the unsaturated zone. After comparing the results of preliminary exploration at Calico Hills, Wahmonie, and Yucca Mountain, the USGS recommended that attention be focused on Yucca Mountain. A technical peer-review group supported the DOE's decision to concentrate exploration efforts on the tuffs of Yucca Mountain (DOE, 1980b).

Because the foregoing process of selecting Yucca Mountain for early exploration was not highly structured, a more thorough, formal analysis was begun in 1980 to evaluate whether Yucca Mountain was indeed appropriate for further exploration. This analysis was conducted in a manner compatible with the area-to-location phase of site screening described in the national siting plan (DOE, 1982b), which was used by the DOE before the passage of the Act and the formulation of the guidelines. Details of the formal analysis are presented by Sinnock and Fernandez (1984). In brief, this formal decision analysis evaluated 15 potential locations and concluded that Yucca Mountain was indeed the preferred location. Several potentially suitable horizons were identified in the saturated and unsaturated zones. Therefore, the DOE identified Yucca Mountain as a potentially acceptable site in February 1983.

1.2.4 NOMINATION OF SITES FOR CHARACTERIZATION

The guidelines, in 10 CFR Part 960.3, require the DOE to implement the following six-part decision process in selecting sites for nomination from among the potentially acceptable sites:

1. Evaluate the potentially acceptable sites in terms of the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

Section 1.3 presents the results of evaluating the nine potentially acceptable sites against the disqualifying conditions of the guidelines (step 1) and explains how the DOE has grouped the potentially acceptable sites by geohydrologic setting (step 2). Chapter 2 begins with a detailed description of the geohydrologic setting in which the Davis Canyon site is located and provides the basis for the identification of a preferred site in that geohydrologic setting (step 3). Chapter 6 evaluates the site against the guidelines and presents the findings required in steps 4 and 5. Chapter 7 provides a comparative evaluation of the sites proposed for nomination (step 6).

Having issued the final EAs, the DOE will formally nominate five sites as suitable for characterization. The Secretary of Energy will then recommend three of these sites to the President as candidate sites for characterization. The Secretary's recommendation is presented and documented in a separate report that is being issued simultaneously with this environmental assessment.

1.2.5 FINAL STEPS IN THE SITE-SELECTION PROCESS

After the President approves the sites recommended by the Secretary, characterization activities will begin at those sites. If site characterization reveals new information that shows that a site is unsuitable for development as a repository under the guidelines, the DOE will eliminate that site from further consideration and take steps to reclaim the site and to mitigate any significant adverse impacts caused by site characterization. In the event that a site is eliminated from further consideration during characterization, the DOE does not expect to substitute another site for characterization.

After characterization is completed, the DOE will again evaluate each site against the guidelines, prepare an environmental impact statement, and recommend one site to the President for the first repository. The President may then recommend the site to the Congress. At this point, the Governor or the legislature of the host State may submit to the Congress a notice of disapproval that can be overridden only by a joint resolution of both Houses of the Congress. If the notice of disapproval is not overridden, the President must submit another repository-site recommendation within 12 months. If no notice of disapproval is submitted, or if the notice of disapproval is overridden, then, as prescribed by the Act, the site designation is effective, and the DOE will proceed to file an application with the NRC to obtain a construction authorization for a repository at that site.

1.3 EVALUATION OF POTENTIALLY ACCEPTABLE SITES AGAINST THE DISQUALIFYING CONDITIONS OF THE GUIDELINES AND GROUPING INTO GEOHYDROLOGIC SETTINGS

1.3.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

Having evaluated the nine potentially acceptable sites against the disqualifying conditions in the guidelines, the DOE has found no evidence to support a finding that any site is disqualified. Details of this analysis are contained in Chapter 6, and a summary of findings for each disqualifying condition is presented in Section 2.3.

1.3.2 DIVERSITY OF GEOHYDROLOGIC SETTINGS AND TYPES OF HOST ROCK

Sections 960.3-1-1 and 960.3-1-2 specify that, to the extent practicable, sites recommended as candidate sites for characterization shall be located in different geohydrologic settings and shall have different types of host rock. This guideline-mandated diversity of geohydrologic settings and host rocks is consistent with similar requirements in the NRC's rule governing the disposal of high-level radioactive waste, 10 CFR Part 60. This requirement will protect against the possibility that future investigations might reveal a generic deficiency in a given rock type or within a given regional geohydrologic environment. Such deficiencies might lead to the disqualification of sites in that setting or rock type. If one rock type or geohydrologic environment were viewed initially as the most favorable for a repository, site nomination and recommendation might be dominated by sites in that type of host rock or geohydrologic environment. If later analyses revealed an unacceptable weakness in either the host rock or in the characteristics of the geohydrologic environment, all candidate sites might have to be eliminated. This could leave the program with no viable alternatives available without lengthy additional site exploration.

The guidelines (Part 960.2) define "geohydrologic setting" as a system of geohydrologic units located within a geologic setting. They further define "geohydrologic unit" as an aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. A "geologic setting" encompasses thousands to hundreds of thousands of square miles and is characterized by general similarities in physiography, stratigraphy, structural style, and ground-water flow.

For the intents and purposes of the analyses contained in this environmental assessment, the term "geohydrologic setting" refers to a large and relatively distinct major geohydrologic province of the United States commonly identified and accepted in the technical literature. Such a geohydrologic province has recognizable distinct geologic, hydrologic, and geochemical characteristics and boundaries that distinguish it from other geohydrologic settings.

1.3.2.1 Geohydrologic classification system

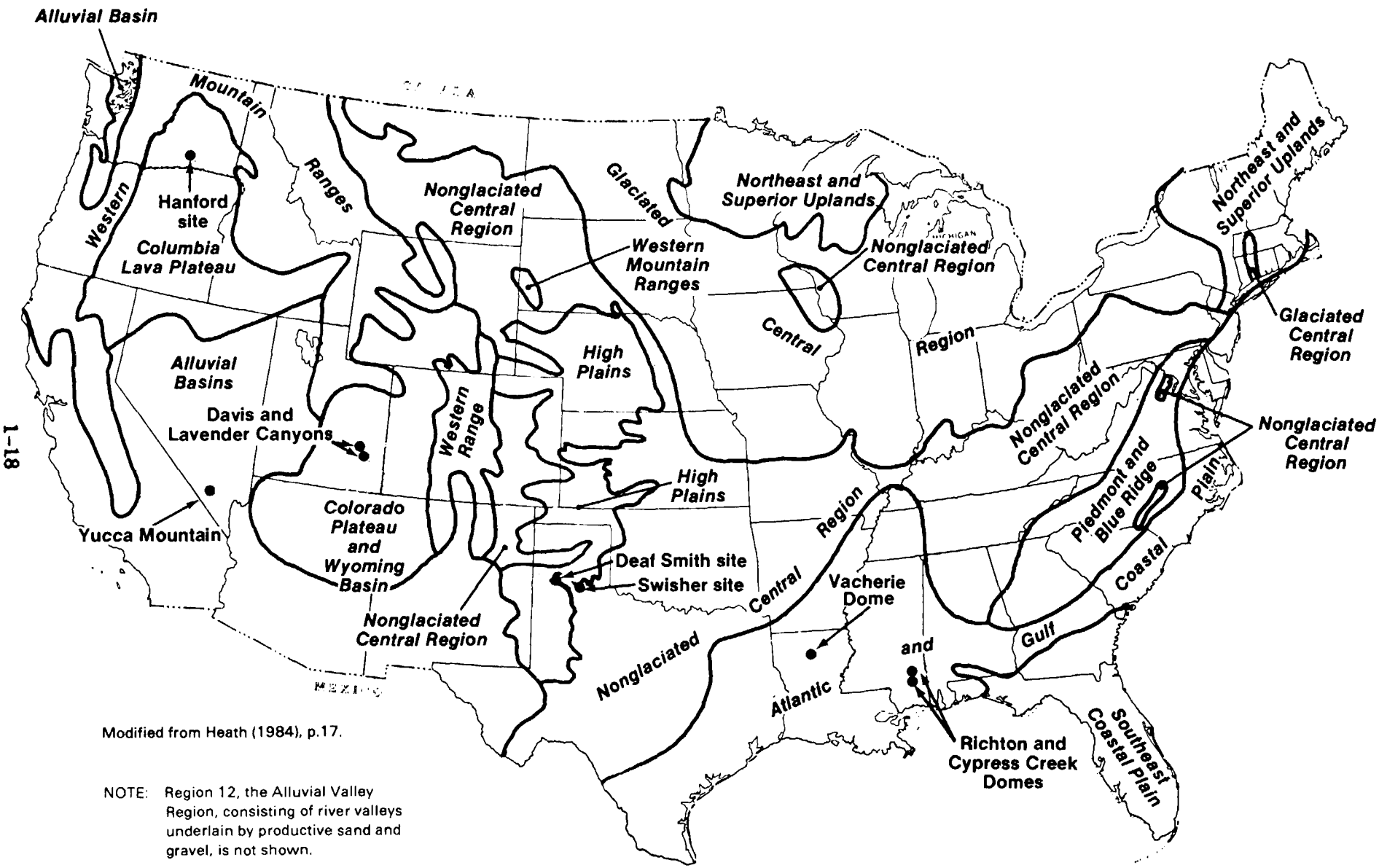
In a report entitled "Ground-Water Regions of the United States" (Heath, 1984), the USGS presents a classification that meets these broad criteria for geohydrologic settings. The USGS applied a logical set of criteria for classifying major geohydrologic regions that considers aquifers and confining units of the system, the nature of water-bearing openings in the rocks, the composition of the rocks, the water-transmitting and water-storage properties of the rocks, and the nature and location of recharge and discharge areas. These characteristics are also those that relate to repository performance (ground-water pathways, rates of radionuclide migration, and other factors important to waste isolation). Therefore, these general criteria appear suitable for application to this guideline requirement.

The USGS classification resulted in the delineation of 12 geohydrologic regions in the contiguous United States (see Figure 1-2). The specific rationale for the delineation and characteristics of each region is described in Heath's report.

It is within the framework of the USGS geohydrologic regions that the nine potentially acceptable sites were examined and classified as to their particular geohydrologic setting. In addition to the general criteria used in the USGS classification, other considerations were used to further subdivide the regions on the basis of tectonic activity, geologic structure, subbasins within the regions, and so on. Accordingly, the DOE has determined that the nine sites fall within the following five distinct geohydrologic settings (the name of the region within which each geohydrologic setting is located is listed in parentheses):

Geohydrologic setting	Site
Columbia Plateau (Columbia Lava Plateau)	Reference repository location as on the Hanford Site, Washington
Great Basin (Alluvial Basins)	Yucca Mountain, Nevada
Permian Basin (High Plains)	Deaf Smith County and Swisher County, Texas
Paradox Basin (Colorado Plateau and Wyoming Basin)	Lavender and Davis Canyons, Utah
Gulf Coastal Plain (Atlantic and Gulf Coastal Plain)	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi

The fundamental distinguishing characteristics associated with these settings as they relate to waste isolation are briefly described below. More-specific details on the characteristics of each of the geohydrologic settings are presented in Section 2.1.



Modified from Heath (1984), p.17.

NOTE: Region 12, the Alluvial Valley Region, consisting of river valleys underlain by productive sand and gravel, is not shown.

Figure 1-2. Geohydrologic regions of the contiguous United States.

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1.3.2.2 Distinct differences among the geohydrologic settings and host rocks

The major distinguishing differences among the five geohydrologic settings of the nine potential repository sites are summarized below.

The Hanford and the Yucca Mountain sites are clearly unique in terms of the host rock, the geologic conditions, and the hydrologic conditions that make up the geohydrologic setting. The Hanford site is located within the Pasco Basin, which is a subunit of the Columbia Lava Plateau geohydrologic setting as defined by Heath (1984). It is underlain by a thick, extensive sequence of rocks composed entirely of basalt lava flows in the lower part and of increasing amounts of interbedded, sedimentary deposits in the upper part. Aquifers generally are in the upper parts of the lava flows and in the interbeds. Ground-water drainage is to the Columbia River or its tributaries.

The Yucca Mountain site is located in a region composed of alternating sequences of block-faulted mountains and alluvium-filled valleys of the Alluvial Basins geohydrologic setting as defined by Heath. Yucca Mountain is a typical small fault-block mountain in this region and is composed entirely of volcanic rocks called tuff. The site is in the relatively dry unsaturated welded zone, well above the water table. This is a unique geohydrologic setting in comparison with the other sites, which are all situated well below the water table. The Hanford site will rely principally on the interaction of the low permeability of the dense basalts, the ion-exchange characteristics of the host rock, and a long ground-water flow path for waste isolation. The Yucca Mountain site will rely principally on a very low water flux through unsaturated rocks in a very arid environment, the natural ability of this type of system to exclude flowing or standing water from the repository, and the sorption characteristics of the minerals in the host rock.

The salt-site settings are also clearly distinguishable from one another, but perhaps not as obviously as the nonsalt sites. The first distinction among the salt settings is between salt domes and bedded salt. Although both bedded and dome salt have salt as a host rock, the properties of the two types of salt are quite different, and the hydrologic framework of salt differs greatly from setting to setting. Bedded salt occurs as sedimentary layers of salt and impurities and is typically bounded by aquifers above or below the salt units or both. The domes are anomalous piercements of the thick unconsolidated to semiconsolidated sedimentary clays, silts, and sands that make up the Atlantic and Gulf Coastal Plain, as defined by Heath. The domes are surrounded by aquifers at different depths. Thus, the geohydrologic conditions around the domes are distinctly different from that of bedded salt.

The pathways and mechanisms by which radionuclides might reach the accessible environment are also quite different for bedded and dome salt because of their fundamental structural and stratigraphic differences. Salt domes originated from thick beds of deeply buried salt. When sediments were deposited on these salt beds, the salt was forced upward, forming a dome. Some domes have risen as much as 20,000 feet above their source rock. The salt rock was intensely deformed and "kneaded" during this intrusive rise of the salt dome; as a result, nearly all of the water originally contained in the salt was squeezed out. Consequently, salt domes contain less water than

salt beds. In addition, and largely because of the different mode of formation, the following differences between the two types of salt rock are noteworthy:

- Because of its higher water content, bedded salt has a lower strength than dome salt.
- At equal depths of burial, bedded salt has lower geothermal temperatures than dome salt.
- Bedded salt tends to have a faster rate of creep than dome salt.
- Bedded salt has a more variable chemical composition than dome salt.
- Bedded salt has a simpler structure than salt domes.

Some of the most important of the above factors affecting waste isolation at salt sites are related to the chemical composition and configuration of the host rock. All salt sites would rely primarily on the extremely low permeability of the salt and the isolation of the host rock from surrounding aquifers. One significant potential failure mechanism in salt that can affect ground-water flow is the dissolution of the salt in ground water, whether initiated by inadvertent human intrusion or by unexpected salt deformation. The nature and the relative importance of this failure mechanism differ significantly for bedded and dome salt in their respective geohydrologic environments. For example, at salt domes dissolution would occur along the flanks by ground water from surrounding sedimentary strata. The dissolution of bedded salt could be induced by laterally migrating dissolution fronts, inter-salt-bed sedimentary aquifers, or vertically circulating water in fault zones.

Finally, although the Paradox Basin in Utah and the Permian Basin in Texas are both bedded-salt settings, they also have significant differences that warrant considering them as separate and distinct geohydrologic settings. The bedded-salt sites in Swisher and Deaf Smith counties, Texas, are located in the High Plains setting as defined by the USGS. This setting is underlain by relatively horizontal bedded sedimentary rocks that are capped by the partially unconsolidated sands, gravels, and clays of the Ogallala Formation. The geohydrologic system is dominated by the High Plains aquifer (the Ogallala Formation). Other aquifers, such as the Triassic Dockum Group, occur in deeper strata, but they produce poor-quality water in comparison with the Ogallala.

The bedded-salt sites of Davis Canyon and Lavender Canyon, Utah, on the other hand, are located in the Paradox Basin, which is a subsetting of the Colorado Plateau and the Wyoming Basin and is characterized by a broad uplifted plateau consisting of gently folded sedimentary sandstones, shales, carbonates, and evaporites. The stratigraphic sequence includes a few low-yield aquifers that generally contain poor-quality water. Ground water generally flows toward drainage systems in deeply dissected canyons of the region. Other specific differences include the following:

- Because of overburden and tectonic stresses, the Paradox Basin salt deposits have been structurally deformed into anticlines and synclines

(thickened and thinned zones) much more than the Permian Basin salt deposits have.

- The recharge and discharge patterns of ground water in the two settings are expected to be significantly different.

- The age, stratigraphic sequence, depositional history, and mineral composition of the salts and interbeds in two settings are different.

- The elevation, climate, and physiography of the two settings are significantly different.

- The ground-water system of the Paradox Basin sites is dominated by a deep aquifer well below the repository level, of low yield and poor water quality, whereas the ground-water system at the Permian Basin sites is dominated by a shallow productive aquifer well above the repository level.

On the basis of the criteria and known site characteristics presented above, the DOE has concluded that the nine potentially acceptable sites lie within five distinctly different geohydrologic settings, as indicated, and four distinctly different types of host rock (basalt, welded tuff, bedded salt, and dome salt).

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40 CFR Part 191, "Environmental Standards for the Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Code of Federal Regulations, Title 40, Part 191.

Chapter 2

SITE SELECTION PROCESS - PARADOX BASIN

As discussed in Section 1.2.2.2, site screening activities have identified the Davis Canyon and Lavender Canyon bedded salt sites within the Paradox Basin as acceptable salt sites for further study as potential nuclear waste repositories.

The Davis and Lavender Canyon sites are located in San Juan County, Utah, approximately 53 kilometers (33 miles) and 59 kilometers (37 miles), respectively, south of Moab, Utah (Figure 2-1). The proposed Davis Canyon geologic repository operations area, located principally in Sections 5 through 8 of T31S, R21E, is southwest of South Six-Shooter Peak in a cul-de-sac near the mouth of the canyon. The proposed Lavender Canyon geologic repository operations area, located principally in Sections 20, 21, 28, 29, and 32 of T31S, R21E, is approximately 1.6 kilometers (1 mile) southeast of the Davis Canyon geologic repository operations area.

This chapter describes the process and analysis used to identify and select a preferred site within the Paradox Basin (Figure 2-2). Section 2.1 describes the geohydrologic setting of the region; Section 2.2 summarizes how potentially acceptable sites were identified; Section 2.3 provides summaries on evaluation of the identified sites against expected disqualifying conditions set forth in U.S. Department of Energy (DOE) guidelines for siting repositories (10 CFR Part 960). Section 2.4 is a comparative evaluation of the potentially acceptable Davis and Lavender Canyon sites that identifies the preferred Paradox Basin site being nominated for site characterization.

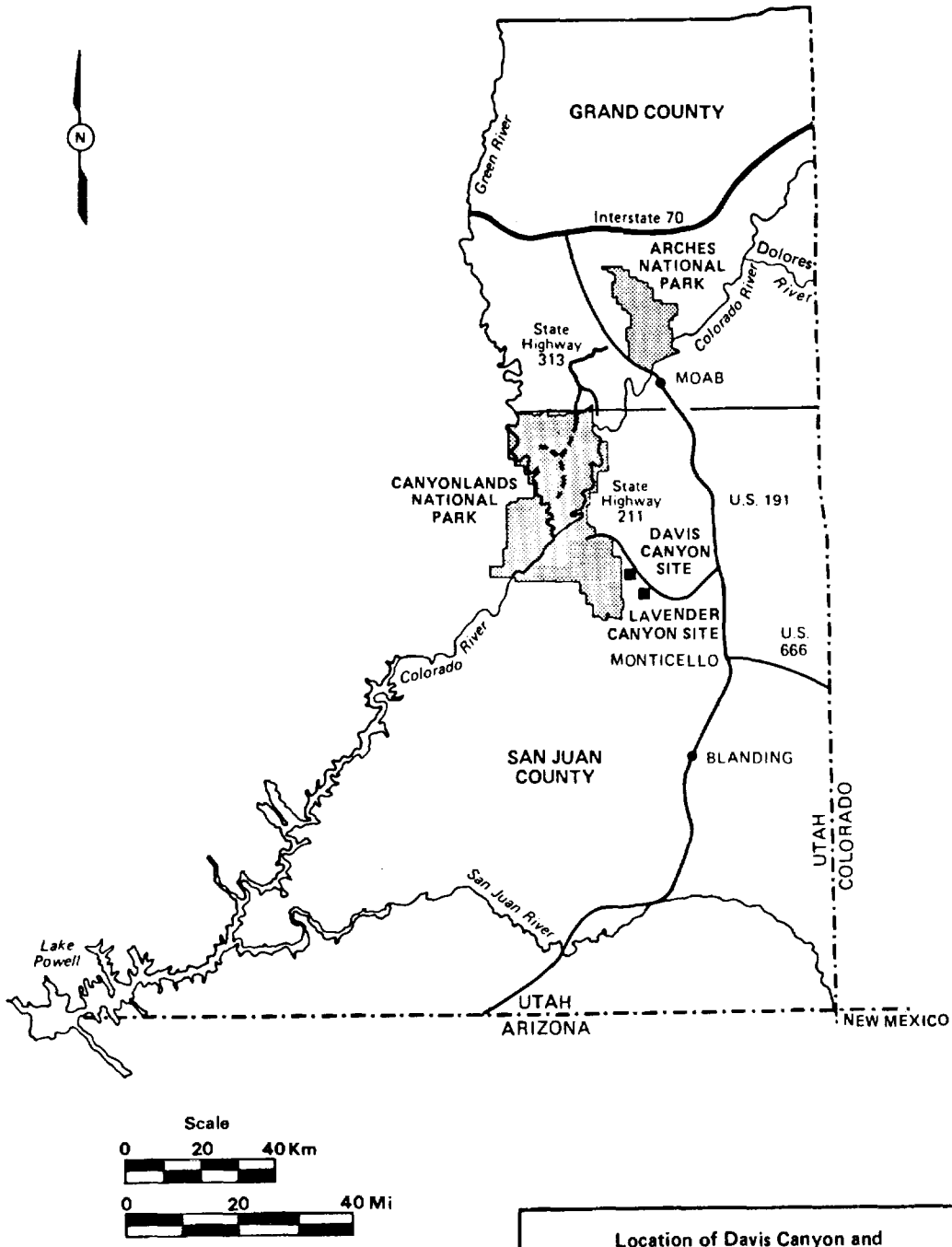
2.1 GEOHYDROLOGIC SETTING

The potentially acceptable Davis Canyon site is located in the Paradox Basin, a regional geohydrologic setting. "Geohydrologic setting" is defined in 10 CFR 960.2 as a system of geohydrologic units located within a geologic setting. "Geohydrologic unit" is further defined as an aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. "Geologic setting" refers to the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

This summary description of the Paradox Basin geohydrologic setting centers on the Gibson Dome area and contiguous areas within the Paradox Basin in which the potentially acceptable Davis Canyon site is located. This geohydrologic setting description provides an overview of the general geologic characteristics of the region.

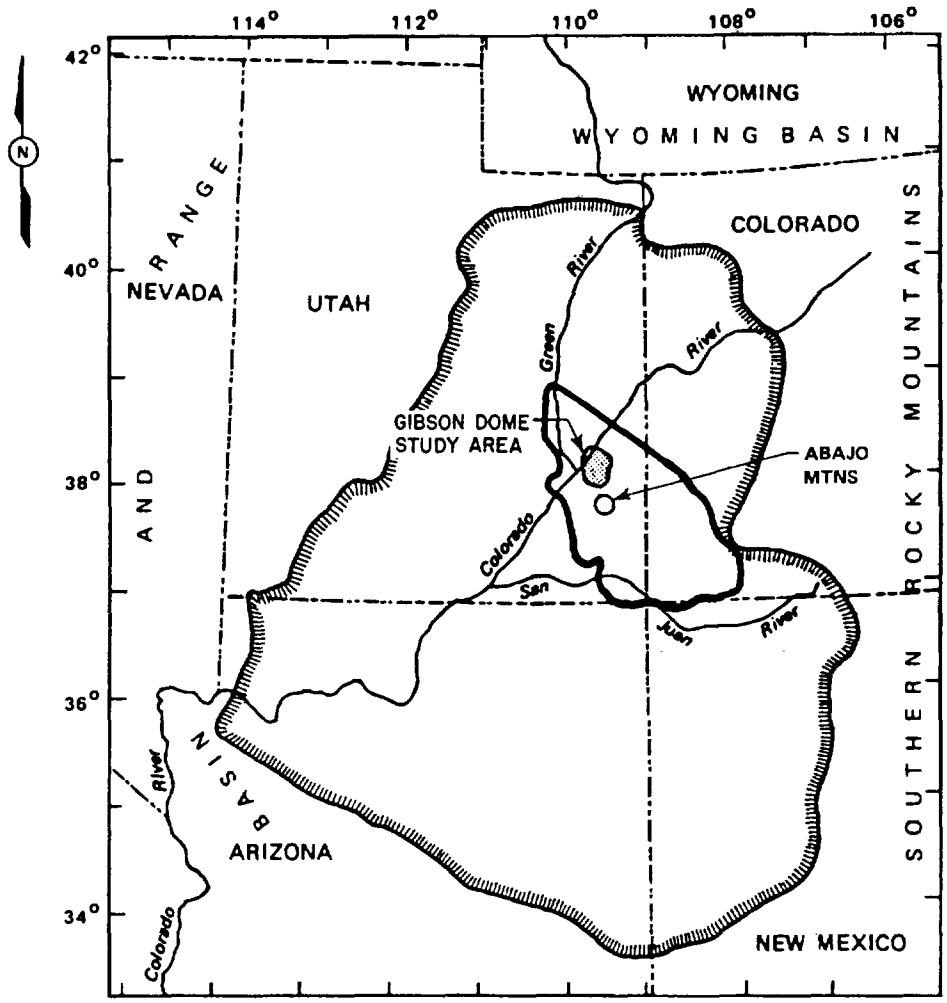
The Paradox Basin (Figure 2-2) comprises approximately 30,000 square kilometers (11,588 square miles) in southeastern Utah and southwestern Colorado underlain by salt deposits of the Paradox Formation. The basin is in the east central part of the Colorado Plateau Physiographic Province. The basin is characterized by rugged topography and classic desert landforms. Because the Colorado Plateau has been slowly and steadily uplifted, erosional features are pronounced. Drainages are deeply incised into plateau surfaces and bench-like canyon sides are common.

The Paradox Basin formed during Middle Pennsylvanian time, coincident with the main deformation along the ancestral Rocky Mountains. The basin contains a sequence of sedimentary rocks that overlies a basement complex of Precambrian crystalline rocks. About 500 to 1,000 meters (1,640 to 3,280 feet) of pre-Paradox strata (mostly limestones and dolomites) were deposited in marine waters that covered the basin during most of Cambrian through Early Pennsylvanian time (Baars, 1966). During Middle Pennsylvanian time, restricted flow of water within the basin resulted in deposition of the thick series of evaporites in the Paradox member of the Hermosa Formation. In the northeastern portion of the basin, the original depositional thickness of the Paradox Formation was approximately 2,130 meters (7,000 feet) (Hite, 1960, p. 87), however, the original thickness of the unit decreases to the southwest.



Location of Davis Canyon and Lavender Canyon Sites San Juan County, Utah

Figure 2-1



Explanation

Approximate location of zero thickness of saline facies (Boundary of Paradox Basin)

Outline of Colorado Plateau

Scale

0 100 200 Km

0 100 200 Mi

Paradox Basin Region
Colorado Plateau
Physiographic Province

Source: Hunt, 1969.

Figure 2-2

Post-Pennsylvanian strata contain primarily continental sandstones and shales, which were overlain by a sequence of about 1,000 meters (3,280 feet) of marine shales of Late Cretaceous age. With regression of the seas at the end of the Cretaceous age, the area has remained above sea level and has been subjected to a long period of erosion. As a result, the total thickness of sedimentary rock remaining in the basin ranges from about 5,600 meters (18,375 feet) along the northeast edge to about 2,000 meters (6,560 feet) in the southwestern part of the basin.

The generalized geohydrologic setting in the Paradox Basin consists of an alternating sequence of aquifers and aquitards. The concept of hydrostratigraphic units is used to describe the flow system within the Paradox Basin (Maxey, 1964, pp. 124-129). The Mesozoic-age Moenkopi and Chinle Formations, which in most areas of the basin overlie the geohydrologic units described here, are aquitards that restrict vertical migration of water from the land surface to the underlying units. The upper Paleozoic strata of the bedded salt area of the western Paradox Basin are tentatively subdivided into three hydrostratigraphic units (Figure 2-3) consisting of stratigraphic intervals that possess similar hydrogeologic characteristics (WCC, 1982, ONWI-290, Vol. I, p. 9-1, Table 9-1). The upper unit consists of Permian-age strata and includes the upper portion of the Pennsylvanian-age Honaker Trail Formation. The middle unit consists of the lower portion of Honaker Trail Formation and Paradox Formation. The lower unit consists of strata below the Paradox Formation in the Pinkerton Trail, Molas, Leadville, Ouray, and Elbert Formations.

The Colorado River and its principal tributaries (the Green, San Juan, and Dolores Rivers) dominate the drainage system of the Paradox Basin. Average annual precipitation ranges from 20 to 40 centimeters (8 to 16 inches) in the low desert areas that make up most of the Paradox Basin to more than 75 centimeters (30 inches) in the adjoining high mountain areas. Principal bedrock aquifers, plus the Quaternary alluvium along rivers and major streams, supply many wells in the basin. Most of these wells are used for stock and domestic purposes, but a few are used for irrigation, municipal, and industrial supplies.

2.2 IDENTIFICATION OF POTENTIALLY ACCEPTABLE SITES

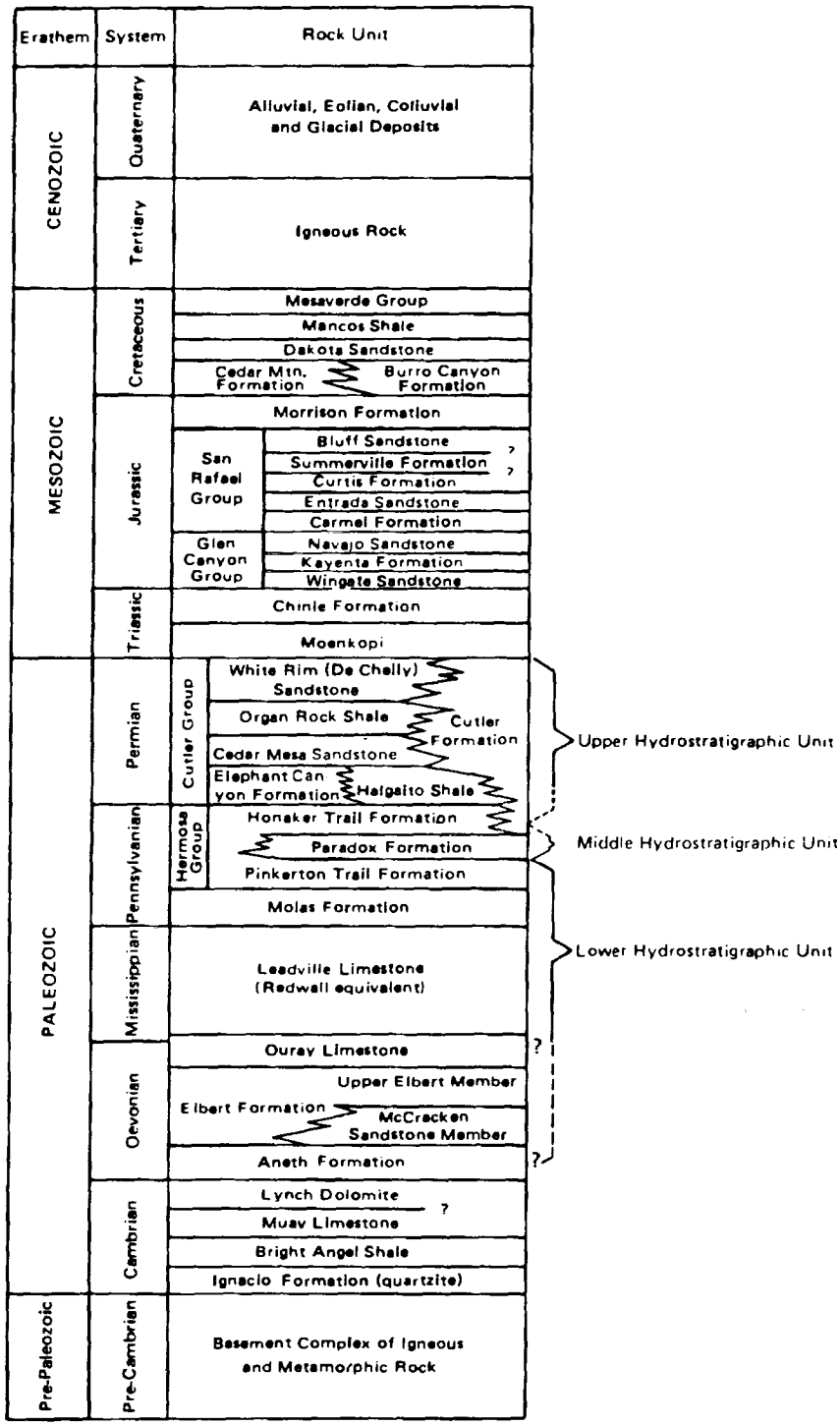
The process for identifying and selecting the potentially acceptable salt sites consisted of a systematic screening, accomplished by a stepwise succession of surveys. In each phase, studies were conducted to selectively evaluate land units against established criteria (DOE, 1981, DOE/NWTS-33(2)). The DOE/NWTS-33(2) criteria include geologic, hydrologic, geochemical, demographic, environmental, and socioeconomic factors.

The first survey and screening step (the national survey, as described in Section 1.2.1) identified the Paradox Basin as one of four large regions of the United States that contain rock salt deposits which are located at a reasonable depth and thick enough to warrant further study. The screening steps, as applied in the Paradox Basin, are shown in Figure 2-4.

The decision as to which successively smaller land unit represented the most promising area for further study was made using those DOE/NWTS-33(2) factors at each screening step that best provided a means of differentiation. Not all performance criteria and screening factors were used at each step of the screening process because either the data were insufficient or the criteria factors were not useful for screening large-sized land units.

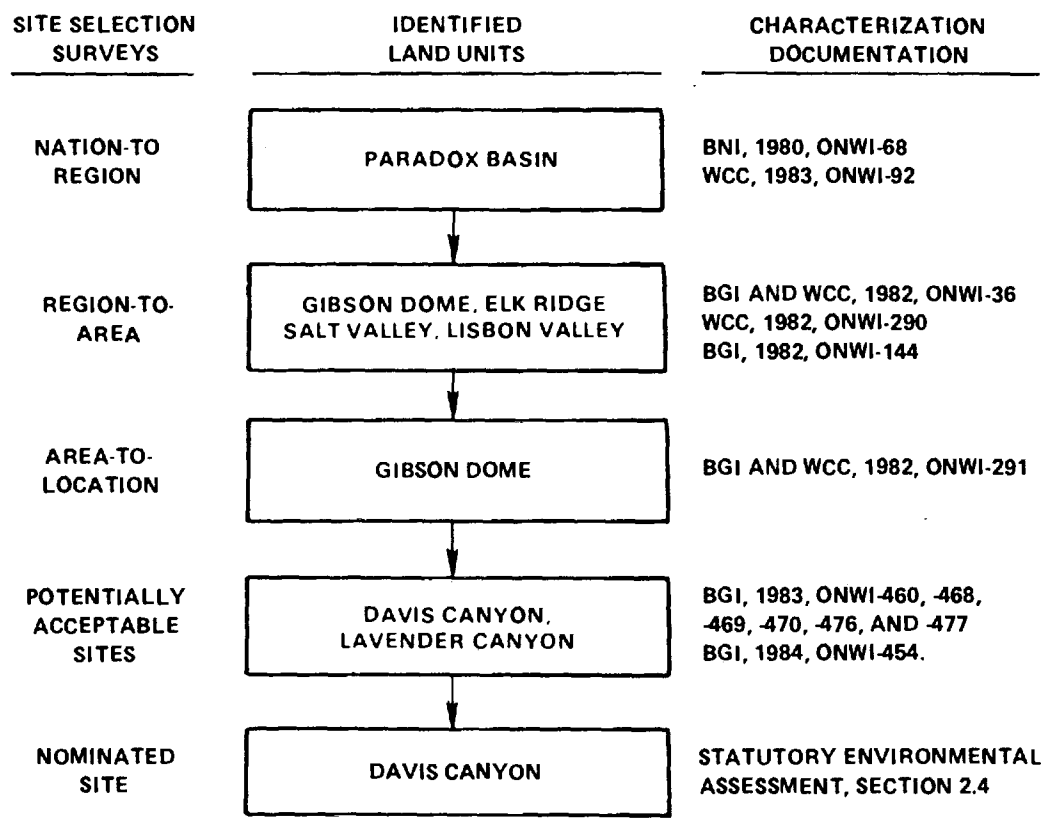
2.2.1 Region-to-Area Screening

Regional surveys were conducted to obtain geologic and environmental characterization information for the Paradox Basin. Each survey was based on a review of existing data obtained primarily from published scientific literature. Additional geologic data sources included geologic maps; drilling records from oil, gas, and mineral exploration programs; and records of earthquake occurrences and intensities. For the environmental characterization surveys, supplemental data sources included topographic maps, and State and Federal agency reports. No field activities were conducted during regional screening.



Generalized Composite Stratigraphic Column and Hydrostratigraphic Units Paradox Basin

Figure 2-3



Paradox Basin Screening Process

Figure 2-4

Regional characterization reports were published presenting the acquired information on geologic and environmental characteristics (WCC, 1983, ONWI-92; BNI, 1980, ONWI-68).

As shown in Table 2-1, the region-to-area screening criteria applied to the Paradox Basin were provided by Brunton and McClain (1977) and the DOE (1981, DOE/NWTS-33(2)). These criteria were divided into two groups: health and safety, and environmental and socioeconomic. For each criterion, screening factors were developed and specifications were assigned to define the range of conditions favorable for repository siting (BGI and WCC, 1982, ONWI-36, pp. 40, 41).

A three-step process was used to identify areas within the Paradox Basin for further study through application of the region-to-area screening criteria. First, boundaries of potential areas having a sufficient depth to salt and thickness of salt (factors judged to be fundamental requirements for a repository) were delineated. Second, those parts of areas having no identified potentially unfavorable health and safety conditions (e.g., proximity to mapped faults, surface igneous features, and areas subject to flooding) were delineated. The third step integrated the results of the health and safety screening with the environmental and socioeconomic criteria (proximity to urban areas, including an 8-kilometer [5-mile] exclusionary radius, and the presence of legally dedicated lands greater than 405 hectares [1,000 acres]).

This process identified the Gibson Dome, Elk Ridge, Lisbon Valley, and Salt Valley areas within the Paradox Basin (Figure 2-5; BGI and WCC, 1982, ONWI-36, pp. 21, 22) for the following reasons:

1. Gibson Dome and Elk Ridge had no identified potentially unfavorable health and safety conditions and provided two variations of bedded salt geometries in the basin.

2. Lisbon Valley was selected as an example of nondiapiric salt anticline geometry located at a favorable distance from possible ground-water discharge areas along the Colorado River and its major tributaries.

3. Salt Valley was selected as one of several salt anticlines with favorable salt depth and thickness and because of its favorable distance from ground-water discharge areas.

2.2.2 Area-to-Location Screening

As in the regional screening, environmental and geologic characterization surveys were conducted for Elk Ridge, Gibson Dome, Lisbon Valley, and Salt Valley areas (BGI, 1982, ONWI-144; WCC, 1982, ONWI-290, Vols. I-V). For each area, existing environmental information similar to the regional characterization data was used, but the level of detail was increased. Environmental characterization considered geography, surface hydrology, meteorology, land and water resources, terrestrial and aquatic ecosystems, land use, demography, and economic, historical, institutional, and social factors (BGI and WCC, 1982, ONWI-291, pp. 3-4).

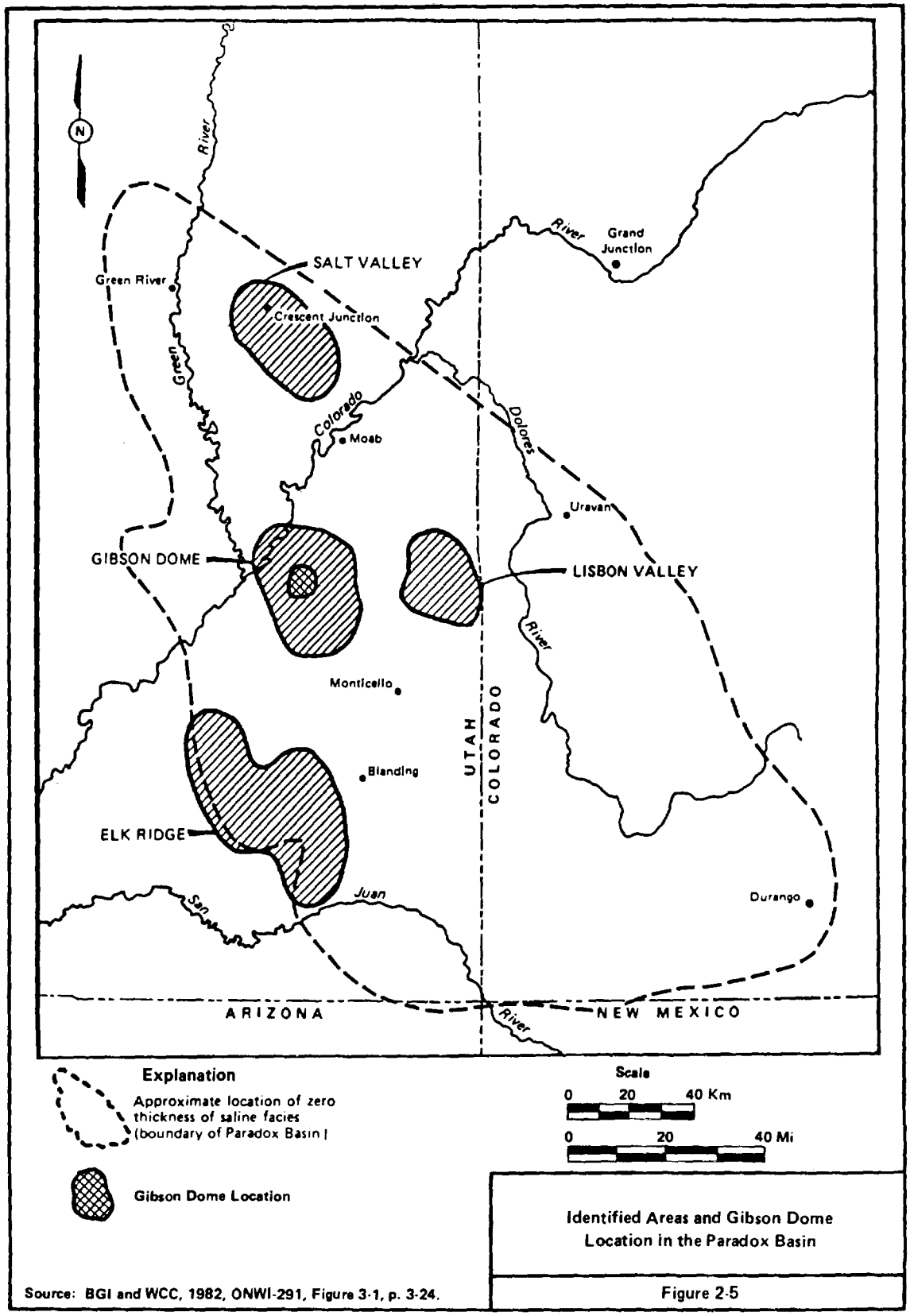
Geologic characterization was based on existing data specific to the four areas, as well as on the results of preliminary geologic field studies. The geologic characterization considered stratigraphy, structure, hydrogeology, seismicity, tectonic history, Quaternary features, physiography, energy and mineral resources, and geotechnical factors (BGI and WCC, 1982, ONWI-291, pp. 3-4). Field investigations included drilling and coring deep boreholes, drill-stem testing, geologic field mapping, and microseismic monitoring.

The area-to-location screening factors and specifications were developed from DOE/NWTS-33(2) criteria to evaluate the areas for potentially favorable locations (Table 2-2). Factors of highest priority were depth to salt, thickness of salt, and proximity to faults, boreholes, and boundaries of dedicated lands (BGI and WCC, 1982, ONWI-291, pp. 4-2, 4-3).

Table 2-1. Paradox Basin Region-to-Area Screening Criteria

Criteria[a]	Screening Factors[b]	Specifications[b]
Health and Safety		
Site Geometry	Depth to Salt	Acceptable range: 305-914 m (1,000-3,000 ft)
		Potentially acceptable range 914-1,219 m (3,000-4,000 ft)
	Thickness of Salt	61 m (200 ft) Minimum total salt
Tectonic Environment	Mapped Faults	8-km (5-mi) exclusionary radius
	Surface Igneous Feature	8-km (5-mi) exclusionary radius
Human Intrusion	Petroleum Production	Exclude oil fields producing more than 8,000 m^3/mo (50,000 bbls/mo)
	Natural Gas	Exclude gas fields producing more than 1 x 10^6 m^3/mo (50 million ft^3/mo)
	Uranium Ore	Exclude 93-km^2 (36-mi^2) areas with minimum production of 272,160 kg (600,000 lb)
	Potash	Exclude mines producing more than 50 x 10^6 kg/yr (50,000 t/yr)
Surface Characteristics	Flooding Potential	1.6-km (1-mi) exclusionary zone from rivers, lakes, and reservoirs
Environmental and Socioeconomic		
Demography	Urban Centers	8-km (5-mi) exclusionary radius around centers with a minimum population of 500
Environmental Protection	Dedicated Lands	Exclude National Parks and Monuments, Primitive Areas, plus State parks 405 ha (1,000 ac) or greater

(a) DOE, 1981, DOE/NWTS-33(2); Brunton and McClain, 1977.
(b) BGI and WCC, 1982, ONWI-36, pp. 40, 41.



Identified Areas and Gibson Dome Location in the Paradox Basin

Source: BGI and WCC, 1982, ONWI-291, Figure 3-1, p. 3-24.

Figure 2-5

Table 2-2. Highest Priority Paradox Basin Area-to-Location Screening Criteria

Criteria[a]	Screening Factors[b]	Specifications[b]
Site Geometry	Depth to Salt	Minimum favorable depth to salt is 305 m (1,000 ft); shallower beds were avoided. Maximum favorable depth to salt is 1,067 m (3,500 ft); all deeper beds were avoided.
	Thickness of Salt	Areas with host rock of 100 percent evaporite lithology greater than 21 m (70 ft) thick are favorable; all others were avoided.
Tectonic Environment	Proximity to Faults	Lands within 8 km (5 mi) of mapped surface faults were avoided; lands within 2 km (1 mi) of surface projections of subsurface faults were avoided.
Human Intrusion	Proximity to Boreholes	Lands within 2 km (1 mi) of boreholes were avoided.
Environmental Protection	Legally Dedicated Lands	National Parks, National Monuments, Wilderness Study Areas, and Indian lands were avoided.

(a) DOE, 1981, DOE/NWTS-33(2).
(b) BGI and WCC, 1982, ONWI-291.

As a result of this screening, Lisbon Valley was eliminated from further study because of unfavorable proximity to surface faults and boreholes; Salt Valley was eliminated because of unfavorable depth to salt in conjunction with proximity to surface faults (BGI and WCC, 1982, ONWI-291, pp. 4-11, 4-12).

Application of the screening factors to the Gibson Dome area showed 147 square kilometers (57 square miles), near the center of the area designated as the Gibson Dome location, with favorable characteristics. The Elk Ridge area contained one large area of 16 square kilometers (6 square miles) and several smaller areas, each less than 8 square kilometers (3 square miles), that were potentially favorable (BGI and WCC, 1982, ONWI-291, pp. 4-13, 4-14). The smaller areas were not large enough to contain a repository and therefore were excluded from further consideration. The larger location was designated the Elk Ridge location.

A further comparison of the Gibson Dome and Elk Ridge locations against National Waste Terminal Storage (NWTS) subcriteria was made. The differentiating factors (Table 2-3) of salt thickness, thickness of shale above and below the repository, and minimum distance to dissolution features were considered the most critical in terms of influencing radionuclide travel path and residence times. Location accessibility and archaeological sensitivity were considered the most important differentiating factors in terms of environment (BGI and WCC, 1982, ONWI-291, pp. 5-74). The Gibson Dome location, shown in Figure 2-5, was preferred, both in terms of the number of favorable factors and in the relative importance of these factors.

2.2.3 Identification of Potentially Acceptable Sites in the Gibson Dome Location Screening

Technical studies and field surveys were conducted in the Gibson Dome location during 1982 and 1983. Included were computer viewshed analyses (BGI, 1984, ONWI-454), archaeological field surveys (BGI, 1983, ONWI-468), probable maximum flood calculations (BGI, 1983, ONWI-476), ambient sound measurements (BGI, 1983, ONWI-460), threatened and endangered species field surveys (BGI, 1983, ONWI-470), vegetation mapping (BGI, 1983, ONWI-469), and air quality analyses (BGI, 1983, ONWI-477).

The Gibson Dome location was divided into three portions for further evaluation: Davis Canyon, Lavender Canyon, and the northern portion (i.e., an area north of Utah State Highway 211 [Utah 211] including Harts Draw) (Figure 2-6). Potential sites were selected in each of these three portions of Gibson Dome based on environmental and engineering considerations, including lithostatic pressures from adjacent mesas, slopes not exceeding 10 percent, and estimated 500-year flood plains (BGI and WCC, 1982, ONWI-291). Because much of the value of southeastern Utah is associated with its scenic and aesthetic character, computer viewshed analyses were performed to determine accessibility and visibility of the three potential sites from various vista points at various elevations (BGI, 1984, ONWI-454). The level, open areas in the northern portion of the Gibson Dome location were found to be less desirable than the Davis and Lavender Canyon sites because this portion of the Gibson Dome location afforded the easiest accessibility and greatest number of observation points of a repository site. Based on these aesthetic considerations, the open northern portion of the Gibson Dome location was deferred.

The evaluations, based on the process described above, led to the conclusion that the Davis and Lavender Canyon sites met the minimum DOE/NWTS-33(2) screening criteria and were suitable for further study. The geographic location of these sites is shown in Figure 2-6.

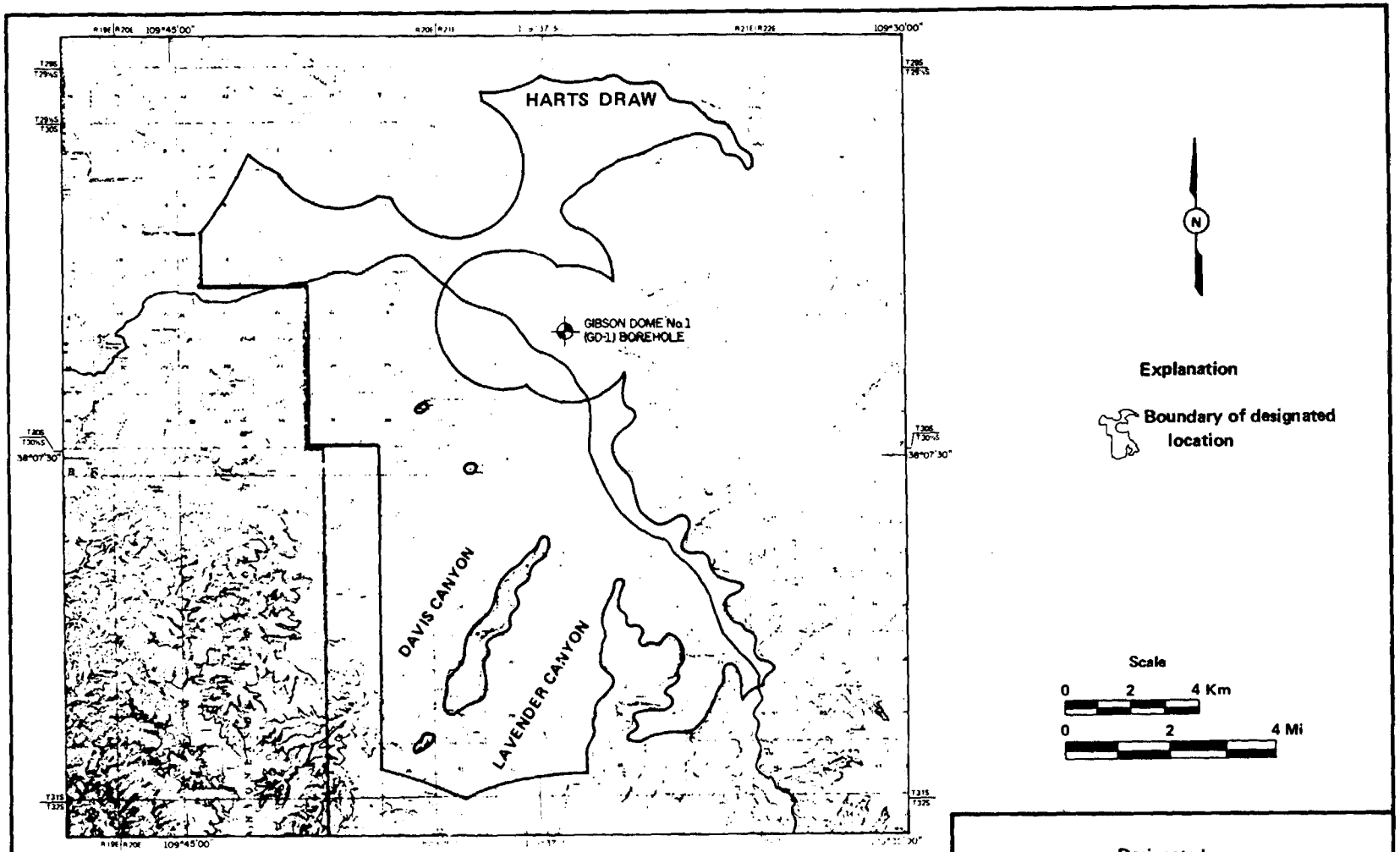
Subsequently, in accordance with Section 116(a) of "Nuclear Waste Policy Act of 1982" (42 USC Sections 10101-10226) (NWPA), the DOE sent letters to the Governor and legislature of Utah in February, 1983 to formally identify the Davis and Lavender Canyon sites in the Paradox Basin as potentially acceptable sites for the planning and development of the nation's first geologic nuclear waste repository.

Table 2-3. Principal Differentiating Factors for Gibson Dome and Elk Ridge Locations

Differentiating Factors	Gibson Dome Location	Elk Ridge Location
Thickness of Cycle 6 salt	49-73 m[a] (160-240 ft)	21-27 m (70-90+ ft)
Size of land unit meeting screening criteria	148 km^2[a] (57 mi^2)	16 km^2 (6 mi^2)
Thickness of shale above repository	47-81 m[a] (155-265 ft)	38-43 m (125-142 ft)
Thickness of shale below repository	70-146 m[a] (230-480 ft)	38-46 m (125-150 ft)
Minimum distance to nearest dissolution feature	8 km (5 mi)	29 km[a] (18 mi)
Minimum distance to concentrated microseismicity	24 km (15 mi)	40 km[a] (25 mi)
Minimum distance to nearest suspected Quaternary tectonic fault	8 km (5 mi)	21 km[a] (13 mi)
Surface hydrologic system (floodplains)	500-year flood-plain present	Not in flood-plain[a]
Accessibility	Smoother terrain in much of location; RR length: 51 km[a] (32 mi)	Rough terrain RR length: 159 km (99 mi)
Archaeological sensitivity	Low sensitivity[a]	High sensitivity
Agricultural productivity	16 ha/AUM (40 ac/AUM)	3 ha/AUM[a] (9 ac/AUM)
National Forests and Parks	None[a]	Manti-La Sal National Forest

(a) Favored location for a particular factor.
AUM = animal-unit month.
RR = Representative Route.

Source: Modified from BGI and WCC, 1982, ONWI-291, Table 5-2, p. 5-83.



Source: BGI and WCC, 1982, ONWI-36.

Designated
Gibson Dome Location

Figure 2-6

2.3 DISQUALIFICATION EVALUATION OF THE POTENTIALLY ACCEPTABLE SITES

From among the nine potentially acceptable sites identified during screening studies (Section 1.2.1), the DOE is required to nominate at least five sites as suitable for further site characterization (NWPA, Section 112(b)). The first step in the nominating process, as required by 10 CFR 960.3-2-2, is to evaluate each potentially acceptable site against the disqualifying conditions specified in the Technical Siting Guidelines of 10 CFR 960.4-2 and 10 CFR 960.5-2.

A disqualifying condition is defined in 10 CFR 960.2 as a condition that, if present at a site, would eliminate that site from further consideration. A site may be disqualified at any time during the siting process if the evidence supports a finding by the DOE that a disqualifying condition exists, or the qualifying condition of any System or Technical Guideline cannot be met (10 CFR 960.3-1-5).

The evaluations of site information against the explicit disqualifying conditions set forth in 10 CFR 960.4 and 10 CFR 960.5 Technical Guidelines are summarized in Table 2-4. Based on the data and analyses, no evidence was found to disqualify either of the potentially acceptable Paradox Basin bedded salt sites. Therefore, Davis Canyon and Lavender Canyon were determined to be suitable candidate sites for possible nomination for further site characterization studies.

2.4 COMPARATIVE EVALUATION OF POTENTIALLY ACCEPTABLE SITES WITHIN THE PARADOX BASIN GEOHYDROLOGIC SETTING, AND SELECTION OF THE PREFERRED PARADOX BASIN SITE

This section compares the two potentially acceptable sites in the Paradox Basin and concludes that the site in Davis Canyon is the preferred site. The guideline findings for the two sites are identical. The more detailed evaluation in this section identified only two significant differences between the two sites. While these differences do exist between the two sites, selection of a preferred site is extremely difficult. Although both sites are very close to the Canyonlands National Park, this factor did not discriminate between the sites. The presence of an additional Federally protected land area, the Bridger Jack Mesa Wilderness Study area, within the Lavender Canyon controlled area resulted in the Davis Canyon site being the preferred site within the Paradox Basin. This is because the transfer and control of the Wilderness Study area at the Lavender Canyon site adds some additional complexity to the land transfer process (Site Ownership and Control), and the proximity to dedicated Federal lands (Environmental Quality).

A key step in the "Nomination of Sites as Suitable for Characterization," (DOE Siting Guidelines [10 CFR 960.3-2-2-2]) requires, for those geohydrologic settings that contain more than one potentially acceptable site, that "the preferred site shall be selected on the basis of a comparative evaluation of all potentially acceptable sites in that setting." This evaluation shall consider the distinguishing characteristics displayed by the potentially acceptable sites within the setting and the related postclosure and preclosure guidelines, placing primary significance on the postclosure guidelines.

Since two potentially acceptable sites (Davis Canyon and Lavender Canyon) were identified in the Paradox Basin geohydrologic setting (Section 2.2) and are not presently disqualified on the basis of specific 10 CFR Part 960 disqualifying conditions (Section 2.3), this section describes the comparative evaluation procedure leading to the selection of one of these as the preferred Paradox Basin site to be subsequently nominated for site characterization by the Secretary of Energy. An evaluation of each Paradox Basin site for all 10 CFR Part 960 guidelines, irrespective of whether they do or do not require site characterization as a prerequisite, is presented in Chapter 6 of this EA.

As specified in 10 CFR 960.3-2-2-2, the basis for this comparative evaluation of the two potentially acceptable Paradox Basin sites should be the qualifying conditions, considering, on balance, the favorable and potentially adverse conditions, for all postclosure and preclosure Technical Guidelines for which the evidence shows distinguishing characteristics between

Table 2-4. Summary of Rationale for Not Disqualifying the Potentially Acceptable Paradox Basin Salt Sites

Disqualifying Condition			Present Rationale for Not Disqualifying	
Guideline	Statement Synopsis	EA Section Reference	Davis Canyon, Utah	Lavender Canyon, Utah
Geohydrology 960.4-2-1(d)	Pre-waste-emplacement ground-water travel time to accessible environment less than 1,000 years.	6.3.1.1	Travel times along any path of likely radionuclide travel is estimated to require much longer than 1,000 years.	
Erosion 960.4-2-5(d)	Any portion of underground facility is less than 200 meters deep.	6.3.1.5	Proposed salt horizon of conceptual repository design is at a minimum depth of approximately 885 meters.	
Dissolution 960.4-2-6(d)	Active dissolution fronts would result in a loss of waste isolation within first 1,000 years after closure.	6.3.1.6	No evidence of past or present salt dissolution apparent at the sites. It is unlikely that dissolution fronts will encroach upon the geologic repository-operations area and cause a loss of waste isolation within the next 10,000 years at either site.	
Tectonics 960.4-2-7(d)	Based on geologic records, the nature and rates of fault movement or other ground motion are expected such that a loss of waste isolation is likely to occur.	6.3.1.7	Shay Graben and the Needles Fault zone located in the site vicinity are known or suspected to have Quaternary activity. However, these structural features are not expected to be a source of tectonic activity that could affect waste isolation at either site.	
Human Interference 960.4-2-8-1(d)(1)	Previous subsurface activities have created significant pathways between the projected underground facility and the accessible environment.	6.3.1.8	No known exploration boreholes or mine excavations have created significant pathways between the underground facility and the accessible environment. The nearest deep hydrocarbon exploration borehole approaching the salt horizon is 8 km (5 miles) from the geologic repository-operations area. Maximum depth of known mine workings within the site is approximately 869 m (2,850 feet) above proposed repository horizon.	No known exploration boreholes or mine excavations have created significant pathways between the underground facility and the accessible environment. The nearest deep hydrocarbon exploration borehole that penetrates the proposed repository horizon is 7.2 km (4.5 miles) from the geologic repository-operations area. Maximum depth of known mine workings within site is approximately 872 m (2,861 feet) above proposed repository horizon.
960.4-2-8-1(d)(2)	Ongoing or future recovery of mineral resources outside the controlled area would lead to an inadvertent loss of waste isolation.		There are no ongoing mineral activities outside the controlled area (site) and within the site vicinity other than sporadic exploration and small near-surface mining of uranium and vanadium ore, sand and gravel, and potable water. Deep drilling for potash, hydrocarbons, and other resources within the site vicinity is unlikely because of the lack of anticipated commercial resources.	
Population Density and Distribution 960.5-2-1(d)(1)	Repository surface facility located in a highly populated area.	6.2.1.2	Moab, UT, the nearest highly populated area, is located 53 km from the site.	Blanding, UT, the nearest highly populated area, is located 48 km from the site.
960.5-2-1(d)(2)	Repository surface facility is located adjacent to a 1 mile by 1 mile area having a population of 1,000 or more individuals.		No such populations located adjacent to repository surface facility.	
960.5-2-1(d)(3)	Inability of DOE to develop an emergency preparedness plan that meets DOE and NRC regulatory requirements.		Compliance anticipated: NRC has not issued 10 CFR Part 60, Subpart I, "Emergency Planning Criteria;" DOE has developed emergency preparedness programs for its other similar rural facilities per DOE Order 5500.3 (DOE, 1981).	
Offsite Installations and Operations 960.5-2-4(d)	Atomic energy defense activities in proximity and which are expected to conflict irreconcilably with a repository.	6.2.1.5	No atomic energy defense activities located in proximity of the sites.	
Environmental Quality 960.5-2-5(d)(1)	Environmental quality of affected area could not be adequately protected, or projected environmental impact that could not be mitigated to an acceptable degree.	6.2.1.6	The quality of the environment in the affected area can be adequately protected, and projected environmental impacts in the affected area can be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.	
960.5-2-5(d)(2)	Location of restricted area or support facilities within boundaries of a national park, wildlife refuge, wilderness preservation area, or wild and scenic river.		No part of the repository support facilities or restricted area located within specified disqualifying areas.	
960.5-2-5(d)(3)	Presence of restricted area of support facilities would conflict irreconcilably with previous designated resource-preservation use of a national park, wildlife refuge, wilderness preservation area, wild and scenic river or forest, or any comparable significant State-protected resource area.		Site located within 0.3 km of Canyonlands National Park, the nearest dedicated Federal land. The presence of the restricted area or repository support facilities will not conflict irreconcilably with previous designated uses of the park.	Site located within 2 km of Canyonlands National Park. The presence of the restricted area or repository support facilities will not conflict irreconcilably with previous designated uses of the park.
Socioeconomic Impacts 960.5-2-6(d)	Repository would significantly degrade the quality or reduce the quantity of water from major sources of offsite supplies, and such impacts cannot be compensated or mitigated by reasonable measures.	6.2.1.7	No significant effect on the Colorado River is expected. Ground-water quality is to be protected by facility design and protection measures. Impacts of repository development on water quantity are anticipated to be short term and not significant enough to disrupt the long-term development of crop irrigation and other future development.	

Table 2-4. Summary of Rationale for Not Disqualifying the Potentially Acceptable Paradox Basin Salt Sites
(Page 2 of 2)

Disqualifying Condition			Present Rationale for Not Disqualifying	
Guideline	Statement Synopsis	EA Section Reference	Davis Canyon, Utah	Lavender Canyon, Utah
Rock Characteristics 960.5-2-9(d)	Repository activities projected to cause significant risk to health and safety of personnel.	6.3.3.2	Potential hazards to personnel during repository construction, operation, and closure consist of excavation instability, gas pockets, brine pockets, water inflow, and dust; such potential hazards, if found at the sites, can be mitigated by proven mine safety and engineering practices.	
Hydrology 960.5-2-10(d)	Based upon expected ground-water conditions, engineering measures beyond reasonably available technology will be required for exploratory shaft or repository.	6.3.3.3	Limited, small flows of ground water expected to enter shaft from above the salt. However, control of such small flows into a shaft under these geologic conditions is well within standard engineering practices.	
Tectonics 960.5-2-11(d)	Based on expected nature and rates of fault movement or ground motion, engineering measures beyond reasonably available technology will be required for exploratory shaft or repository.	6.3.3.4	Ground motion from potential tectonic sources found in the area is not expected to be greater than that which can be accommodated by application of available engineering technology.	

Source: Based on the U.S. Department of Energy Final General Guidelines for Recommendations of Sites for Nuclear Waste Repositories (10 CFR Part 960).

the two sites. A comparison of the favorable and potentially adverse guideline condition findings for both the Davis and Lavender Canyon sites does not allow a clear selection of a preferred Paradox Basin site, because the findings for all favorable and potentially adverse postclosure and preclosure guideline conditions are identical. This is attributable to the nearness (approximately 6.4 kilometers [4 miles]) of the two sites to each other. This results in overlapping of portions of the proposed controlled areas for each site. In addition, the closest controlled area boundary for each site is less than 2 kilometers (1.2 miles) from Canyonlands National Park. The surface facilities and the restricted area are further from Canyonlands National Park than the controlled area boundary.

In order to determine a preferred Paradox Basin site it became necessary to continue the comparative evaluation process through the development of a more detailed list of distinguishing characteristics or descriptors for differentiating between the two sites. This site comparative evaluation procedure was based directly on the Technical postclosure and preclosure 10 CFR Part 960 Guideline conditions and included the following eight steps:

1. A comprehensive list of quantitative and qualitative data descriptors that characterize the favorable and potentially adverse guideline conditions was developed.

2. A comparable data base of site conditions for each descriptor was developed.

3. Site data for each descriptor were compared to identify data differences between the two sites.

4. A size or range of significant difference where data differences between the two sites had been recognized and was identified.

5. A list of those descriptors that discriminate between the sites was developed.

6. The discriminating descriptors at the Technical Guideline level were summarized and a favorability rating was assigned to each site.

7. The Technical Guideline favorability ratings for the one postclosure and three preclosure system guideline groups were summarized.

8. The preferred site was identified using the hierarchy of guideline groups with decreasing order of importance, as specified in 10 CFR 960.3-1-5:

   - Postclosure repository performance
   - Preclosure radiological safety
   - Environment, socioeconomics, and transportation
   - Ease and cost of siting, construction, operation, and closure.

The comprehensive list of data descriptors (Table 2-5) was established directly from the favorable conditions and potentially adverse conditions, and from Appendix IV of the DOE Siting Guidelines (10 CFR Part 960), which discusses the types of information required for the nomination of sites.

Step three of the comparative evaluation process (identification of data differences between the sites) resulted in 10 descriptors with data differences that distinguished between the potentially acceptable Davis and Lavender Canyon sites. These descriptors are listed in Table 2-6. Each of these distinguishing descriptors and its relative size or range of significant differences is discussed below.

Only two distinguishing descriptors were determined to have a size or range of significant difference broad enough to discriminate between the two sites. These are summarized by Technical Guidelines and aggregated according to the hierarchy of 10 CFR 960.3-1-5 guideline groups. Specific data presented below for each guideline are taken from the appropriate EA section, as indicated in Table 2-6.

Table 2-5. 10 CFR Part 960 General Guidelines for Recommendation of Sites for Nuclear Waste Repositories and Comparative Evaluation Procedure Descriptors

POSTCLOSURE GUIDELINES AND DESCRIPTORS

Geohydrology
- Expected ground-water travel time in the host rock
- Prewaste ground-water travel time outside the host rock
- Hydrologic processes
- Geohydrologic modeling
- Hydraulic conductivity in geohydrologic units
- Hydraulic gradient within geohydrologic units
- Potentiometric head difference between surrounding geohydrologic units
- Saturation level in and around host rock (unsaturated zone)
- Depth of water table (unsaturated zone)[a]
- Presence of geohydrologic diversion units above host rock (unsaturated zone)[a]
- Host rock drainage (unsaturated zone)[a]
- Precipitation and evapotranspirtation (unsaturated zone)[a]
- Expected changes in hydraulic gradient
- Expected changes in hydraulic conductivity
- Expected changes in ground-water flux
- Presence of potable or irrigation ground water along flow paths

Geochemistry
- Nature and rates of geochemical processes
- Geochemical conditions inhibiting radionuclide transport - inside repository
- Geochemical conditions inhibiting radionuclide transport - outside repository
- Stability of mineral assemblages under expected repository conditions
- Expected dissolution of radionuclides in the repository
- Retardation factors - outside the repository
- Geochemical effects on sorption or rock strength
- Ground-water effects on engineered barrier system

Rock Characteristics
- Vertical thickness of host rock
- Areal extent of host rock
- Fracture healing characteristics of host rock
- Effects of waste heat on waste isolation

Climatic Changes
- Effects of climatic change on waste isolation

Erosion
- Rate of erosion

Dissolution
- Host rock dissolution

Tectonics
- Tectonic processes that affect isolation
- Tectonic and igneous activity in Quaternary
- Magnitude intensity and frequency of earthquakes
- Geothermal gradient
- Regional in situ stress field

Human Interference (Natural Resources)
- Presence of natural resources
- Presence of mines
- Deep drilling history
- Human activities affecting ground-water flow
- Total dissolved solids concentration in ground water

Human Interference (Site Ownership and Control)
- Present land ownership and control
- Surface and subsurface mineral rights
- Land acquisition

PRECLOSURE RADIOLOGICAL SAFETY GUIDELINES AND DESCRIPTORS

Population Density and Distribution
- Proximity to highly populated areas
- Proximity to places with 1000 persons in a 1-mi-by-1-mi area
- Regional population density
- Population within site boundary

Site Ownership and Control
- Present land ownership and control
- Surface and subsurface mineral and water rights
- Land acquisition

[a]Not applicable to salt.

Table 2-5. 10 CFR Part 960 General Guidelines for Recommendation of Sites for Nuclear Waste Repositories and Comparative Evaluation Procedure Descriptors (Page 2 of 2)

Meteorology
- Dispersion of potential radioactive releases
- Potential for public exposure
- History of extreme weather

Offsite Installations and Operations
- Offsite nuclear facilities
- Presence of nearby hazardous installations or operations

- -

ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION GUIDELINES AND DESCRIPTORS

Environmental Quality
- Anticipated ability to comply with applicable environmental requirements
- Air quality
- Aesthetics
- Noise
- Access corridors
- Water quality
- Dedicated Federal lands
- State park land
- Native American or cultural resources
- Threatened or endangered species' critical habitat

Socioeconomic Impacts
- Increased resource competition
- Housing and related services
- Adequacy of local labor force
- Potential net increases in local employment
- Potential net increases in local business sales
- Potential increases in local government revenues
- Potential disruptions to the regional economic base
- Water limitations on future development
- Potential for social problems

Transportation
- Access routes: construction cost
- Federal condemnation for land for access routes
- Access route proximity to local cities/towns
- Proximity to adequate existing highways/railroads
- Proximity to national transportation system
- Railroad interchanges
- Transportation life-cycle costs
- Waste transportation risks

Transportation (Continued)
- Regional waste carriers
- Adoption of Federal transportation regulations
- State and local transportation accident response plans
- Delays caused by weather
- Local environmental impact
- Enactment of state or local laws in governing high-level nuclear waste transportation
- Salt disposal transportation
- Compatibility of repository transportation plans with local and regional plans

- -

EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE GUIDELINES AND DESCRIPTORS

Surface Characteristics
- Terrain with low relief
- Potential flooding of surface and underground facilities
- Drainage of site
- Foundation stability and soils characteristics

Rock Characteristics
- Vertical thickness of host rock
- Areal extent of host rock
- Extent of required artificial support for underground openings
- Extent of maintenance of underground openings
- Retrieval difficulty and hazards
- Hazards due to anomalies in host rock
- Host rock discontinuities above and below repository openings

Hydrology
- Presence of aquifers between host rock and land surface
- Complexity of required engineering ground-water control measures

Tectonics
- Expected preclosure impact of earthquakes
- Active faulting
- Maximum credible earthquake

[a] Not applicable to salt.

Table 2-6. Summary of Descriptors Within Technical Guidelines Which Provide the Basis for Possible Discrimination Among the Potentially Acceptable Paradox Basin Sites

Descriptors Within Potentially Discriminating Guidelines				Site Data Differences			
Guideline	Condition[a]	EA Section Reference	Descriptor	Davis Canyon		Lavender Canyon	
	Postclosure Guidelines						
	None						
	Preclosure Radiological Safety Guidelines						
Population Density and Distribution 960.5-2-1(b)(2) and (c)(2)	+ Remoteness of the site from highly populated areas	6.2.1.2	Proximity to Highly Populated Areas Distance in km	Moab, UT - 53 km		Blanding, UT - 48 km	
	- Proximity of the site to highly populated areas, or to areas having at least 1,000 individuals in an area 1 mile by 1 mile as defined by the most recent decennial count of the U.S. Census		Proximity to places with more than 1,000 persons in a 1 mi by 1 mi area Distance in km	Moab, UT - 53 km		Blanding, UT - 48 km	
Site Ownership and Control 960.5-2-2(c)	- Projected land-ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings	6.2.1.3	Land Acquisition Federal land transfers required	BLM multiple use lands Private and State lands		BLM multiple use lands and a portion of the Bridger Jack Mesa Wilderness Study Area Private and State lands	
	Environment, Socioeconomic, and Transportation Guidelines						
Environmental Quality 960.5-2-5(b)(2) and (c)(3)	+ Potential significant adverse environmental impacts to present and future generations can be mitigated to an insigificant level through the application of reasonable measures, taking into account technical, programmatic, social, economic, and environmental factors	4.2.1.3 5.2.5	Air Quality o Maximum 24-hour TSP (g/m^3) during:	A		A	
			- site characterization	46		28	
			- repository construction	64		45	
			- repository operation	29		25	
			o Annual Average NO_x (g/m^3) during:	A		A	
			- site characterization	11		11	
			- repository construction	22		43	
			- repository operation	13		11	
		4.2.1.6	Noise o L_{dn} (dBA) during:	A	B	A	B
			- site characterization	36	28	24	37
			- repository construction	36	38	26	50
			- repository operation	27	32	24	42

A - nearest Canyonlands National Park Boundary.
B - nearest Bridger Jack Mesa Wildarness Study Area Boundary.

Table 2-6. Summary of Descriptors Within Technical Guidelines Which Provide the Basis for Possible Discrimination Among the Potentially Acceptable Paradox Basin Sites (Page 2 of 2)

Descriptors Within Potentially Discriminating Guidelines				Site Data Differences	
Guideline	Condition[a]	EA Section Reference	Descriptor	Davis Canyon	Lavender Canyon
	- Proximity to, or projected significant adverse environmental impacts of the repository or its support facilities on, a component of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Land	Figure 3.2	Dedicated Federal Lands Distance (in km) from Controlled Area Boundary to:		
			- Canyonlands National Park	0.3 km	2 km
			Bridger Jack Mesa Wilderness Study Area	2 km	0 km
Transportation 960.5-2-7(b)(i)	+ Availability of access routes from local existing highways and railroads to the site which have any of the following characteristic: (i) such routes are relatively short and economical to construct as compared to access routes for other comparable siting options	6.2.1.8	Access routes: construction cost Projected total cost in 1984 dollars considering all terrain characteristics, for construction of highway and rail access routes	$79M $141M-269M	$80M $142M-272M
			Access routes: length		
			- highway	40 km	40 km
			- railroad	61-87 km	68-87 km
	Ease and Cost of Siting, Construction, Operation, and Closure Guidelines				
Tectonics 960.5-2-11(c)(1) and (2)	- Evidence of active faulting within the geologic setting	6.3.3.4	Active Faulting Distance to nearest Quaternary Fault	16 km	12 km
	- Historical earthquakes or past man-induced seismicity that, if either were to recur, could produce ground motion at the site in excess of reasonable design limits		Expected preclosure impact of earthquakes Mean-value estimate for peak ground acceleration at the site over next 100 years	0.25 G	0.30 G

Based on the U.S. Department of Energy and U.S. Nuclear Regulatory Commission concurred Final General Guidelines for Recommendation of Sites for Nuclear Waste Repositories (10 CFR Part 960).

(a) In the left-hand column, a favorable condition is preceded by a "+" sign and a potentially adverse condition by a "-" sign. The sequence of conditions for each guideline is the same as in 10 CFR Part 960.

2.4.1 Evaluation of Paradox Basin Postclosure Distinguishing Site Characteristics and Discriminating Technical Guidelines

Postclosure repository guidelines specified in 10 CFR Part 960, Subpart C, which form one of the four guideline groups, include a System Guideline and eight Technical Guidelines. This subpart of the guidelines specifies the characteristics, processes, and events that may affect the long-term performance of the repository after waste emplacement and repository closure and which must be considered in evaluating and comparing potential sites. The objective of the Postclosure System Guideline (10 CFR 960.4-1) is to require compliance with those EPA and NRC regulations that are intended to ensure that the health and safety of the public and the quality of the environment are protected until the radioactivity in the waste has diminished to safe levels. These are the considerations most important for ensuring the long-term protection of the health and safety of the public. The eight Technical Guidelines included under this postclosure System Guideline have numerous qualifying, favorable, potentially adverse, and disqualifying conditions related to Geohydrology (10 CFR 960.4-2-1); Geochemistry (10 CFR 960.4-2-2); Rock Characteristics (10 CFR 960.4-2-3); Climatic Changes (10 CFR 960.4-2-4); Erosion (10 CFR 960.4-2-5); Dissolution (10 CFR 960.4-2-6); Tectonics (10 CFR 960.4-2-7); and Human Interference (Natural Resources, 10 CFR 960.4-2-8-1, and Site Ownership and Control, 10 CFR 960.4-2-8-2).

There are no Davis Canyon and Lavender Canyon site data differences which distinguish between the two sites on the basis of postclosure performance.

2.4.2 Evaluation of Paradox Basin Preclosure Discriminating Technical Guidelines

The preclosure repository guidelines specified in 10 CFR Part 960, Subpart D, include three System Guidelines and eleven Technical Guidelines. Subpart D of the guidelines specifies the factors to be considered in evaluating and comparing sites on the basis of expected repository performance before closure. The Technical Guidelines in Subpart D set forth qualifying, favorable, potentially adverse, and disqualifying conditions on which to base the suitability of a site relative to the three preclosure System Guidelines.

2.4.2.1 Preclosure Radiological Safety Guideline Group

This guideline group focuses on compliance with applicable safety requirements specified in various DOE, NRC, and EPA regulations relating to any projected radiological exposures of the general public and releases of radioactive materials to restricted and unrestricted areas during repository operation and closure. The preclosure Radiological Safety Guideline group includes Population Density and Distribution (10 CFR 960.5-2-1), Site Ownership and Control (10 CFR 960.5-2-2), Meteorology (10 CFR 960.5-2-3), and Offsite Installations and Operations (10 CFR 960.5-2-4). As discussed below, Davis Canyon and Lavender Canyon site data differences have been identified for two of the four preclosure radiological safety guidelines, but only the Site Ownership and Control data differ significantly enough to discriminate between the two sites.
These data differences are summarized in Table 2-6.

2.4.2.1.1 Population Density and Distribution (10 CFR 960.5-2-1). The qualifying condition for the Population Density and Distribution Technical Guideline (10 CFR 960.5-2-1) requires that the repository site be located such that, during repository operation and closure, the expected average radiation dose to members of the public within any highly populated area will not be likely to exceed a small fraction of the allowable limits, and the expected radiation dose to any member of the public in an unrestricted area will not be likely to exceed allowable limits. One favorable condition specified under this guideline is remoteness of the site from highly populated areas. A descriptor that characterizes this favorable condition is the distance (in kilometers) to the nearest highly populated area, which is defined, in part, as "any incorporated place (recognized by the decennial reports of the Bureau of the Census) of 2,500 or more persons, or any census designated place (as defined and delineated by the Bureau) of 2,500 or more persons" (10 CFR 960.2).

The demographic data for the Paradox Basin sites indicate that the Davis Canyon site is located 53 kilometers (33 miles) from Moab, Utah (1980 population 5,333) and that the Lavender Canyon site is located 48 kilometers (30 miles) from Blanding, Utah (1980 population 3,118). However, given this small difference of 5 kilometers (3 miles) in the distance to the nearest highly populated area and the overall total distance of 48 kilometers (30 miles) or more from either repository site to the nearest highly populated area, projected average radiation doses to members of the public within either Moab or Blanding from a repository at either the Davis Canyon or Lavender Canyon site are several orders of magnitude below the NRC standards. Therefore, the difference in distance to the nearest highly populated area is not considered a discriminating factor between the two sites.

A potentially adverse condition specified under the Population Density and Distribution Guideline (10 CFR 960.5-2-1(c)(2)) is the proximity of a site to highly populated areas, or to areas having at least 1,000 individuals in a 1 mile by 1 mile area as defined by the most recent decennial count of the U.S. Census. A descriptor which characterizes this second potentially adverse condition is the proximity (in kilometers) of a repository site to places having such a population density.

The available demographic data indicate that Moab and Blanding are the nearest places to the Davis and Lavender Canyon sites, respectively, having the specified population density; as stated above, the difference in distance to the nearest highly populated areas and areas having 1,000 persons in a 1-mile-by-1-mile area is not considered large enough to discriminate between the two sites.

2.4.2.1.2 Site Ownership and Control (10 CFR 960.5-2-2). This preclosure site ownership and control guideline is similar to the postclosure Site Ownership and Control Guideline (10 CFR 960.4-2-8-2). The DOE has determined that the necessary land area and controls are the same for both the preclosure and postclosure periods. Because the DOE must obtain ownership and surface and subsurface rights before commencing preclosure activities, the preclosure and not the postclosure site ownership and control guideline was analyzed to determine if there was a basis for discriminating between the two sites.

The qualifying condition for the Site Ownership and Control Technical Guideline (10 CFR 960.5-2-2) requires that a repository site be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR Part 60, the ownership, surface and subsurface rights, and control of access that are required in order that surface and subsurface activities during repository operation and closure will not be likely to lead to radionuclide releases to an unrestricted area greater than specified allowable limits. A potentially adverse condition specified under this guideline consists of projected land ownership conflicts that cannot be resolved successfully through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings. A descriptor which characterizes this potentially adverse condition is Federal land transfers which the DOE must obtain for ownership and control of required lands.

Both the Davis and Lavender Canyon sites are located on multiple-use public lands managed by the U.S. Bureau of Land Management (BLM) as well as private and State-owned land. The proposed controlled area of the Lavender Canyon site, however, includes a portion of the Bridger Jack Mesa Wilderness Study Area.

The BLM has specific guidance on activities in wilderness study areas. "During the period of review of such areas and until Congress has determined otherwise, the Secretary shall continue to manage such lands according to his authority under this Act and other applicable laws in a manner so as not to impair the suitability of such areas for preservation as wilderness..." ("The Federal Land Policy and Management Act of 1976" [43 USC Section 1782]) Under the "Wilderness Act", for a wilderness area "... except as necessary to meet minimum requirements for the administration of the area for the purpose of the Act (including measures required in emergencies involving the health and safety of persons within the area) there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area" ("Wilderness Act" [16 USC Section 1133]).

For the DOE to acquire the necessary land at either the Davis Canyon or Lavender Canyon Site, Congressional action will be required to permanently withdraw the land. The Lavender Canyon site contains lands that have been designated as a Wilderness Study Area. The Bureau of Land Management (BLM) has made a recommendation that Bridger Jack Mesa not be designated as a Wilderness Area but as an Outstanding Natural Area (BLM, 1983). The protection requirements and restrictions for an Outstanding Natural Area are much less than for a Wilderness Area. However, the outcome is uncertain until Congress makes a final determination, and a time frame for Congressional action on this matter has not been scheduled.

While the designation of Bridger Jack Mesa as a Wilderness Study Area does not prevent the DOE from getting permanent transfer and control of the necessary land, it does add some additional complexity to the land transfer process. In addition, as part of the Nuclear Regulatory Commission's land control requirements (10 CFR 60.51) there is a need to provide permanent markers designing the controlled area. Because Bridger Jack Mesa is not easily accessible, it is unlikely to be used in the future for activities that could impair the long term isolation capability of a repository. Therefore, the need for placing permanent markers on Bridger Jack Mesa is greatly reduced. This issue, however, could also introduce some additional complexities into the licensing process while the DOE and NRC resolve the specific needs, types, and locations for permanent markers.

Any real difference in complexity for the DOE to obtain land ownership and control is considered significant because it could affect the ability to characterize the site and obtain lands for construction, as well as the ability to place permanent markers. While the differences between the sites are very slight, based on the available evidence, the Davis Canyon site is more favorable than the Lavender Canyon site because of the uncertainties associated with the Bridger Jack Mesa Wilderness Study Area.

2.4.2.1.3 Preclosure Radiological Safety Guidelines - Paradox Site Preference. Based on the evidence (as discussed above), the site ownership and control preclosure guideline which discriminates between the two sites indicates that the Davis Canyon site is more favorable than the Lavender Canyon site, primarily because of the present land transfer uncertainties of required controlled area lands within the Bridger Jack Mesa Wilderness Study Area. The evidence for the remaining preclosure radiological safety Technical Guideline conditions do not distinguish between the two sites, given the close proximity of the sites to each other.

2.4.2.2 Environmental, Socioeconomic, and Transportation Guideline Group

The second preclosure guideline group - environment, socioeconomics, and transportation - includes conditions related to Environmental Quality (10 CFR 960.5-2-5) and Socioeconomic Impacts (10 CFR 960.5-2-6) in areas potentially affected by a repository, and the Transportation (10 CFR 960.5-2-7) of waste to a repository site. This guideline group focuses on adequately protecting the public and the environment during repository siting, construction, operation, closure, and decommissioning from the hazards posed by the disposal of radioactive waste. As shown in Table 2-6 and discussed below, Davis Canyon and Lavender Canyon site data differences have been identified for two of the three environmental, socioeconomics, and transportation guidelines, but only the environmental quality data are of significant range or size difference to discriminate between the two sites.

2.4.2.2.1 Environmental Quality (10 CFR 960.5-2-5). The qualifying condition for the Environmental Quality Technical Guideline (10 CFR 960.5-2-5) requires, in part, that the site shall be located such that the quality of the environment in the affected area during this and future generations will be adequately protected during repository siting, construction, operation, closure, and decommissioning, and that projected environmental impacts in the affected area can be mitigated to an acceptable degree taking into account programmatic, technical, social, economic, and environmental factors. A favorable condition specified under this guideline is potential significant adverse environmental impacts to present and future generations which can be mitigated to an insignificant level through the application of reasonable measures, taking into account technical, social, economic, and environmental factors. Air quality and noise are two descriptors with data differences that characterize this favorable condition.

2.4.2.2.3 Environment, Socioeconomics, and Transportation Guidelines - Paradox Site Preference. Based on the data discussed above, the environmental quality preclosure guideline which discriminates between the two sites indicates that the Davis Canyon site is a more favorable Paradox Basin repository site than the Lavender Canyon site, primarily because of environmental considerations related to the proximity of the repository to protected areas. While the Davis Canyon site is near the Canyonlands National Park boundary, the Bridger Jack Mesa Wilderness Study Area is within the conceptual Lavender Canyon controlled area. Available evidence shows that the remaining preclosure environment, socioeconomics, and transportation guideline conditions do not discriminate between the two Paradox Basin sites, given the close proximity of the sites to each other.

2.4.2.3 Ease and Cost of Siting, Construction, Operation, and Closure Guideline Group

The third preclosure guideline group, ease and cost of siting, construction, operation, and closure, includes conditions related to the surface characteristics of the site (10 CFR 960.5-2-8), the characteristics of the Host Rock and surrounding strata (10 CFR 960.5-2-9), Hydrology (10 CFR 960.5-2-10), and Tectonics (10 CFR 960.5-2-11). These guidelines serve to demonstrate that repository siting, construction, operation, and closure are technically feasible on the basis of reasonable available technology, and that associated costs are reasonable relative to other available and comparable siting options.

2.4.2.3.1 Tectonics (10 CFR 960.5-2-11). The qualifying condition for the Tectonics guideline (10 CFR 960.5-2-11) requires, in part, that the site shall be located in a geologic setting in which the nature and rates of faulting are such that the magnitude and intensity of the associated seismicity are significantly less than those generally allowable for the construction and operation of nuclear facilities. A potentially adverse condition is present if there is evidence of active faulting within the geologic setting. The descriptor which characterizes this potentially adverse condition is the distance from the repository site to the nearest fault active during the Quaternary Period.

Data suggest that the Needles Fault Zone and the Shay/Bridger Jack/Salt Creek Graben System may be found to be active Quaternary faults within the Paradox Basin geologic setting. The Shay Graben system is located closer to both sites than the Needles fault zone. Although the Lavender Canyon site is closer to the Shay Graben system by approximately 4 kilometers (2.5 miles), this difference in distance is not expected to cause significant differences in the construction, operation, or closure of a repository located at either site. Thus, the evidence of active faulting present in the proximity of both Paradox Basin sites is not significant enough to discriminate between them.

A second potentially adverse condition specified under the Tectonics guideline 10 CFR 960.5-2-11(c)(2) is historical earthquakes or past human-induced seismicity that, if either were to recur, could produce ground motion at the site in excess of reasonable design limits. The mean-value estimate for peak ground acceleration expected at the sites is the descriptor which characterizes this potentially adverse condition for tectonic earthquakes. Induced earthquakes would be smaller than the maximum earthquake, and the potential for induced seismicity does not provide a discriminator between the sites.

Geophysical data indicate that a mean-value estimate for peak ground acceleration expected at the Davis Canyon site is 0.25 G, whereas the estimate at the Lavender Canyon site is 0.30 G. However, these ground motion projections are based, in part, on distance from the fault systems, and a repository at either location is required to be designed to withstand this ground motion at that site. The difference of 0.05 G in ground motion between the two sites can be accommodated by design and will not cause significant differences between the preclosure repository performance for a repository at either site. Therefore, it does not discriminate between the potentially acceptable Davis and Lavender Canyon sites.

2.4.2.3.2 Ease and Cost of Siting, Construction, Operation, and Closure - Paradox Site Preference. No preclosure ease and cost of siting, construction, operation, and closure guideline conditions have differing site data that discriminate between the potentially acceptable Davis and Lavender Canyon sites in the Paradox Basin.

Results from preliminary modeling indicate that the projected maximum 24-hour TSP, annual average NO_x, and noise levels during site characterization and repository activities (Table 2-6) at the Canyonlands National Park boundary differ only slightly between the two sites. The air quality parameters are well below established primary and secondary air quality standards. Given the limitations of the air and noise modeling resulting from the lack of site-specific meteorological data and the generally rough terrain, these minor air quality and noise level differences are not considered large enough to discriminate between the Davis Canyon and Lavender Canyon sites.

A potentially adverse condition specified under the environmental quality guideline is the proximity to, or projected significant adverse environmental impacts of the repository or its support facilities on, a component of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Land. A descriptor which characterizes this potentially adverse condition is the distance (in kilometers) from the repository controlled area boundary to the nearest dedicated Federal land.

Distances shown in Table 2-6 for the Davis and Lavender Canyon repository control areas taken from conceptual site designs, indicate that the Lavender Canyon repository control area is within the Bridger Jack Mesa Wilderness Study Area, whereas the closest Lavender repository controlled area boundary is 2 kilometers (1.2 miles) from Canyonlands National Park. The closest Davis Canyon repository controlled area boundary is approximately 0.3 kilometer (0.2 mile) from the Canyonlands National Park boundary and 2 kilometers (1.2 miles) from Bridger Jack Mesa. Until Congressional action has taken place, the management of a Wilderness Study Area is similar to that of a National Wilderness Area. Therefore, the Davis Canyon site is more favorable than the Lavender Canyon site for the potentially adverse Environmental Quality guideline condition 10 CFR 960.5-2-5(c)(3).

2.4.2.2.2 Transportation (10 CFR 960.5-2-7). The qualifying condition for the transportation Technical Guideline (10 CFR 960.5-2-7) requires, in part, that (1) a repository be located such that the access routes to be constructed from existing local highways and railroads to the site can be designed and constructed using reasonably available technology, and (2) transportation operations be conducted without causing an unacceptable risk to the public or unacceptable environmental impacts. A favorable condition listed under this guideline is the availability of access routes from local existing highways and railroads to the site, including routes that are relatively short and economical to construct as compared with access routes for other comparable siting options. A descriptor which characterizes this favorable guideline condition is the projected total cost in 1984 dollars, considering all terrain characteristics, for constructing highway and rail access routes and upgrading existing inadequate routes. Construction cost estimates are based on very preliminary highway and rail access designs. These estimates indicate that approximately 79 and 80 million dollars (approximately a 1-percent difference) will be required to construct adequate highways to the Davis and Lavender Canyon sites, respectively. For railroads, the ranges are 142 to 269 million dollars for the Davis Canyon site and 141 to 272 million dollars for the Lavender Canyon site. However, since the minor difference in these preliminary cost estimates is attributable to the total length of highway and railroad construction requirements and is only considered accurate within 10 percent, the small corridor construction cost difference is not a reliable basis for discriminating between the two Paradox Basin sites.

Conceptual transportation route access to the Paradox Basin sites, as shown in Table 2-6, indicate that the total length of the access routes and rail line is at most 5 kilometers (3 miles) shorter for the Davis Canyon site than for the Lavender Canyon site. Since the routes chosen for this comparative evaluation are essentially identical, the terrain, cost per mile, and environmental impacts are equal for both sites, differing only because of the length of the access routes. Since the minimum distance to both sites exceeds 61 kilometers (38 miles) and is based on reference conceptual transportation access corridors rather than specific engineering alignments, the minor difference (approximately 7 percent) is not significant and thus is not a discriminating factor between the two Paradox Basin sites.

2.4.3 Preferred Paradox Basin Site

The comparative evaluation results from Section 2.4.1 postclosure discriminating Technical Guidelines, and Section 2.4.2 preclosure discriminating Technical Guidelines are summarized in Table 2-7. The Davis and Lavender Canyon sites are very similar due to the nearness of the sites to one another.

The Davis Canyon site is preferred to the Lavender Canyon site for the preclosure radiological safety guideline group and the preclosure environment, socioeconomics, and transportation guideline group. No guideline discriminates between the two sites for the postclosure guideline group or the preclosure ease and cost of siting, construction, operation, and closure guideline group.

The comparative evaluation of the potentially acceptable Davis and Lavender Canyon sites shows that there are very few differences between the sites. These two sites are located such that the controlled areas overlap. A comparison of the favorable and potentially adverse conditions for the postclosure and preclosure guidelines for the two sites did not allow a clear selection of a preferred site. Development of a more detailed list of distinguishing characteristics led to a basis for the identification of a preferred site. The presence of the Bridger Jack Mesa Wilderness Study Area in the Lavender Canyon controlled area is the most significant difference between the two sites. Based on this distinguishing characteristic, the Davis Canyon site was selected as the preferred site in the Paradox Basin geohydrologic setting.

Table 2-7. Summary of Findings Based on Discriminating Guidelines Between the Potentially Acceptable Paradox Basin Sites

	Distinguishing Guideline	Finding	
		Less Favorable	More Favorable
Postclosure Discriminating Guideline Conditions			
No discriminating guidelines			
Preclosure Radiological Safety Discriminating Guideline Conditions			
Site Ownership and Control 960.5-2-2	Degree of difficulty for DOE to obtain all required surface and subsurface lands and rights	Lavender Canyon	Davis Canyon
Overall Preclosure Radiological Safety Guideline Group		Lavender Canyon	Davis Canyon
Preclosure Environment, Socioeconomics, and Transportation Discriminating Guideline Conditions			
Environmental Quality 960.5-2-5	Proximity to dedicated Federal lands	Lavender Canyon	Davis Canyon
Overall Preclosure Environment, Socioeconomics, and Transportation Guideline Group		Lavender Canyon	Davis Canyon
Preclosure Ease and Cost of Siting, Construction, Operation, and Closure Discriminating Guidelines			
No discriminating guidelines			

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2.5.2 Federal Regulations and Statutes

10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories; Technical Criteria.

10 CFR Part 960, Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines.

Federal Land Policy and Management Act of 1976, 43 USC Secs. 1701-1782.

Nuclear Waste Policy Act of 1982, 42 USC Secs. 10101-10226.

Wilderness Act, 16 USC Secs. 1131-1136.

Chapter 3

THE SITE

This chapter is a summary of the present information base concerning the Davis Canyon site in the State of Utah. This information is the foundation for evaluations and assessments in other chapters as mandated by the "Nuclear Waste Policy Act of 1982" (NWPA) (42 USC Sections 10101-10226).* Data and information summarized here have been developed from reviews of applicable literature and completion of various field surveys conducted during the site selection process described in Chapter 2. These data are the basis for the evaluations and assessments required for nominating a site as suitable for characterization and for recommending a candidate site for site characterization.

3.1 LOCATION, GENERAL APPEARANCE AND TERRAIN, AND PRESENT USES

Davis Canyon is located in San Juan County, southeastern Utah (Figure 3-1). For purposes of discussion of the surface features associated with the vicinity of Davis Canyon, the following geographic terms of reference are used in this environmental assessment (EA):

Geologic Repository Operations Area (GROA) (Figure 3-2) comprises the proposed surface area which encompasses all land affected by site preparation and construction of surface and underground facilities.

Controlled Area is the surface location, and the underlying subsurface, which has been proposed for use as a geologic repository and from which incompatible activities would be prohibited before, during, and after permanent closure. This area, shown on Figure 3-2, is based on preliminary estimates of size of the GROA and performance assessment analyses. (For purposes of the EA, the controlled area is called the Davis Canyon site.)

The Davis Canyon candidate area includes the Gibson Dome area defined in the Paradox Basin screening process (Section 2.1) and contiguous areas that will require evaluation during site characterization. These contiguous areas include Lockhart and Beef basins, the Shay Graben system, and the Needles Fault zone. The Davis Canyon candidate area is a square, approximately 58 kilometers (36 miles) on a side, centered approximately on the GROA, which is located in Sections 5 through 8 of T31S, R21E, southwest of South Six-Shooter Peak in a cul-de-sac near the mouth of the canyon (Figures 3-1 and 3-2).

The nearest cities are Moab, Monticello, and Blanding (Figure 3-1). Moab, approximately 53 kilometers (33 miles) north of the site, is in southern Grand County. Blanding and Monticello are in San Juan County, approximately 56 kilometers (35 miles) and 39 kilometers (24 miles) southeast of the site, respectively. These communities are the focus of the two-county socioeconomic study area (Section 3.6).

The Paradox Basin, which is located within the Colorado Plateau physiographic province (Figure 3-3), is characterized by rugged topography and classic desert landforms. Because the Colorado Plateau has been slowly and steadily uplifted, erosional features are prominent. Drainages are deeply incised into plateau surfaces, and bench-like canyon sides are common.

The Davis Canyon candidate area is principally used for agriculture and recreation. Primary agricultural uses are alfalfa production and winter cattle grazing. Recreational resources within and adjacent to the candidate area include the Needles District of Canyonlands National Park; Manti-La Sal National Forest; Newspaper Rock State Historical Monument, and three areas managed by the Bureau of Land Management (BLM): Canyon Rims Recreation Area, Beef Basin, and Dark Canyon Primitive Area.

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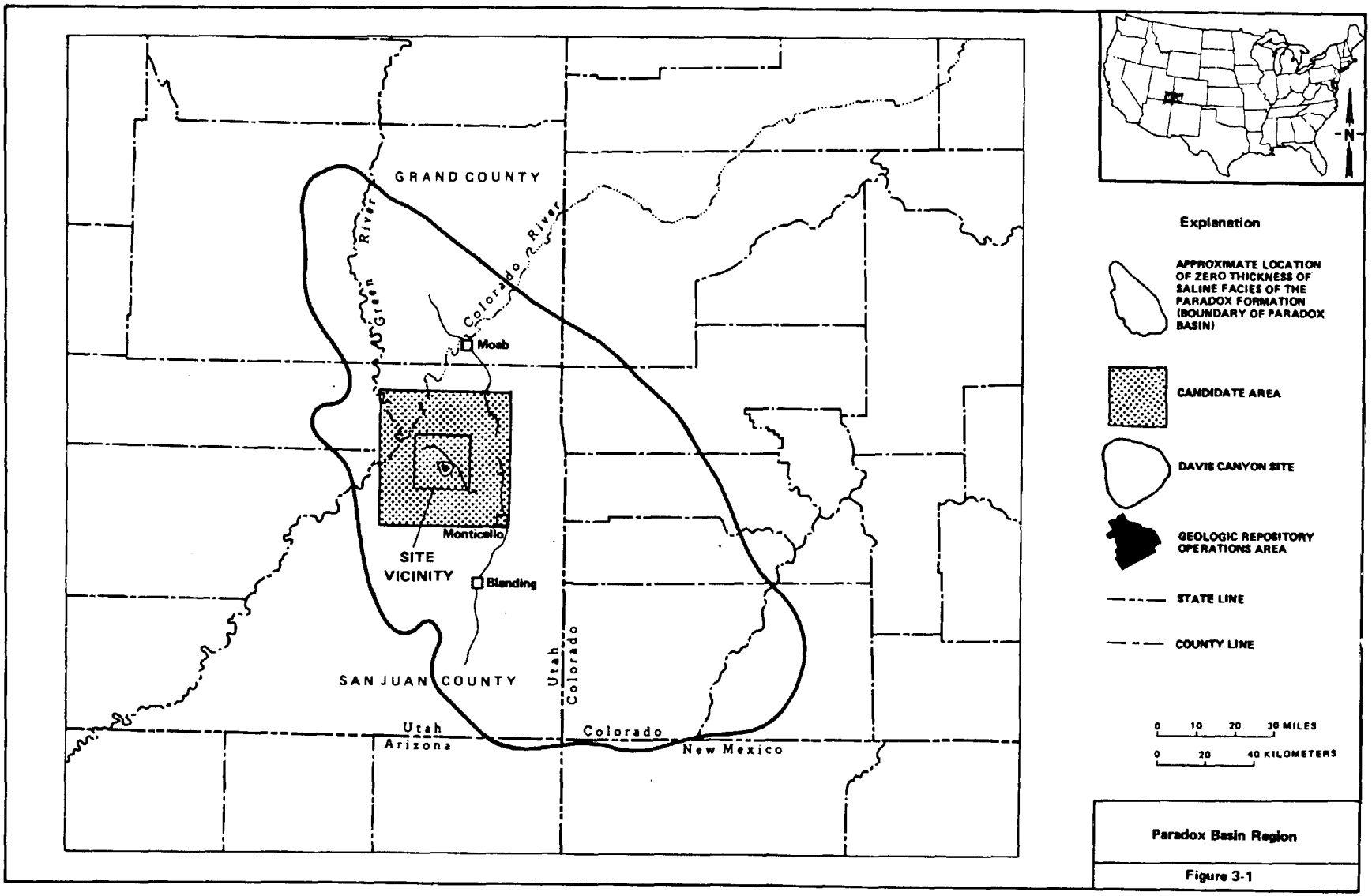
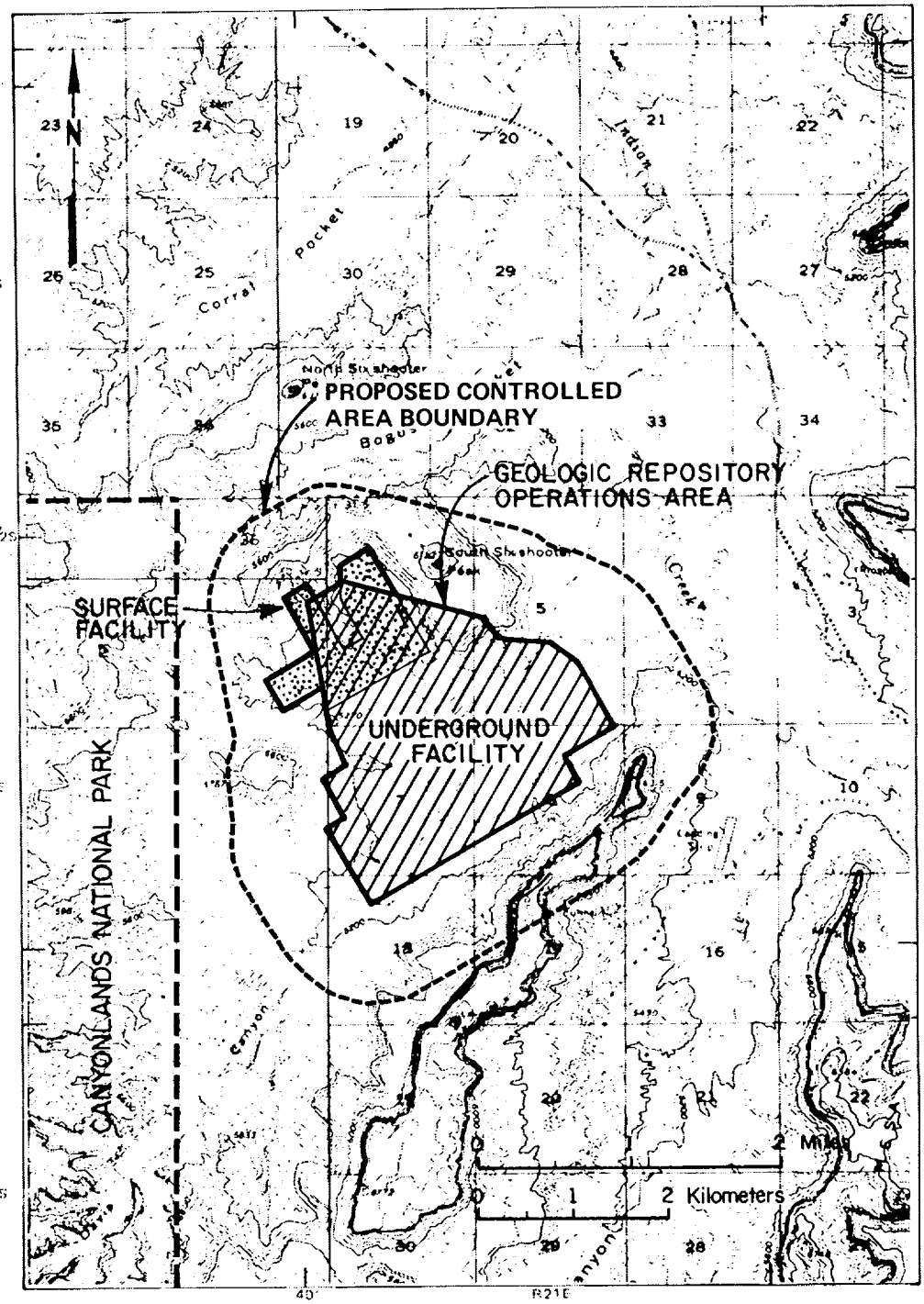
*Regulations and statutes are listed at the end of the chapter after the list of references.



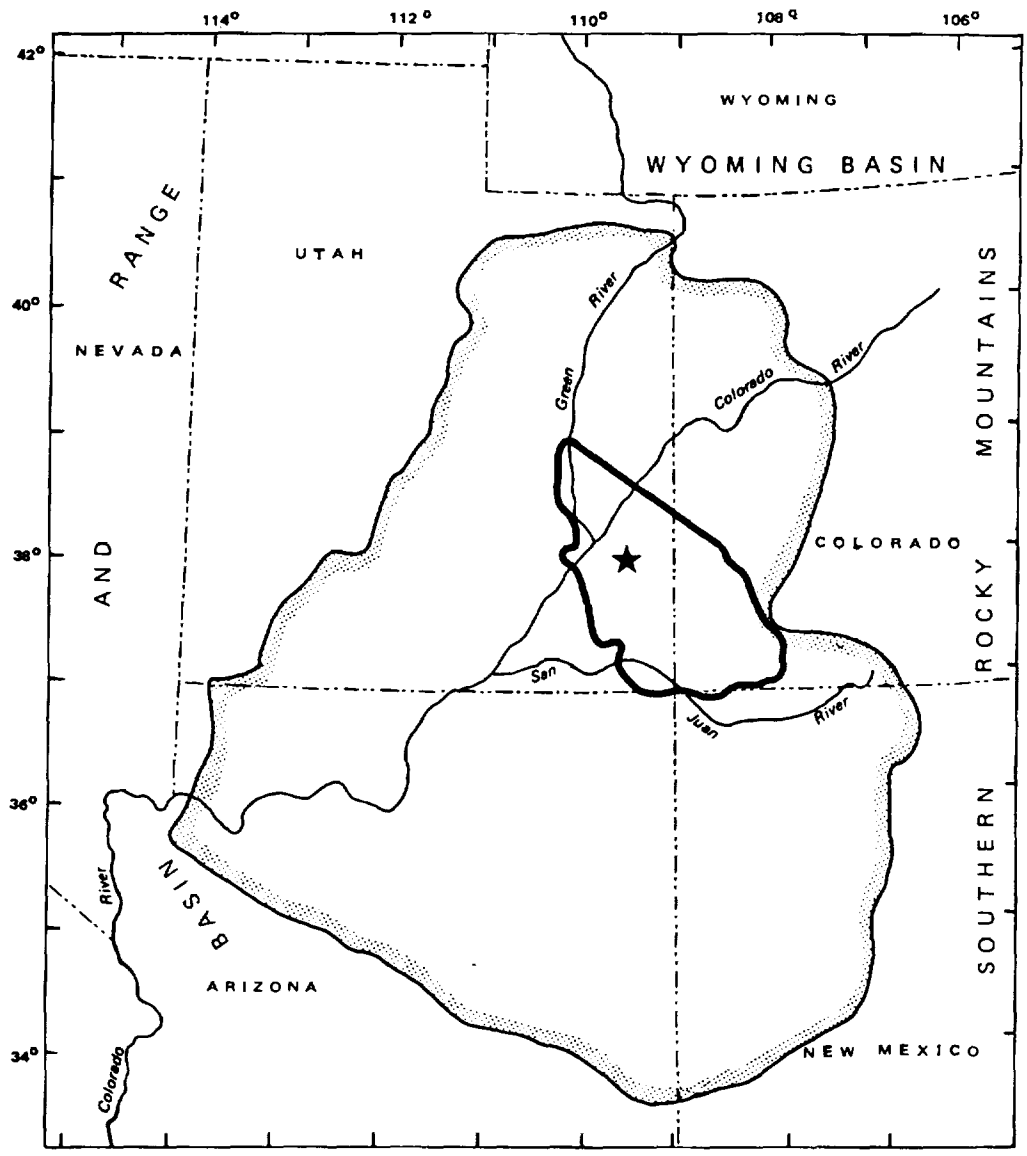
Paradox Basin Region

Figure 3-1



Preliminary Facility Location Within the Site

Figure 3-2



Explanation

Approximate location of zero thickness of saline facies (Boundary of Paradox Basin)

Outline of Colorado Plateau

★ Approximate location of Davis Canyon Site

0 50 100 Mi

0 100 Km

Colorado Plateau Physiographic Province and Paradox Basin Region

Figure 3-3

3.2 GEOLOGIC CONDITIONS

Section 3.2.1 describes the broad geologic framework of the region. Subsequent sections describe geologic conditions at the candidate area and site.

3.2.1 Regional Geology

The Davis Canyon site is located within the west-central part of the Paradox Basin, which in turn is located in the east-central part of the Colorado Plateau. The Colorado Plateau has maximum dimensions of 770 and 640 kilometers (480 and 400 miles) in the north-south and east-west directions, respectively. The boundaries of the Plateau province are defined by major zones of recurrent tectonic activity that have persisted since Precambrian or Paleozoic time.

The Plateau is bounded on all sides by major structural zones (Figure 3-4) that have experienced large amounts of deformation during the Cenozoic and, with the exception of the Uinta Mountains at the north end of the Plateau, significant magmatic activity. The Plateau interior is characterized by low heat flow, few Cenozoic magmatic centers, thick crust, low incidence of surface faulting, low to moderate seismicity, and a thick cover of flat-lying Phanerozoic sedimentary rocks overlying the Precambrian crystalline basement. Phanerozoic strata within the Plateau interior are locally deformed by (1) latest Cretaceous and early Cenozoic (Laramide) monoclinal folds that overlie steeply dipping faults in the basement (Davis, 1978, p. 215), and (2) late Cenozoic normal faults (Shoemaker et al., 1978, pp. 341-342).

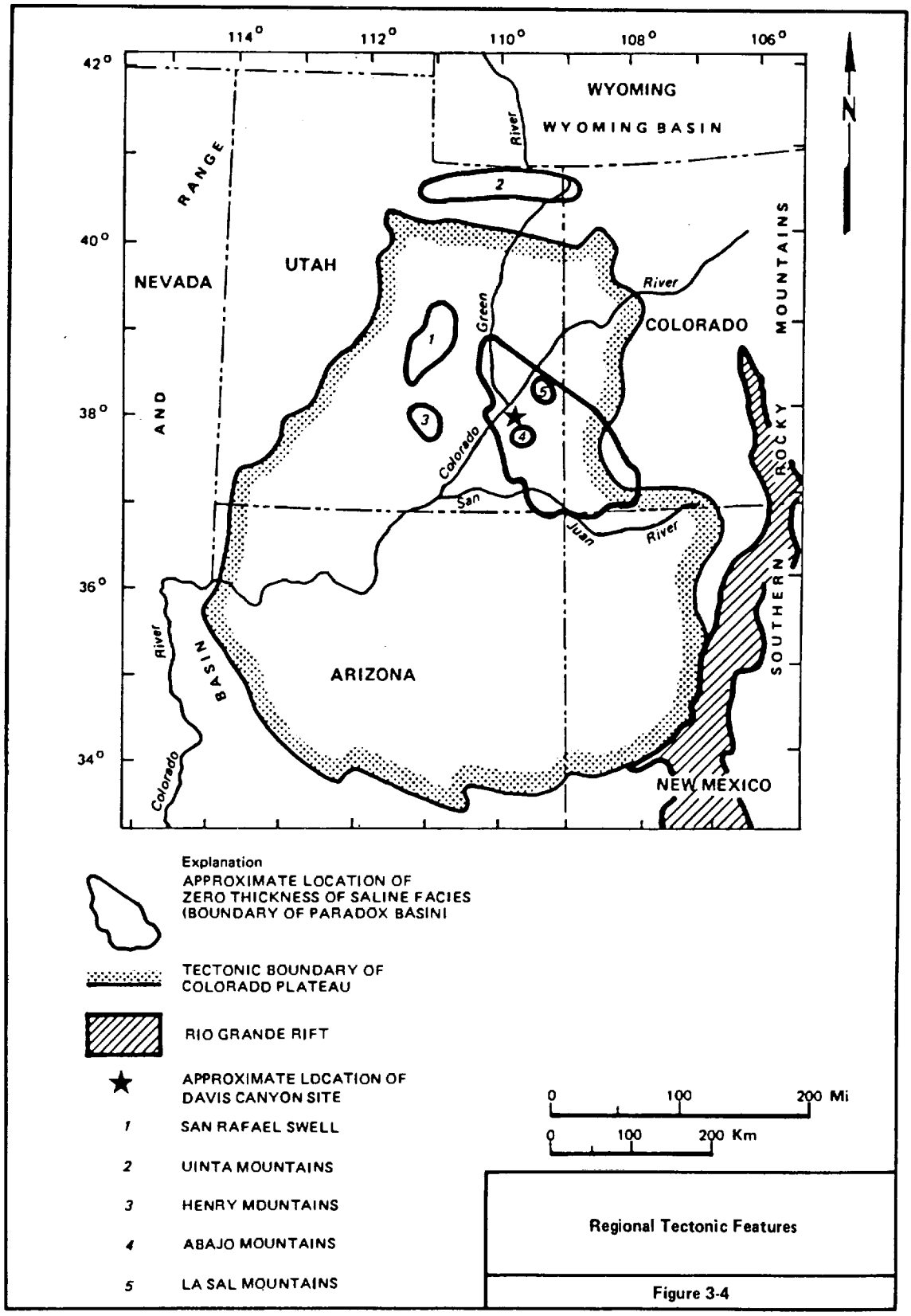
No igneous or plutonic centers are known to have been active within the Colorado Plateau between approximately 1 billion and 90 million years ago. Sporadic magmatic activity has occurred since then at widely separated centers, but no activity is known to have occurred within the Paradox Basin since the early Miocene (23.5 million years before present[BP]) (Armstrong, 1969, p. 2084). Magmatic phenomena within the Plateau interior include latest Cretaceous to middle Cenozoic age stocks and laccoliths, middle Cenozoic and Pliocene age dikes and diatremes, and Pliocene-Quaternary age volcanism in the Grand Canyon region. The peripheral regions of the plateau are transitional to surrounding provinces, and exhibit a higher degree of Cenozoic magmatism and faulting. Heat flow is higher in these regions, and the crust and lithosphere become thinner to the west, south, and southeast (Smith, 1978, p. 117; Thompson and Zoback, 1979, pp. 155-158).

The Colorado Plateau is bounded on the west, south, and east by the Basin and Range province (Figure 3-4), a region of thin crust that has been strongly affected by volcanism, high heat flow, and crustal extension during the middle and late Cenozoic. The Basin and Range province can be subdivided into three subprovinces (Great Basin, Southern Basin and Range, and the Rio Grande Rift) based on significant contrasts in neotectonic behavior and tectonic history.

The Great Basin subprovince includes most of Nevada and Western Utah. High heat flow, Quaternary faulting, and basaltic volcanism are concentrated around the margins of the subprovince, whereas the core is cooler and tectonically quiescent (Eaton et al., 1978; Blackwell, 1978).

The Southern Basin and Range subprovince lies south of the Colorado Plateau and appears to be less tectonically active at present than the Great Basin subprovince. Quaternary basaltic volcanism is not as prevalent as in the Great Basin subprovince. Pliocene and younger faulting has, for the most part, taken place on steeply dipping north-trending normal faults (Shafiqullah et al., 1980).

The Rio Grande Rift subprovince, which lies east of the Colorado Plateau (Figure 3-4), is a narrow region of crustal extension, basaltic volcanism, and high heat flow that projects northward from the Southern Basin and Range subprovince. The rift appears to follow a north-south system of Laramide right-lateral wrench faults (Chapin and Cather, 1981).



Regional Tectonic Features

Figure 3-4

The Colorado Plateau is bounded on the north by the Uinta Mountains, an east-west oriented Laramide Age uplift of Precambrian rocks, flanked on the north and south sides by thrust faults that dip beneath the center of the range (Hansen, 1984, p. 10). Tectonism during the Laramide orogeny uplifted the Uinta Mountains to their present high elevation. The eastern end of the range has subsequently subsided, primarily during the late Oligocene-Miocene (Hansen, 1984, p. 5) coincident with crustal extension along the Rio Grande Rift to the southeast.

3.2.2 Geomorphology

This section describes the physiography of the Davis Canyon site and candidate area and the geomorphic processes operating within the Quaternary (the last 1.6 million years) which contributed to its geomorphological development. First, the physiographic and geomorphic setting of the Davis Canyon site is described. Second, estimates of the Quaternary rates of erosion and incision in the region are presented, because they provide a general estimate of erosion rates expected to occur in the area of the site in the future. Finally, climatic fluctuations during the Quaternary are discussed for a similar reason.

3.2.2.1 Physiography

The Davis Canyon site is located in the Inner Canyonlands physiographic subprovince of the Colorado Plateau physiographic province (Figure 3-5). Landforms include vertical cliff faces, steep talus slopes, and relatively flat surfaces that are coincident with resistant horizontal to gently dipping bedrock layers. Several orders of bench-like relief commonly exist, and surface relief can be extreme. The elevation of the Davis Canyon site varies from approximately 1,537 to 1,951 meters (5,040 to 6,400 feet) above mean sea level (MSL).

The surface elevation of the Davis Canyon geologic repository operations area (GROA) is approximately 1,585 meters (5,200 feet) MSL in the relatively flat valley bottom of Davis Canyon (Figure 3-2) and a side canyon. The level canyon floor is surrounded by nearly vertical cliffs of long, narrow mesas that separate drainages. The nearest prominent landform is South Six-Shooter Peak (elevation 1,869 meters [6,132 feet]), a remnant spire 0.5 kilometer (0.3 mile) north of the GROA.

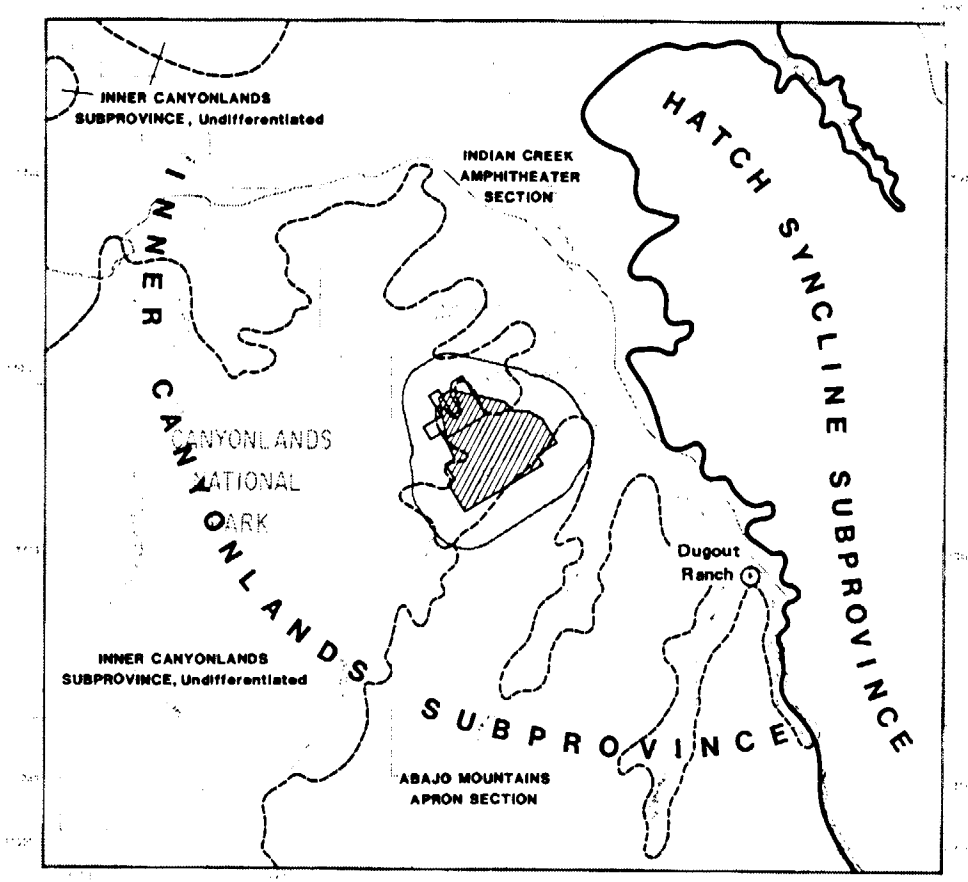
The Davis Canyon site, including the GROA, is drained by Indian Creek and its tributaries. Indian Creek, which rises in the Abajo Mountains at an elevation above 2,740 meters (9,000 feet) MSL, joins the Colorado River in the north-western portion of the candidate area at an elevation of 1,190 meters (3,900 feet) MSL. The western portion of the candidate area is drained by Salt Creek, whose headwaters drain the high plateaus west of the Abajo Mountains.

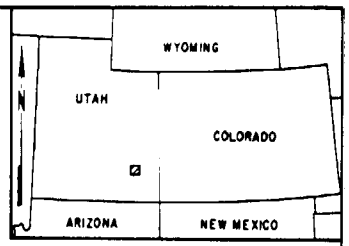
The landforms in the site vicinity include major cliffs, nearly flat lowlands with minimally incised drainages, and remnant buttes and spires. Local changes in elevation may be as great as 365 meters (1,200 feet) within a distance of 0.4 kilometer (0.25 mile).

3.2.2.2 Erosion Processes

The Quaternary history of the Colorado Plateau has been dominated by Cenozoic uplift and by fluctuating global climatic conditions. Erosion has been the dominant process affecting this area, but episodes of alluviation, colluviation, and eolian deposition are recorded by deposits along streams, at the bases of cliffs, and on plateau surfaces.

Rates of local erosion and geomorphic processes are influenced by the variable resistance of the underlying bedrock. The influence of lithologic resistance on local erosion rates, measured or estimated, in the Paradox Basin must, therefore, be considered in order to obtain meaningful estimates of regional and long-term erosion rates in the study areas. On the basis of weathering characteristics and landform development observed in the field and on aerial photographs, the geologic formations exposed in the Paradox Basin have been grouped into erodibility classes (Table 3-1). This grouping of units is supported by previous authors (King and Mace, 1953, pp. 19-21; Hains et al., 1952, pp. 142-146; Schumm and Chorley, 1966,





Explanation:

Approximate boundary of physiographic subprovinces

Approximate boundary of physiographic section

Proposed controlled area boundary

Geologic repository operations area

0 1 2 3 4 MI

0 1 2 3 4 5 Km

Physiographic Subprovince and Section in Site Vicinity

Figure 3-5

Table 3-1. Relative Erodibility of Rock Units in the Paradox Basin

Erodibility Class[a]	Lithology and Texture	Formations in Class[b]	Characteristic Landforms
1	Porphyritic igneous rock	Intrusive rock of the La Sal and Abajo Mountains	Mountains
2	Predominantly limestone	Elephant Canyon Formation (Indian and Shafer limestones only)	Vertical canyon walls, benches
		Honaker Trail Formation of Hermosa Group	
	Silica-cemented sandstone	Dakota, Cedar Mountain, Burro Canyon Formations	Mesa tops, vertical scarps
		Shinarump Conglomerate	Ledges, cliffs
		Moss Back Member of Chinle Formation (Gibson Dome area and south)	Ledges, cliffs, mesa tops
		Sandstone above C Marker of Cedar Mesa Formation (Elk Ridge area)	Ledges, mesa tops
3	Gravel	Quaternary pediment and alluvial deposits	Terraces, pediments
	Massive, friable sandstone; predominantly calcite-cemented	Entrada, Navajo, Kayenta, Wingate Formations; White Rim/De Chelley Sandstone of Cutler Group; Cedar Mesa Formation	Rounded knobs, vertical cliffs, mesa tops, vertical or overhanging canyon walls, hogback or flatirons in monoclinal folds
4	Sandstone with minor associated siltstone	Salt Wash, Recapture, West-water Canyon members of Morrison Formation	Prominent ledges, steep slopes
		Summerville-Curtis Formation (Lisbon Valley Area)	

Table 3-1. Relative Erodibility of Rock Units in the Paradox Basin
(Page 2 of 2)

Erodibility Class[a]	Lithology and Texture	Formations in Class[b]	Characteristic Landforms
		Moss Back Member of Chinle Formation (north of Gibson Dome area)	
		Cutler Formation (Gibson Dome area)	
		Elephant Canyon Formation (most areas)	
5	Siltstone and mudstone with associated sandstone	Carmel, Chinle, Moenkopi Formations; Organ Rock Shale of Cutler Group	Gentle slopes with sandstone ledges, valleys
6	Siltstone and bentonitic mudstone	Brushy Basin Member of Morrison Formation; mudstone immediately underlying Moss Back Member of Chinle Formation	Hummocky slopes, landslides
7	Shale	Mancos Shale	Badlands, valleys with flood plains
	Unconsolidated sand, silt	Quaternary eolian deposits, fine-grained alluvium	Dunes, eolian sheets, valley fill cut by arroyos

(a) Erodibility class 1 is most resistant; class 7 is least resistant.
(b) Formations are listed in descending stratigraphic order. Where variation in erodibility has been observed, locations or erodibility types are given in parentheses.

pp. 14-16; Hansen, 1965, pp. 16-21) working in the same units in nearby areas. A more refined classification of units is not appropriate on a regional scale because of lateral facies changes within most exposed formations. The amount and minerology of cementing agents, the grain size and minerology of different facies, the thickness of beds, and the spacing of joints affect erodibility and show considerable variation within many of the exposed units.

Igneous rock of erodibility class 1 occurs as intrusive rock in the Abajo and La Sal Mountains adjacent to, but not within the site area. However, igneous clasts are predominant in the gravel veneer of terraces found in the area. Igneous rock may also include basalt flows, which do not occur in the vicinity of the site.

In general, limestone and silica-cemented sandstone are the most resistant sedimentary rock types exposed in the Paradox Basin (class 2, Table 3-1). The rocks are strongly indurated and form resistant ledges on slopes and vertical canyon walls. Relatively resistant (class 3) units include gravel-capped terraces and pediments, and massive, but friable and moderately indurated, sandstone units that form extensive cliffs in the region. These units weather to single grains and form rounded knobs at some localities, whereas joint-controlled slabs are characteristic weathering products at other localities.

Formations composed of mixed sandstone and siltstone, or mudstone of classes 4 through 6 (Table 3-1), are increasingly erodible and have higher proportions of finer-grained beds. These classes are characterized by sandstone ledges in the more gentle slopes developed on the finer-grained units, which commonly underlie valleys and coincide with the flood plains of many streams. The Mancos Shale, which commonly erodes to form badlands and unconsolidated fine-grained Quaternary alluvium, is the least resistant unit (class 7) exposed in the basin. Observations of the effects of rock types on specific processes are discussed in the following discussion on erosion.

Estimates of the rate at which erosion is occurring in southeastern Utah, and hence in the Davis Canyon site, were derived by various means. Long-term and shorter-term rates of stream incision were calculated from the topographic position above present river levels of deposits having age control. These derived rates can be compared against rates based on historical data on sediment concentrations in rivers or reservoir sedimentation data. Scarp retreat rates are also derived from geomorphic relationships and an estimate of time of scarp formation.

3.2.2.2.1 Stream Incision. The most accurate estimate of incision rates is derived from locations where Tertiary or Quaternary deposits are dated radiometrically or, secondarily, where a minimum age can be assigned to deposits on the basis of magnetic polarity or pedologic development. In calculating incision rates for the proposed site in Davis Canyon, estimates of incision rates for the major rivers of the Colorado River system were made. The larger rivers of the system would more accurately reflect the long-term incision rate than would small, ephemeral tributary streams, such as those in Davis Canyon, where the initiation of channel downcutting lagged behind that of the main channel. It is expected that after downcutting began in the tributary streams, it would proceed at a rate comparable to that of the main channel, to maintain the established gradient of the tributary stream.

The locations along the Colorado River and its major tributaries where radiometric dates are available are listed in Table 3-2, Part A. Less precise estimates, based on paleomagnetic signature and soil development in Quaternary terrace deposits along the major streams are listed separately (Table 3-2, Part B). Two other categories, incision rates from geomorphic relationships along smaller tributary streams and rates induced by climatic change, are also given (Table 3-2, Parts C and D).

The long-term incision rates derived from the radiometrically dated deposits (nine locations) range from 1.2 to 24 centimeters (0.04 to 0.8 feet) per 1,000 years (Table 3-2). These rates represent an averaged rate for the entire time of canyon development. In actuality, the data indicate that canyon cutting has not proceeded at a constant rate. At two locations where intermediate age control is available (from the Roaring Fork River, near its junction with the Colorado River at Glenwood Springs, Colorado; and in the Grand Canyon), it

Table 3-2. Long-Term Incision Rates

Location	Basis for Calculation	Estimated Downcutting (m	[ft])	Time Interval (10^6 yrs)	Calculated Incision Rates (cm/ 1,000 yrs)	(ft/ 1,000 yrs)
A. Long-Term Incision Rates From Radiometrically Dated Deposits of the Colorado River System						
Roaring Fork River; near junction with Colorado River-Glenwood Springs, Colorado	Channel cutting since emplacement of K/Ar-dated basalt flows (Larson et al., 1975, pp. 101-102)	610	(2,000)	8 - 10.0	30.5	1.0
		67	(220)	1.5 - 8.0	1.0	0.03
		300	(980)	0 - 1.5	20.0	0.65
	Total	975	(3,200)	0 - 10.0	10.0	0.32
Colorado River, Grand Canyon area	Channel cutting since emplacement of K/Ar-dated basalt flows					
Grand Wash Bay	(Damon et al., 1978)	810	(2,657)	3.8 - 5.9	0.4	0.8
		110	(361)	0 - 3.8	2.7	0.09
Lava Falls	(McKee et al., 1968, p. 133)	15	(50)	0 - 1.2	1.2	0.04
Shivwits Plateau	(Lucchitta and McKee, 1975)	1,524	(5,000)	0 - 6.0	25.4	0.8
Colorado River, Lake Mead, Arizona	River gravels at Sandy Point contain K/Ar-dated basalt clasts (Lucchitta, 1972, p. 1933)	107	(350)	0 - 3.3	3.4	0.18
Colorado River, Grand Mesa, Grand Junction, Colorado	Channel downcutting since emplacement of K/Ar-dated lava flow (Luedke and Smith, 1978)	1,524	(5,000)	0 - 9.7	15.7	0.52

Table 3-2. Long-Term Incision Rates
(Page 2 of 4)

Location	Basis for Calculation	Estimated Downcutting (m [ft])	Time Interval (10^6 yrs)	Calculated Incision Rates (cm/ 1,000 yrs)	Calculated Incision Rates (ft/ 1,000 yrs)
Gunnison River, Upper Black Canyon, Colorado	Pearlette ash above channel (Hunt, 1969, p. 75; Naeser et al., 1971)	61 (200)	0 - 0.6 to 0 - 1.96	10 or 3	0.33 or 0.10
Animas River, near Durango, Colorado	Channel downcutting since deposition of Lava Mountain (Pearlette "0") ash in alluvial deposits (Gillam, 1979, p. 13)	146 (480)	0 - 0.6	24	0.8
Green River, Canyon of Ladore, Utah	Channel downcutting since emplacement of K/Ar-dated lava flows (Hansen, 1984, p. 26)	750 (2,460)	0 - 5.0	15	0.5
B. Estimates of Long-Term Incision Rates for Colorado and Green Rivers Based on Paleomagnetic Signature or Pedogenic Development					
Colorado River at confluence with Green River	Channel downcutting into pre-canyon erosional surface	700 (2,300)	4 (CD) 8 (CD)	17.5 8.8	0.58 0.29
Colorado River, Bullfrog Basin, Lake Powell, Utah	Channel cutting since deposition of alluvium having reversed magnetic polarity	305 (1,000)	>0.73 (M) >3.32 (G)	<43 < 9.2	1.4 0.3

Table 3-2. Long-Term Incision Rates
(Page 3 of 4)

Location	Basis for Calculation	Estimated Downcutting (m [ft])	Assumed[a] Time Interval (10^6 yrs)	Calculated Incision Rates (cm/ 1,000 yrs)	Calculated Incision Rates (ft/ 1,000 yrs)
Green River, Keg Knoll, Utah	Channel cutting since deposition of alluvium having reversed magnetic polarity and Stage IV-V pedogenic carbonate	402 (1,320)	>0.5 (C)	<80	2.6
			>0.73 (M)	<55	1.8
			>3.32 (G)	<12	0.4
Colorado River near Hall's Crossing, Utah	Channel cutting since deposition of alluvium having Stage IV-V pedogenic carbonate	244 (800)	0 - >0.5 (C)	49	<1.6
Green River near Horseshoe Utah	Channel cutting since deposition of alluvium having Stage IV-V pedogenic carbonate	384 (1,260)	0 - >0.5 (C)	49	<1.6
C. Data Points on Tributary Streams of the Colorado River					
Pack Creek/Mill Creek, near Moab, Utah	Channel downcutting since deposition of alluvium having reversed magnetic stratigraphy	260 (850) (Pack Creek)	>0.73	<37.0	<1.2
			>3.32	8.0	<0.3
		168 (550) (Mill Creek)	>0.73	24.0	<0.8
			>3.32	5.0	<0.2
Cotton Wash/ Johnson Creek near Blanding, Utah	Channel downcutting since deposition of alluvium having reversed magnetic stratigraphy	290 (950) (Cottonwood)	>0.73	40.0	<1.3
			>3.32	9.0	<0.3
		137 (450) (Johnson)	>0.73	19.0	<0.64
			>3.32	4.0	<0.14

Table 3-2. Long-Term Incision Rates
(Page 4 of 4)

Location	Basis for Calculation	Estimated Downcutting (m [ft])	Assumed Time Interval (10^6 yrs)	Calculated Incision Rates (cm/ 1,000 yrs)	Calculated Incision Rates (ft/ 1,000 yrs)
Paradox Valley, Colorado	Channel downcutting since deposition of Bishop Ash in alluvium (Cater, 1970, p. 49)	85 (280)	0 - 0.7	12.0	0.4
D. Inclusion Rates That May be Climate-Related					
Pack Creek, near Moab, Utah	Vertical separation of gravel terraces of Beaver Basin and Placer Creek age (Pinedale and Bull Lake equivalents, respectively) (Richmond, 1962, Plate 1)	21 (70)	0.075 - 0.135	36	1.2
Indian Creek, near Davis Canyon	Vertical separation of gravel terraces of Pindale- and Bull Lake-equivalent ages	12 (40)	0.075 - 0.135	20	0.7

Note: Data without specific references are published in WCC (1982, ONWI-290, Vol. I, Chapter 3; Vol. II, Chapter 4) and Biggar (1983).

(a) Time intervals represent estimated time for canyon development (CD), or for minimum ages of Matayama (M), or Gilbert (G), reversed epoch, or for development of pedogenic carbonate (C).

appears that the Colorado River may have initially incised its channel at a more rapid rate of approximately 30.5 centimeters (1 foot) per 1,000 years (Table 3-2) (Larson et al., 1975, p. 101; Damon et al., 1978, pp. 101-102). At Glenwood Springs, downcutting slowed to a minimal rate of 1 centimeter (0.03 feet) per 1000 years between 8 and 1.5 million years before present (BP). Since then, incision has been occurring at an average rate of 20 centimeters (0.65 feet) per 1,000 years (Larson et al., pp. 101-102). Alternatively, a 1.2-million-year date on basalt, 15 meters (50 feet) above present stream level at Lava Falls in the Grand Canyon (McKee et al., 1968, p. 133), indicates that downcutting has been minimal along that part of the river during the last half of Quaternary time. These data indicate the potential variability in the shorter-term incision rates. They also indicate that short-term maximum rates are not significantly greater than the long-term average rate. Therefore, the long-term incision rate for Indian Creek and its tributary in Davis Canyon is expected to be 0.24 meters (0.8 feet) or less per 1,000 years.

Comparable or lower rates are obtained for rates of channel downcutting for the Colorado and Green Rivers when paleomagnetic data are examined (Table 3-2). If the paleomagnetically reversed deposits are estimated to be a minimum of 730,000 years in age, the derived maximum incision rate (less than 55 centimeters [1.8 feet] per 1,000 years) is higher than those based on the radiometric dates. These rates are very conservative calculations because 730,000 years represents the end of the most recent reversal (the Matayama epoch) which extended from 2.41 to 0.73 million years BP (LaBrecque et al., 1977, p. 332). If canyon cutting by the Colorado River actually began between 5 and 10 million years BP, the reversed magnetic signature of the deposits may represent the Gilbert Epoch, which occurred between 3.32 and 5.12 million BP (LaBrecque et al., p. 332), or perhaps an even earlier reversal. If the deposits are estimated to be 3.32 million years old, and are representative of the end of the Gilbert reversed epoch, the calculated incision rates are less than 9 to 12 centimeters (less than 0.3 to 0.4 foot) per 1,000 years (Table 3-2). These lower rates are still considered to be maximum rates because of evidence that canyon cutting probably began more than 3 million years ago (Table 3-2) (Larson et al., 1975, pp. 101-102; Damon et al., 1978).

Similarly, the incision rates derived from calcic-soil age estimates are maximum rates. These rates range from less than 49 to 80 centimeters (1.6 to 2.6 feet) per 1,000 years, based on a minimum age of 500,000 years for deposits along the Colorado and Green Rivers. Geologic ages of calcic soils are based on morphological features in the soil, and are correlated to areas where the soil ages have been determined by other means (Machette, 1985, Table 2). Morphological changes become increasingly minimal with time, and the rate at which calcic soils form varies between different areas, because the source amount of calcium ions varies between geographical areas. Therefore, a calcic soil assessed to be 0.5 million years old at one location may have the same appearance as one that is 1.5 million years old at another location (Machette, Table 2). Where the deposits in which the soils have formed are paleomagnetically reversed, such as at Keg Knoll (Table 3-2), the 500,000-year estimated age is obviously a minimal age for the deposit, although the soils that develop on a deposit are necessarily younger than the deposit. Therefore, the incision rates derived by estimating the age of calcic soils are maximum rates only, and are less informative than those derived from the paleomagnetic data.

An example of an incision rate that is likely climate-induced is provided by the Pack Creek and Indian Creek terrace data derived from DOE studies near Moab (WCC, 1982, ONWI-290, Vol. I, p. 3-21, Table 3-10) and the GROA (WCC, 1982, ONWI-290, Vol. II, p. 4-13; Biggar, 1983, pp. 99-100). This rate is based on the recognition of gravel deposits associated with two successive glacial periods that reached their maximums approximately 75,000 and 135,000 years ago (Imbrie and Imbrie, 1979, Figure 48). Stream flow during glacial periods was higher than the current level, as evidenced by clast size in the deposits. These "short-term" rates of downcutting for an estimated 60,000-year period in late Pleistocene time range from less than 20 to 36 centimeters (less than 0.7 to 1.2 feet) per 1,000 years, or higher than the calculated long-term rates of less than 0.24 meters (0.8 foot) per 1,000 years. These rates have been averaged to provide an estimated short-term incision rate of 30 centimeters (1 foot) per 1,000 years during periods of glaciation.

Radiocarbon dates of up to 10,000 years BP (WCC, 1982, ONWI-290, Vol. III, Table 4-4) have been derived from the fine-grained fluvial deposits that occur as fill within bedrock channels, rather than on strath terraces above the present channel. The oldest age derived from fill in the vicinity of the GROA is 7,760 ±155 years BP (WCC, 1982, ONWI-290, Vol. II, Table 4-4). Periodic flushing of fine-grained stream channel deposits, and subsequent refilling of the bedrock channel with up to 18 meters (60 feet) of fill, has occurred during Holocene time, as indicated by cut-and-fill structures observed in streambank exposures (WCC, 1982, ONWI-290, Vol. II, p. 4-9) However, little or no evidence of significant bedrock incision during Holocene time was observed in the vicinity of the proposed site, and the rate at which streams downcut into bedrock during the last 10,000 years BP is assessed to be almost imperceptible. It appears that the long-term bedrock incision rate of 0.3 meter (0.8 foot) per 1,000 years does not reflect the rate at which bedrock incision occurs under interglacial climatic conditions. It is possible that bedrock incision of a very local nature has occurred by upstream migration of bedrock knickpoints in the stream channels.

Historic erosion rates can be calculated by estimating the average annual sediment yield or denudation of a drainage basin. These yields can be estimated in two ways: by periodically sampling the sediment concentration in rivers, and by measuring the changes in reservoir volume caused by sedimentation. These data can also be compared on the basis of erodibility of stratigraphic units exposed in the drainage basin.

Denudation rates for watersheds in the Colorado Plateau are shown in Table 3-3. Historic denudation rates of 0.09 to 0.9 meter (0.3 to 3.1 feet) per 1,000 years, based on the data of reservoirs in lithologic units of erodibility classes 2 through 4, fall within the same range as the erosion rates calculated from geomorphic relationships (Table 3-2). The rates show considerable variability because of local climatic conditions, different time intervals used in the calculation, and variations in lithology, drainage-basin area, topographic setting, and human activities. For example, particularly high erosion rates (0.5 to 2.2 meters [1.5 to 7.2 feet] per 1,000 years) are measured in areas underlain by the Mancos Shale, of erodibility class 7.

3.2.2.2.2 Mass Wasting. Erosion can also occur through the mass wasting processes. In the vicinity of the site, the mass wasting process of greatest interest is rock falls that result from the weathering and sudden release of rock along joint planes. The slopes that bound Davis Canyon are composed primarily of slope-forming siltstone and mudstone units of the Cutler, Moenkopi, and Chinle Formations, and occasional ledge-forming sandstone beds. The most prominent of the cliff-forming sandstones is the Moss Back Member of the Chinle Formation, which ranges in thickness from approximately 8 meters (25 feet) to over 23 meters (75 feet) (WCC, 1982, ONWI-290, Vol. II, p. 5-7) where it fills the channels cut into the underlying rock. Locally, silica is the primary cementing agent of this sandstone. Above the Chinle Formation, South Six-Shooter Peak represents an erosional remnant of the Wingate Formation, which commonly forms 90-meter (300-foot-)-high cliffs elsewhere in the area. Calcium carbonate is the primary cementing agent in the Wingate (Schumm and Chorley, 1966, p. 13).

The units most susceptible to rock fall in the vicinity of the site are the sandstone cliff-forming units, of which the Moss Back and Wingate sandstones are the most prominent. Large blocks of Moss Back Sandstone litter the hillslopes below the outcrops, but bedrock blocks are rarely seen in the flat-lying areas at the base of the cliffs. The size of the sandstone blocks is controlled by relatively closely spaced joints along the margin of the cliffs. The distribution and extent of bedrock joints in the vicinity of the Davis Canyon site are discussed in Section 3.2.5.7. Rubble on the slopes below the Wingate outcrop is not coarse. Calcium carbonate is not a strong cementing agent, and it appears that when the Wingate blocks fall, they disintegrate into rubble that readily weathers away (Schumm and Chorley, 1966, p. 33).

Based on a preliminary assessment, the typical rock fall consists of individual blocks that remain on the bedrock slopes and do not fall into the low-lying areas. No visible evidence of rotational block slides or debris flow was seen on the photographs in the site area.

Table 3-3. Denudation Rates for Watersheds in the Colorado Plateau[a]

Location	Drainage Area (mi^2)	Length of Record (yrs)	Average Annual Precipitation (in)	Lithology[b] (erodibility class in parentheses)	Erosion Rate (ft/1,000 yrs)
Little Colorado River (Hains et al., 1952)	0.2-4.7	6-12	12-16	DeChelley (3)	0.3
	0.1-2.1	5-13	12-16	Shinarump (2)	0.4
	0.15-2.3	10-22	12-16	Mesa Verda (2)	0.5
	0.2-18.2	2-5	12-16	Mixed Jurassic, Mancos (4-7)	1.7
	0.5-0.6	2-6	12-16	Chinle (5)	2.5
Little Colorado River Basin	22,100	--	12-16	Mixed	0.9
San Rafael Swell (King and Mace, 1953)	0.11	13	7-12	Morrison sandstone (4)	0.2
	0.13	12	7-12	Ferron sandstone (4)	0.3
	0.80	13	7-12	Curtis (4)	0.6
	0.46	11	7-12	Quaternary gravel (3)	0.6
	0.10	7	7-12	Entrada-Curtis (4)	0.8
	0.25	11	7-12	Curtis-Summerville (4)	1.9
	0.54	12	7-12	Entrada (3)	3.1
	0.14	12	7-12	Morrison (6)	1.6
	0.99	11	7-12	Mancos (7)	>2.3
	0.24	12	7-12	Mancos (7)	>3.0
	0.75	13	7-12	Entrada-Curtis (3-4)	>4.5
	3.45	10	7-12	Mancos (7)	>3.4
	0.92	14	7-12	Mancos (7)	7.8
	0.34	12	7-12	Morrison, Mancos (6-7)	4.1
	0.12	8	7-12	Mancos (7)	>6.2
San Rafael River Basin	1,690	--	5-13	Mixed	0.5-4.1
Badger Wash (Lusby, 1979)	.084	18	8	Mancos (7)	2.1
	.158	18	8	Mancos (7)	3.0
	.048	18	8	Mancos (7)	3.7
	.019	18	8	Mancos, Ferron (5)	3.11
Crescent Wash (Hains et al., 1952)	19.0	3	8-9	Mesa Verde, Mancos (2, 7)	2.5
Dirty Devil River (Hains et al., 1952)	0.24	12	7	Mancos (7)	1.5
Bullfrog Creek (Hains et al., 1952)	0.28	1	5	Mancos (7)	7.2
Zuni River (Hains et al., 1952)	9.4	1	12	Chinle (5)	8.0
Dolores River (Hains et al., 1952)	1.9	10, 6	16	Mesa Verde, Mancos (2, 7)	0.3-0.5
San Rafael River (King and Mace, 1953)	1,690	3	--	Mixed	1.3
Cottonwood Wash (USGS, 1974)	205	1	--	Intrusive rocks	1.0

(a) Based on reservoir sedimentation and modern sediment load data (last two estimates are based on suspended sediment yields).
(b) Erodibility classes are defined in Table 3-1.

Estimated rates of scarp retreat for the repository area can be examined in terms of the relative erodibility of local stratigraphic units. Calculated rates of scarp retreat (Table 3-4), based on long-term geomorphic relationships, range from 0.2 to 0.5 meter (0.8 to 1.6 feet) per 1,000 years in formations of erodibility classes 2 through 5, and from 7 to approximately 23 meters (23 to 74 feet) per 1,000 years for cliffs developed in Cretaceous marine shales, such as the Mancos Shale (erodibility class 7). Locally, rates may vary considerably because of variations in lithology; differences can be readily observed in the Paradox Basin by comparing the relative widths and depths of canyons developed in lithologies of different erodibility. However, in the area of the proposed repository site, strata of erodibility class 7 have already been removed from the stratigraphic column, and incision and scarp retreat that occur during the lifetime of the repository will be occurring in rock units of erodibility classes 2 through 5. Therefore, a scarp retreat rate in the site area is approximately 0.2 to 0.5 meter (0.8 to 1.6 feet) per 1,000 years.

3.2.2.2.3 Graben Formation. Another mass movement process that is of interest to the Davis Canyon site is the large-scale deformation that is occurring in the Grabens area of the Needles Fault zone. This is probably caused, in part, by gravitational sliding. The concern is whether the deformation will propogate eastward and reach the site.

The Grabens are an arcuate system (Needles Fault zone) of linear downdropped bedrock blocks (Section 3.2.5.1) that extend for 25 kilometers (16 miles) along the east side of Cataract Canyon on the Colorado River (Figure 3-6). The Grabens system averages approximately 7.2 kilometers (4.5 miles) in width and extends 12 kilometers (7.5 miles) east from the river at its widest point. Cataract Canyon is approximately 341 meters (1,120 feet) deep, below the confluence of the Colorado and Green Rivers.

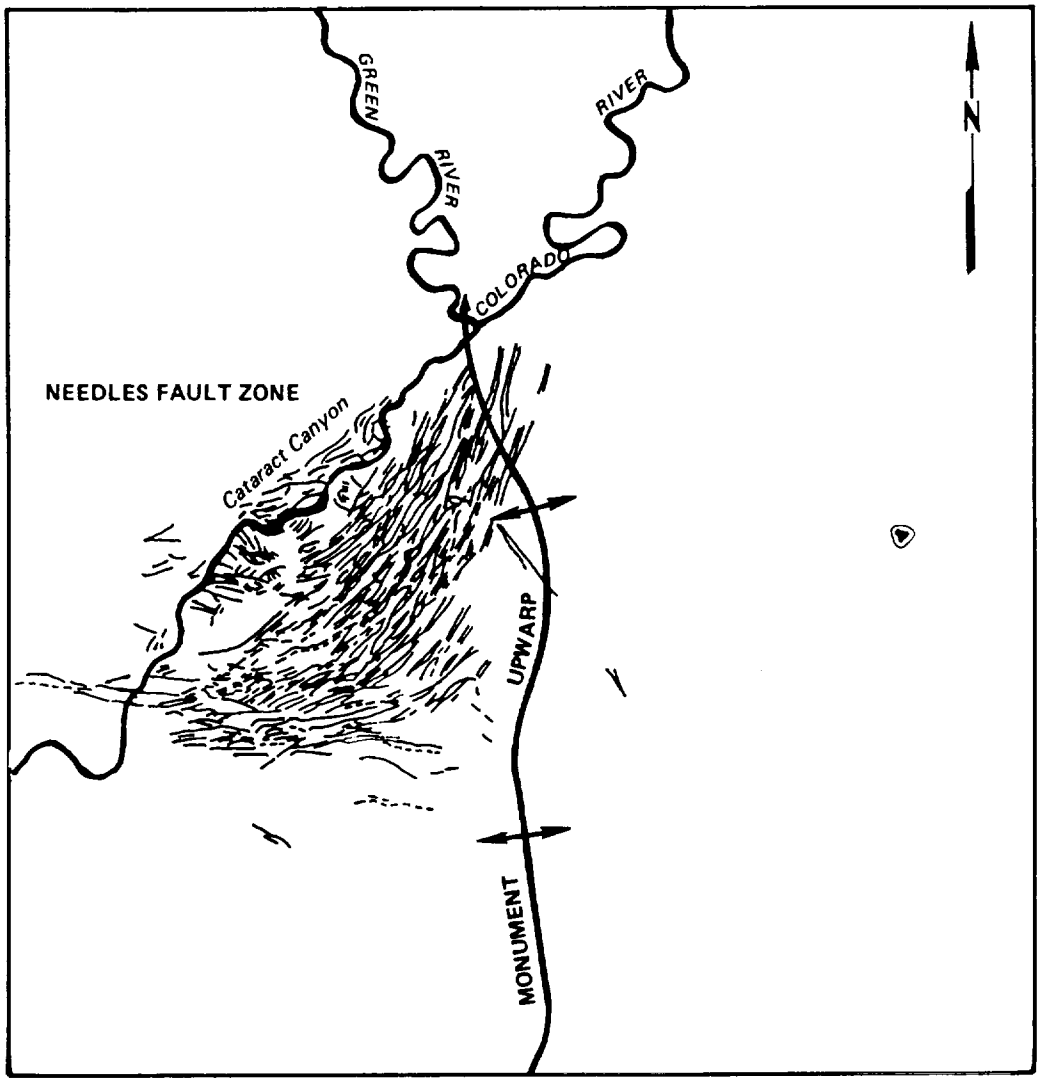
Issues of interest related to the Davis Canyon site are (1) the mechanism by which the grabens have formed, (2) the rate at which development has occurred, and (3) whether graben development will propagate eastward toward Davis Canyon. Proposed mechanisms for graben formation suggest processes of gravitational sliding, off the western flank of the Monument Upwarp into Cataract Canyon, dissolution (discussed in Section 6.3.1.6), and tectonic processes (Section 6.3.3.4). If graben formation is due to gravitational sliding or mass-movement processes, the initiation of sliding would have occurred only after the Colorado River had sufficiently eroded to create a free face, or a sufficiently low horizontal confining stress along the western margin of the bedrock mass. It is theorized that the plane of sliding or decoupling is within the salt section of the Paradox Formation. Local bedrock strata dip gently to the west off the northwestern nose of the Monument Upwarp (Figure 3-6), thereby, facilitating the massive sliding westward toward the chasm produced by the Colorado River.

The rate at which graben development has proceeded can be estimated by defining when the Grabens began to form. The upper limit is provided by the age of Cataract Canyon, which is 341 meters (1,120 feet) deep. Assuming the conservative river incision rate of 0.24 meter (0.8 foot) per 1,000 years, Cataract Canyon began forming approximately 1.4 million years ago. The lower limit is more difficult to define. At the present time, the oldest date that has been derived for samples collected from Quaternary sediments, accumulated in the downdropped graben structures, is 65,370 years BP (Betancourt and Biggar, 1985, BMI/ONWI-570, p. 27). Due to the lack of other age data, this date has been used to define the minimum age of the Grabens. The graben from which the dated sample was collected is located 3.2 kilometers (2 miles) from the river, in an area where the entire graben system is 12 kilometers (7.5 miles) wide. The sample was collected from probable eolian (dune) deposits along the eastern margin of a downdropped graben block. The eolian deposits were subsequently buried by colluvium derived from the adjacent horst block.

Development of the overall graben system would have actually begun prior to 65,000 years ago in order for the graben in which the sample was collected to have formed, and for graben development to have progressed eastward from the river to the sampling site. As described above, the sample site is located 3.2 kilometers (2 miles) from the river, and the entire graben system is 12 kilometers (7.5 miles) wide at this point. Assuming that graben development has progressed linearly eastward from the river through time, the 65,000-year-old date

Table 3-4. Average Rates of Scarp Retreat on the Colorado Plateau, Based on Geomorphic Interpretations

Location	Basis for Calculation	Amount of Scarp Retreat		Estimated Time Interval (10^6 years)	Calculated Scarp Retreat Rate		Erodibility Class
		meters	feet		(centimeters/ 1,000 years)	(feet/ 1,000 years)	
Virgin River at St. George	Shale scarp capped by K/Ar-dated basalt (Hamblin et al., 1975, p. 1098)	671	(2,200)	0 - 2.2	30.5	(1)	1
Colorado River at Green River	Cutting of inner canyon since late-Pleistocene time (Hunt, 1969, p. 85)	1,609	(5,280) (1 mile)	0 - 3	55.0	(1.8)	2 to 5
Circle Cliffs	Retreat of cliffs since mid- to late-Tertiary time (Hunt, 1969, p. 103)	12,875	(42,240) (8 miles)	0 - 30	43.0	(1.4)	7
Book Cliffs	Apparent retreat of Book Cliffs at north end of Uncompaghre Plateau, assuming present Colorado River established in late-Pleistocene or possibly earliest-Pleistocene time (Hunt, 1969, p. 82-83)	45,062	(147,080) (28 miles)	0 - <2	<2,256.0	(<74)	7
Book Cliffs	Distance between Book Cliffs near Grand Junction and near Cortez, Colorado (Sinnock, 1978, p. 173)	209,215	(686,400) (130 miles)	0 - 30	700.0	(23)	7
Colorado River at Green River	Creation of outer canyon, assumed to have begun 20 m.y. BP (Hunt, 1969, p. 101) on basis of canyon size	4,828 to 6,437	(15,840 to 21,120) (6 to 8 miles)	0 - 20	24.0 to 30.5	(0.8 to 1.0)	2 to 5
Grand Canyon	Width of canyon; canyon cutting began in early-Miocene-time (Hunt, 1956, p. 77; Schumm and Chorley, 1966, p. 30)	12,070	(39,600) (7.5 miles average)	0 - 20	60.4	(2)	2 to 5



Explanation

Fault, dashed where approximate dotted where concealed

Fold axis

Davis Canyon Site

0 5 10 Mi

0 5 10 Km

Map of the Needles Fault Zone and Monument Upwarp

Figure 3-6

Sources: Modified from Huntoon et al., 1982; Williams and Hackman, 1971; Williams, 1964.

reflects the minimum time in which 25 percent of the system had formed. This approach results in a calculated minimum age of approximately 85,000 years for the graben system.

The estimated range for the age of the graben system provides a means of calculating rates at which the grabens may propagate eastward to the GROA. Given the assumption that mass-movement processes (hence graben formation) did not begin until after 1.4 million years ago, and have developed over a distance of 7.2 kilometers (4.5 miles) since then, the lower bound on the rate of graben formation is 5.2 meters (17 feet) per 1,000 years. The upper limit on the rate of graben growth is provided by the assumption that graben development began 85,000 years BP and has progressed eastward over a distance of 12 kilometers (7.5 miles) from the river. These parameters provide a maximum rate of graben development of 140 meters (465 feet) per 1,000 years. At its closest distance, the eastern margin of the grabens is 16.4 kilometers (10.5 miles) from the proposed GROA in Davis Canyon. If graben development were to continue eastward at the rate estimated above without being influenced by the geologic structure of the Monument Upwarp, grabens might begin to form in the GROA within approximately 120,000 to 3,250,000 years.

This time span, particularly the lower bound, is considered a very conservative estimate due to the structural influence of the Monument Upwarp. The grabens are now concentrated on the western flank of the Upwarp (Figures 3-6 and 3-28), which dips gently to the west. At the Davis Canyon site, which is approximately 14.5 kilometers (9 miles) east of the crest of the Upwarp (Figure 3-6), the strata dip 1.6 degrees to the northeast (Section 3.2.5). If the grabens are a manifestation of mass-movement processes and the downdip void created by erosion of Cataract Canyon, the grabens should not propagate eastward over the crest of the upwarp. Therefore, they would not reach the site, where the strata dip in the opposite direction.

3.2.2.3 Influence of Joints on Drainage Pattern

In some geological settings of the world bedrock joints exert strong control over drainage-pattern development. The resultant regional pattern reflects the primary and secondary joint orientations, and is commonly a trellis or rectangular form (Bloom, 1978, pp. 268-272). In a study of joint orientations in the vicinity of the Davis Canyon site, the principal joint trend, in number and areal coverage, is between N. 5 E. and N. 35 E., and is most prominently expressed southwest of the site. Another conspicuous set that trends N. 50 W. to N. 75 W. is limited to the Gibson Dome structure, north of the site (Section 3.2.5.7). In the vicinity of Gibson Dome, Indian Creek flows through an incised canyon along the axis of the dome, along which the joint trend developed. South and southeast of Gibson Dome, tributary streams to Indian Creek have a distinct, large-scale, approximately N. 30 E. trend. On the northern end of Harts Point the pattern is strongly suggestive of structural control. However, on neither a regional nor a more local level do the streams exhibit a prominent rectangular or trellis drainage pattern, characteristic of joint-controlled drainage.

Examination of aerial photos in the Harts Point area did not reveal a major joint trend, particularly one that trends northeast, in the surficial bedrock unit (the Kayenta Formation). However, the joint study revealed that the expression of joints was primarily limited to the massive sandstone units, such as the Cedar Mesa, Navajo, Entrada, and Wingate sandstones (Section 3.2.5.7). Joint trends were not readily observed in the more friable siltstone and mudstone interbeds. Because the upper surface of the Wingate is commonly covered by the Kayenta Formation, and is exposed only along the margins of cliffs, the study of aerial photographs was not able to thoroughly address how extensive joint development is in the Wingate, and accordingly, verify that joints control stream development in this area. It is likely that the larger scale geologic structures, such as the Monument Upwarp, exert more control on the regional pattern of drainage development than the joint set in the vicinity of the Davis Canyon site.

On a local scale, joints may influence the rate of stream incision. Over long periods of time, however, tectonic uplift, sea level, and geologic structures provide the ultimate control of base level for a stream. A resistant rock stratum may form a local or temporary base level for a graded reach of stream, as demonstrated by a thin limestone bed that forms

the local base level for the Davis Canyon site. The limestone, informally referred to as the Indian Limestone in the DOE studies (WCC, 1982, ONWI-290, Vol. II, p. 5-5), marks the top of the Elephant Canyon Formation,and forms an approximately 10-meter- (30-foot-) high waterfall in both Indian and Salt Creeks. If joints were extensively developed in the Indian Limestone, streams would more easily incise a channel, a knickpoint would not form, and it would not be a local base level for upstream drainages.

3.2.2.4 Paleoclimate

Climate in southeastern Utah has varied during late Quaternary time. Periods of probable cooler temperatures and greater effective moisture are evidenced by several observations. There are coarse-grained stream terrace deposits, glacial deposits in the La Sal Mountains where glaciers are no longer present, and specific plant species found in pack rat middens at elevations that are hundreds of meters lower than where the plants now grow. Other periods having a drier climate than the present are indicated by widespread eolian deposits and stabilized vegetated dunes. These paleoclimatic changes, recorded in the geologic and biologic records of the Paradox Basin, are comparable to findings reported worldwide, which indicate that glacial advances have occurred cyclically throughout Pleistocene time.

During Quaternary glaciations, mountain glaciers formed and expanded in the higher elevations of the western United States. In the Paradox Basin only the La Sal Mountains, which reach an elevation of 3,877 meters (12,721 feet) and are approximately 50 kilometers (30 miles) northeast of the site, were glaciated. No glacial deposits have been observed in the Abajo Mountains (up to 3,462 meters [11,360 feet] high, 35 kilometers [22 miles] south of the site) or the Henry Mountains (up to 3,540 meters [11,615 feet] high, 100 kilometers [62 miles] west of the site) (Kottlowski et al., 1965, p. 294; Hunt, 1956, p. 35). The lowest elevation reached by early Quaternary glaciers in the La Sal Mountains is 2,000 meters (6,600 feet), and the maximum glacier length was 14.5 kilometers (9 miles) (Richmond, 1962, Plate 1, p. 33).

Glacial conditions last occurred approximately 15,000 to 21,000 years ago (Spaulding et al., 1983, p. 263). Reconstruction of paleoclimatic conditions that may have characterized the site during the glacial maximum uses data collected elsewhere in the southwest, because data spanning this time interval are sparse in the Davis Canyon candidate area and have not yet been collected in the vicinity of the site. During the glacial intervals, annual temperatures throughout the Southwest may have been approximately 10 C (18 F) cooler than present (Spaulding et al., p. 286; Galloway, 1983, p. 236). Estimates of the decrease in annual temperatures for this period range from 2.5 C (4.5 F) (Antevs, 1952, in Spaulding et al., 1982, p. 288) to 13 C (23 F) (Mears, 1981, p. 185) below present average temperatures. The degree to which precipitation amounts have changed is subject to debate; estimates range from no change from modern amounts to a 100-percent increase over present-day values (Antevs, 1952, in Spaulding et al., 1982, p. 288). An analysis of Quaternary vegetation data indicates an effective increase in precipitation. However, changes in vegetation attributed to increased rainfall can also be attributed to increased cloud cover, cooler temperatures, and concentration of annual rainfall in winter months.

The transition to warmer conditions following the last period of glaciation was gradual in the southwest and, depending on elevation and latitude, occurred from 15,000 to 7,800 years before present (Spaulding et al., 1983, p. 263). Throughout the Holocene (the last 10,000 years) a relatively warm climate has prevailed in the southwest. However, Holocene climatic fluctuations have occurred, and were of sufficient magnitude to develop small mountain glaciers in the western mountain ranges, including the La Sal Mountains (Richmond, 1962, pp. 90-91; 1965, pp. 222-223).

An indication of paleoclimates in southeastern Utah during the Holocene and pre-Holocene transition periods has been derived in a preliminary study of pack rat middens (Betancourt and Biggar, 1985, BMI/ONWI-570; Betancourt, 1984). Analysis of vegetation collected from datable pack rat middens provides a means of reconstructing paleotemperatures and precipitation amounts for the surrounding area. Data from middens up to 13,000 years old, which were collected from rock shelters that are 30 and 80 kilometers (20 and 50 miles) south of the Davis

Canyon geologic repository operations area, suggest that temperatures were no more than 5 C (9 F) below present-day temperatures during the last 13,000 years, and that annual precipitation 11,000 to 13,000 years ago may have exceeded present-day values by as much as 114 percent (Betancourt and Biggar, 1985, BMI/ONWI-570, pp. 68-72).

The approach provides upper limiting values for predicted precipitation during the period from 11,000 to 13,000 years ago. Betancourt (1984, pp. 26-27) used an approach that was more selective with regard to the data base used, resulting in an estimated annual precipitation that exceeds present amounts by only 62 percent for the same time period.

Given that the present-day annual precipitation at the Davis Canyon site is approximately 25 centimeters (10 inches), a 114 percent increase would result in an annual rainfall of 54 centimeters (21 inches); a 62 percent increase would result in an annual rainfall estimate of 41 centimeters (16 inches). It is unlikely that annual precipitation ever exceeded approximately 54 centimeters (21 inches) for any significant period of time, as indicated by the preservation of calcic soils in Quaternary deposits of varying ages throughout the Paradox Basin (WCC, 1982, ONWI-290, Vol. I, pp. 3-10 to 3-19). These soils are indicative of a prevalent arid or semiarid climate (Gile and Grossman, 1979, p. 44).

The midden data suggest that summer and mean annual temperatures increased during the early and middle Holocene (approximately 10,000 to 4,000 years before present), and climatic conditions shifted from winter- to summer-dominant rainfall, relative to conditions during the last glacial interval. However, aridity also appears to have increased during the late Holocene (the last 4,000 years) (Betancourt and Biggar, 1985, BMI/ONWI-570, pp. 52-56).

Another indicator of paleoclimates is calcic soil. The accumulation of calcium carbonate in a soil profile is a function of climate (temperature, and particularly precipitation); the concentration of calcium cations in rainfall, aerosolic dust, silt, and eolian sand; the character of host material in which the soil forms; and carbonate-rich rocks in the parent material or in nearby source areas. In southeastern Utah, the potential rate of soil carbonate accumulation is a balance, primarily, between the supply of calcium to the ground surface and the amount of rainfall. At locations where rainfall is sufficient to move all the available calcium cations down through the soil profile, the rate of soil carbonate accumulation can actually increase with an increase in rainfall. On the other extreme, excess precipitation leaches calcium from the soil profile. A calcic soil horizon subject to an increase in rainfall infiltration may exhibit a discontinuous or laterally variable accumulation of soil carbonate (Machette, 1985).

Calcic soils have been used in the Paradox Basin project as indicators of a persistent arid and semiarid climate through Pleistocene time. The presence of calcic soils implies that rainfall has not, for any significant period of time, exceeded the amount which would leach carbonate from soils. The boundary between calcic soils (pedocals) and leached soils (pedalfers) in the mid-United States corresponds to an annual isohyet of 50 to 60 centimeters (20 to 23.5 inches). Studies elsewhere indicate that other factors, such as seasonal distributions of rainfall, average temperatures, and soil texture, can control the leaching of carbonate; at Reno, Nevada, for example, the pedocal/pedalfer boundary coincides with 18 centimeters (7.1 inches) of rainfall (Birkeland, 1974, p. 232).

An indication that the amount of precipitation controls soil carbonate accumulation in southeastern Utah is provided by Richmond's (1962) study of Quaternary deposits and soils in the La Sal Mountains near Moab. In that area, prominent calcic soils were not found above 1,890 meters (6,200 feet), although calcium coatings on pebbles in soil horizons up to 120 centimeters (48 inches) thick were described up to elevations of 2,800 meters (9,200 feet) (Richmond, 1962, p. 38). Averaged annual precipitation amounts for a 22-year weather record at 2,865 meters (9,400 feet) in the La Sal Mountains is 74.48 centimeters (28.93 inches) (Betancourt and Biggar, 1985, BMI/ONWI-570, Table 13-1, p. 103). Precipitation amounts calculated from elevational lapse rates for precipitation (developed from the historic weather data [Betancourt and Biggar, 1985, BMI/ONWI-570, p. 25]) for the other elevations given are 27.2 centimeters (10.1 inches) at 1,890 meters (6,200 feet) and 71.8 centimeters (28.3 inches) at 2,800 meters (9,200 feet). Richmond (1962, p. 124) also observed calcareous coatings on

the underbeds of most rock fragments of a rubble sheet at 3,368 meters (11,050 feet) elevation in the La Sal Mountains. Projected precipitation for this elevation is 119 centimeters (47 inches), although the average annual precipitation shown by Butler and Marsell (1972) for the peak area (elevation 3,875 meters [12,720 feet]) of the La Sal Mountains does not exceed 89 centimeters (35 inches).

Based on Richmond's (1962) observations, prominent calcic soils are observed below 1,890 meters (6,200 feet) where current annual rainfall is less than 27.2 centimeters (10.1 inches) (Betancourt and Biggar, 1985, BMI/ONWI-570, p. 25). These soils have also survived the more pluvial glacial periods without much visible evidence of leaching and carbonate erosion. The cooler, wetter climate of late Pleistocene time resulted in minimum elevational depression of 700 to 850 meters (2,300 to 2,800 feet) of alpine and montane plant species on the southern flank of the Abajo Mountains (Betancourt and Biggar, 1985, BMI/ONWI-570, p. 77). Therefore, the calcic soils observed today at 1,890 meters (6,200 feet) in the La Sal Mountains could likely have been subject to present-day precipitation amounts at 2,590 to 2,740 meters (8,500 to 9,000 feet) elevation. Current precipitation amounts at these higher elevations are 58.1 centimeters (22.9 inches) and 67.7 centimeters (26.7 inches), respectively. Those observations support the theory that precipitation in the vicinity of the site has not exceeded 50 to 70 centimeters (20 to 27.5 inches) during Quaternary time, based on the preservation of calcic soils in the area.

3.2.3 Stratigraphy

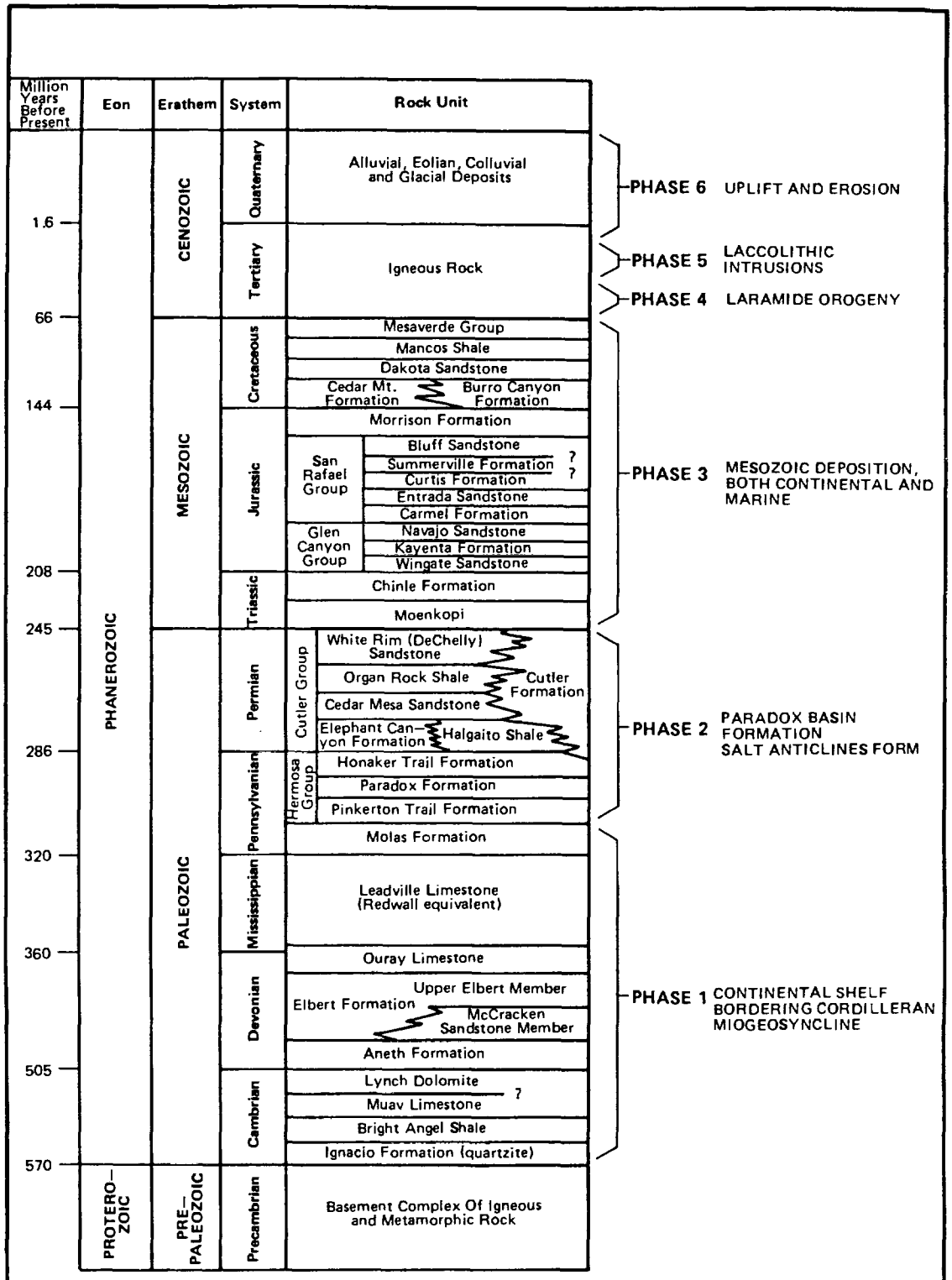
The candidate area and Davis Canyon site (Figure 3-1) are located within the Paradox Basin, a late Paleozoic, elongated, asymmetrical, depositional trough (deeper on the northeast, shallower to the southwest) in southeastern Utah and southwestern Colorado. In order to understand the stratigraphic framework of the candidate area and site, it is helpful to be familiar with the sedimentary and tectonic processes that have operated in the Paradox Basin region through geologic time. These sedimentary and tectonic processes are discussed in Section 3.2.3.1. Sections 3.2.3.1 and 3.2.3.2 discuss the formal stratigraphic subdivisions of the region and site, respectively. In Section 3.3.2.1 (Hydrology and Modeling) the upper Paleozoic stratigraphic section for the western Paradox Basin is tentatively subdivided into hydrostratigraphic units (Table 3-22) for the purposes of discussion.

3.2.3.1 Regional Stratigraphic History of the Paradox Basin

The Phanerozoic stratigraphic history of the Paradox Basin can be divided into six phases (Figure 3-7). Terminology used in this section is generally based on the work of Hintze (1973). The first phase is both the longest and the least eventful. From Cambrian to early Pennsylvanian time, the area that would become the Paradox Basin was part of the continental shelf bordering the Cordilleran miogeosyncline, which was located in western Utah and eastern Nevada. This phase lasted approximately 270 million years and included the deposition of a number of stratigraphic units, mostly in a marine environment.

During the Cambrian, the sea transgressed eastward onto the continental shelf. The resulting deposits, in ascending order, are the Ignacio Quartzite or Sandstone (known as the Tapeats, Tintic, and Prospect Mountain farther to the west); the Bright Angel Shale; the Muav Limestone; and, in the area west of the Green and Colorado Rivers, the Lynch Dolomite (Figure 3-7) (Baars, 1958, p. 100). The top of the Cambrian strata in the Paradox Basin region is an erosion surface.

The Ordovician and Silurian periods were times of nondeposition or slight erosion. Although this time interval was long (approximately 105 million years), the contact between the Cambrian and overlying Devonian rocks is not greatly discordant, indicative of the relative tectonic stability during this time period. It has been described as paraconformable where it is exposed in the San Juan Mountains (Parker and Roberts, 1963, p. 35).



Generalized Composite Stratigraphic Column Paradox Basin

Figure 3-7

The Devonian period is represented by the Aneth, Elbert, and Ouray Formations in the Paradox Basin region, although the upper part of the Ouray is probably Mississippian in age (Parker and Roberts, 1963, p. 41). These units were also deposited in a marine environment on the continental shelf (Parker and Roberts, 1963, p. 45).

The Leadville Limestone (Redwall Limestone in the Grand Canyon region) was deposited during the Mississippian on a broad carbonate shelf. After its deposition, the region was uplifted and exposed to subaerial erosion and weathering, resulting in the development of a red soil and karst topography on the Leadville surface (Armstrong and Mamet, 1976, p. 14). This period of erosion lasted approximately 24 million years (Late Mississippian and Early Pennsylvanian) (Merrill and Winar, 1958, p. 2111). The red soil, which includes chert and solution-rounded limestone clasts, comprises the lower portion of the overlying Molas Formation (Armstrong and Mamet, 1976, p. 4). The Upper Molas Formation records the return of marine deposition to the Paradox Basin region and includes fossiliferous laminated red siltstones, limestones, and sandstones (Merrill and Winar, 1958, p. 2111).

The second phase of the stratigraphic history of the Paradox Basin region includes Middle and Late Pennsylvanian and all of Permian time, and marks the formation and filling of the Paradox Basin (Figure 3-7). The stratigraphic units deposited during this phase include, in ascending order, the Pinkerton Trail Formation, the Paradox Formation, the Honaker Trail Formation, and the Cutler Group. The Pinkerton Trail, Paradox, and Honaker Trail Formations make up the Hermosa Group (Figure 3-7). Following the terminology of Baars et al. (1967, p. 396, Figure 2) and the suggestion of Hite and Buckner (1981, p. 149), the terms Pinkerton Trail and Honaker Trail are appropriate only where the Paradox Formation is also present. Outside the area of evaporite deposition, the name Hermosa Formation is used for the entire sequence (Figure 3-8).

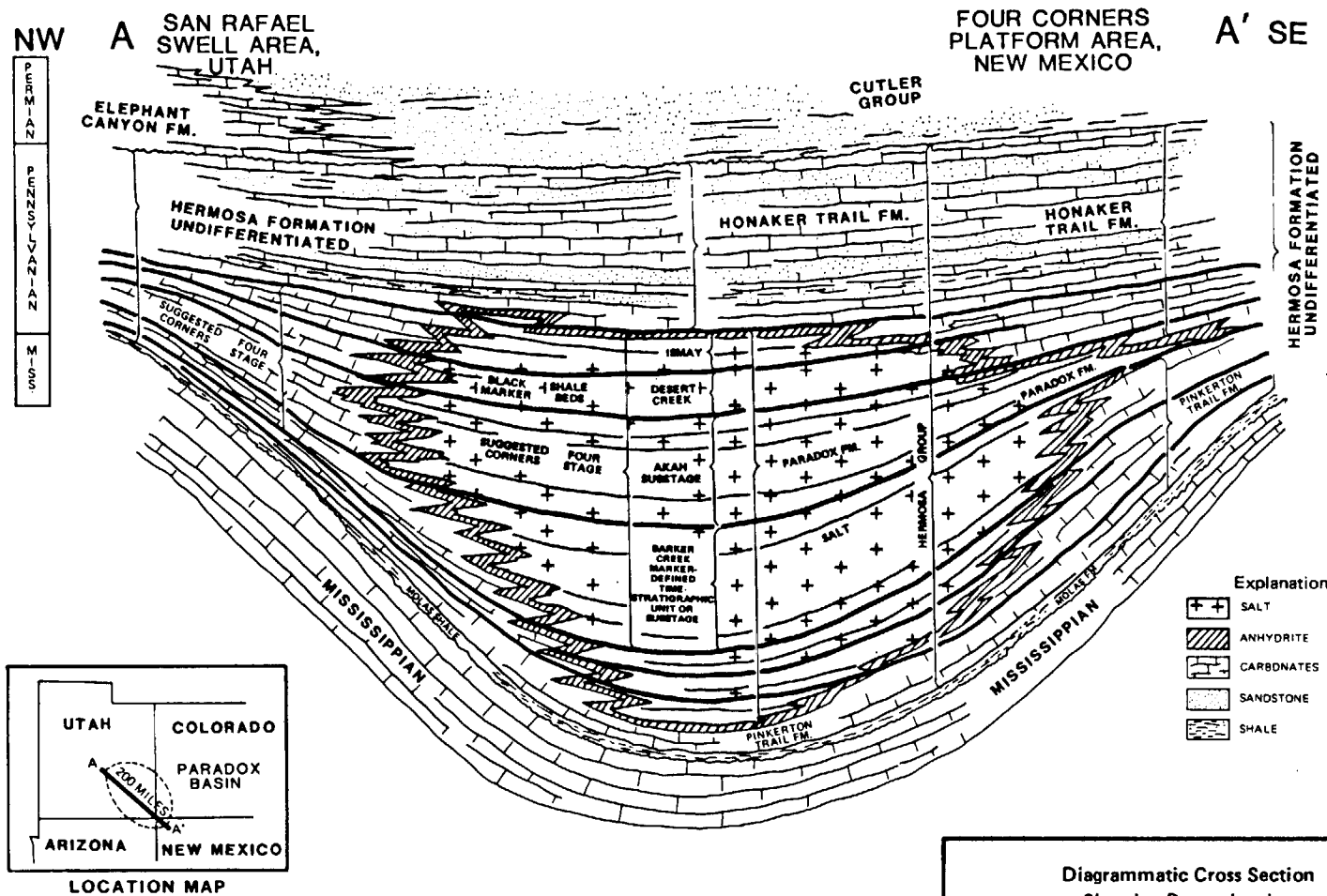
The Hermosa Formation was divided into producing zones by the various oil companies active in the basin. Hite (1960, p. 87) correlated these zones to the numbered cycles in the Paradox Formation (described below and in Section 3.2.3.2) as follows:

Zone	Salt Cycle
Ismay	2 and 3
Desert Creek	4 and 5
Akah	6 through 10
Barker Creek	11 through 19

These zones closely approach time stratigraphic units (substages) and were formally proposed as such by Baars et al. (1967, pp. 400-402). This scheme of nomenclature is workable because the black shale marker beds approximate time lines (Baars et al., 1967, pp. 400-402). This terminology is used in Sections 3.2.8 (Mineral Resources), 3.3.2 (Ground Water), and 6.4.2.3.5 (Ground-Water Flow Paths and Travel Times) where appropriate.

Isopach maps of the Pinkerton Trail and Paradox Formations indicate that the Paradox Basin began forming during Pinkerton Trail deposition but that most of the subsidence was contemporaneous with Paradox Formation deposition (McCleary and Romie, 1985, pp. 41-44, Figures A-7 and A-9). The lithologies of the Pinkerton Trail Formation (limestone, dolomite, dark shale, siltstone, and anhydrite) are indicative of the change from the open marine conditions present during deposition of the upper Molas strata to the restricted marine-evaporite basin conditions present during deposition of the Paradox Formation.

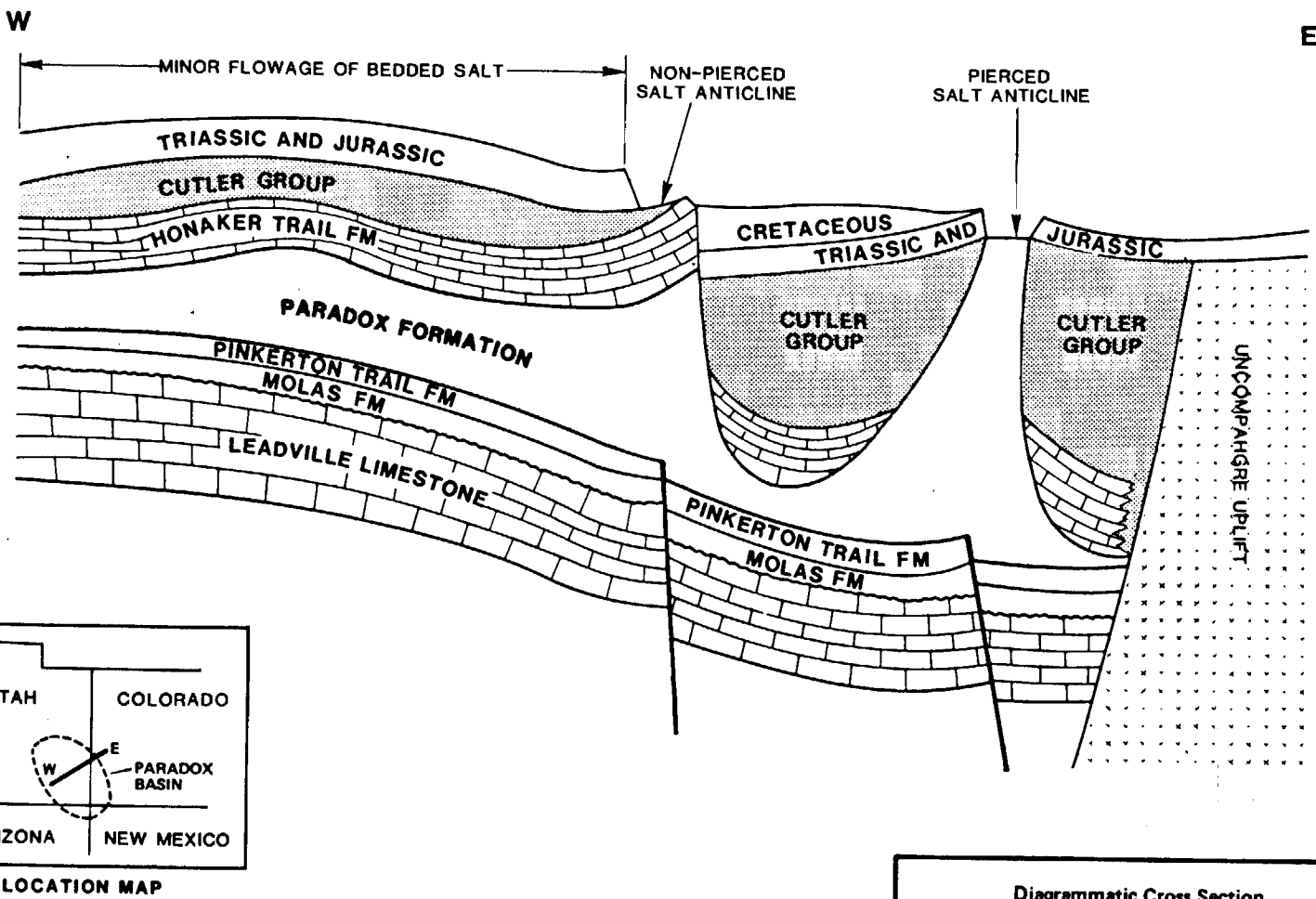
The Paradox Formation consists of approximately 29 salt (evaporite) cycles separated by clastic and carbonate interbed sequences (Hite, 1960, p. 87). Salt (halite) and potash salts were precipitated at low stands of sea level. Rising sea level brought in fresher water and clastic sediments resulting in deposition of interbed sequences. These cyclic sea level changes were probably glacially controlled (Hite and Buckner, 1981, p. 158). The salt is a deep water deposit precipitated from hypersaline sea water (Hite and Buckner, 1981, pp. 151, 156, 157). In the deeper parts of the basin, near the Uncompahgre Uplift (Figure 3-9), the original depositional thickness of the Paradox Formation was approximately 2,130 meters

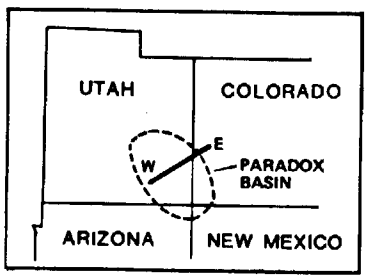


Diagrammatic Cross Section Showing Pennsylvanian Stratigraphic Nomenclature

Source: Baars et al., 1967.

Figure 3-8

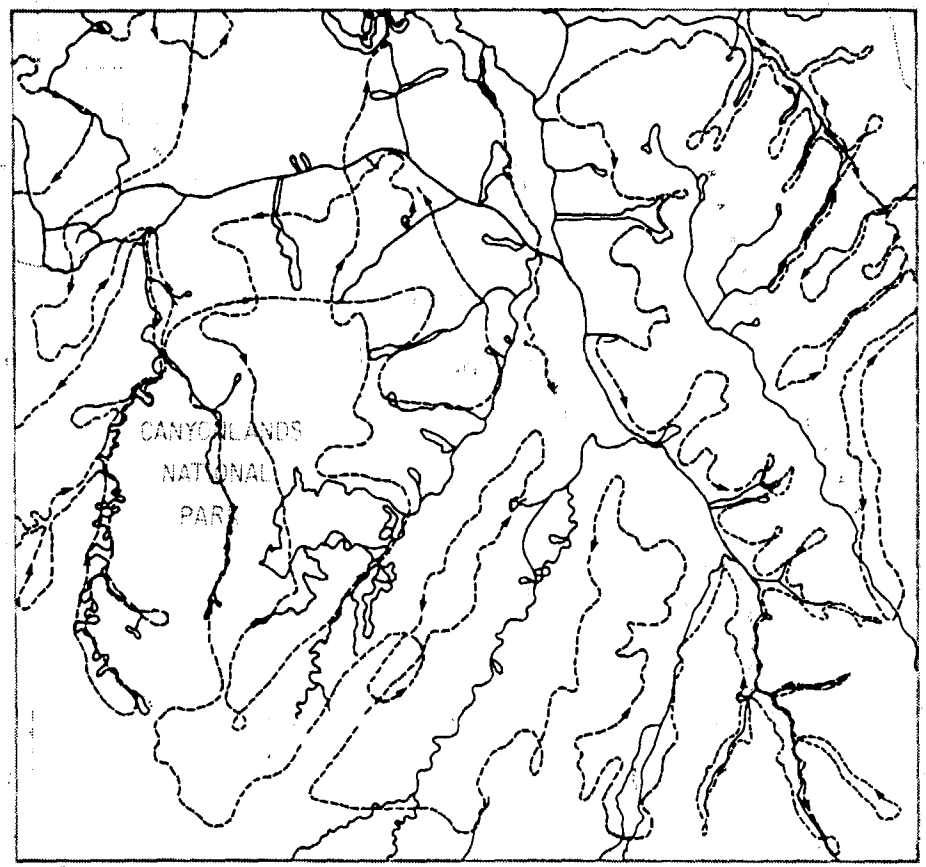


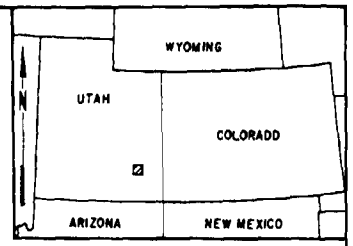


LOCATION MAP

Diagrammatic Cross Section of the Paradox Basin Showing Three Salt Geometries

Figure 3-9





Explanation

Helicopter flight line

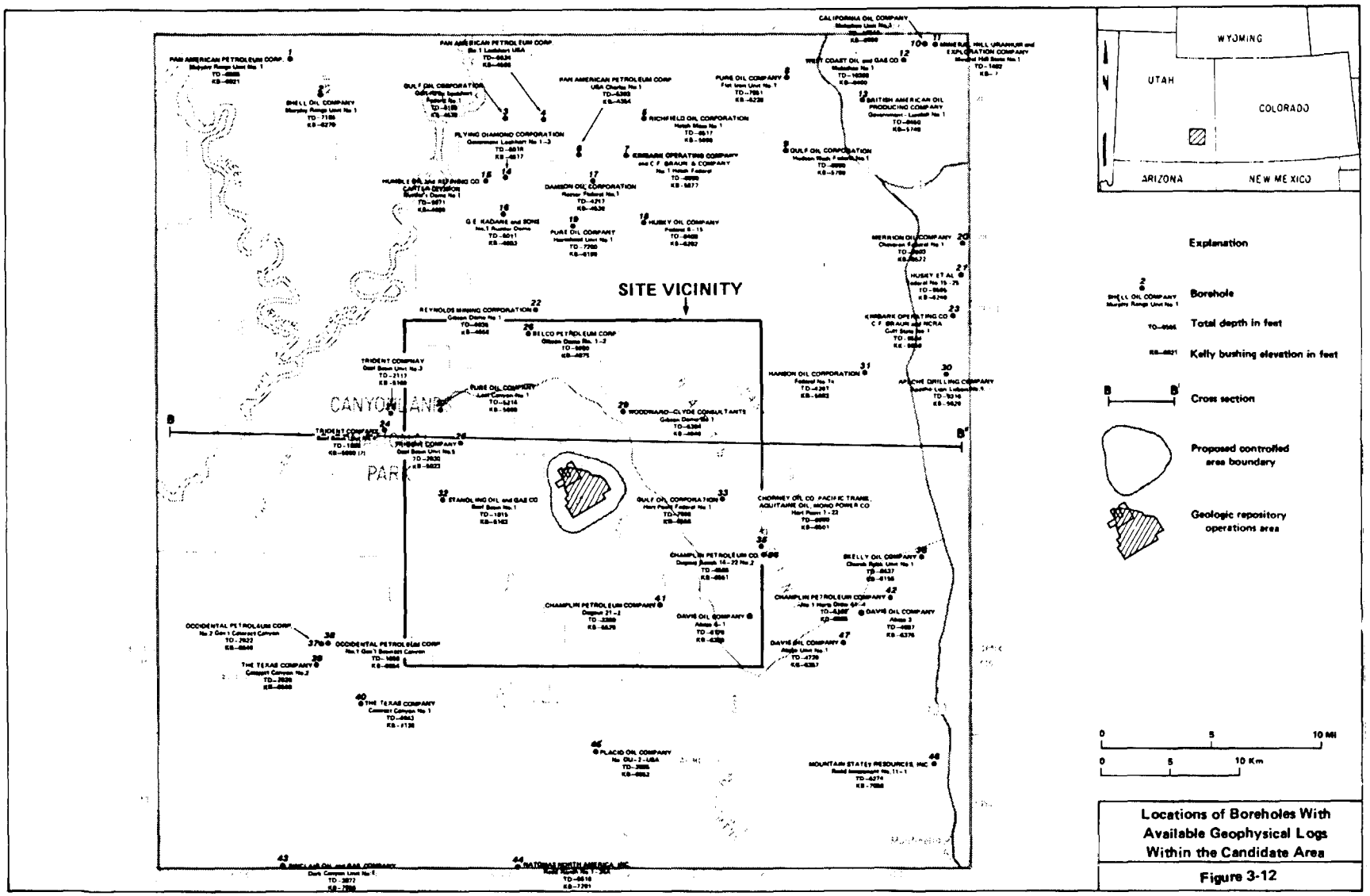
Ground traverse

0 1 2 3 4 MI

0 1 2 3 4 5 Km

Surface Geologic Exploration in the Site Vicinity

Figure 3-11



Locations of Boreholes With Available Geophysical Logs Within the Candidate Area

Figure 3-12

Analysis of this data indicates that the stratigraphy, in terms of recognition of formation contacts, marker beds, and salt cycles, appears to be consistent and traceable for tens of kilometers surrounding the site (Figure 3-13). This is not to imply that all formation properties (e.g., hydrologic properties, or hardness) are consistent across the entire area because there is certainly some variation. It is only the major stratigraphic and lithologic units that are being correlated.

The stratigraphic units predicted to be present within or adjacent to the GROA are described below* and are shown on Figure 3-14. The stratigraphic units that will be penetrated by the shaft extend from the Moenkopi Formation, exposed at the surface, into the salt beds of the Paradox Formation. The proposed repository host rock is Salt Cycle 6 of the Paradox Formation.

3.2.3.2.1 Surficial Deposits. Surficial deposits on the canyon floors consist of unconsolidated cobbles, sand, and silt. At the GROA, these deposits are estimated not to exceed 5 meters (15 feet) in thickness.

3.2.3.2.2 Navajo Sandstone. The Navajo Sandstone is a fine-grained, cross-bedded eolian quartz sandstone that is generally light brown in color. It is approximately 107 meters (350 feet) thick adjacent to the GROA.

3.2.3.2.3 Kayenta Formation. The Kayenta Formation is a fluvial red-bed sequence of sandstone and siltstone with minor claystone and conglomerate. The Kayenta Formation is adjacent to the GROA and is approximately 69 meters (225 feet) thick.

3.2.3.2.4 Wingate Sandstone. The Wingate Sandstone is a thick eolian sandstone that unconformably overlies the Chinle Formation. Adjacent to the GROA it is massive to cross-bedded and columnarly jointed, and is approximately 99 meters (325 feet) thick.

3.2.3.2.5 Chinle Formation. The Chinle Formation consists of mudstone, siltstone, and sandstone with thin limestone lenses. The Chinle Formation is approximately 168 meters (550 feet) thick adjacent to the GROA.

3.2.3.2.6 Moenkopi Formation. The Moenkopi Formation is approximately 114 meters (375 feet) thick in the GROA and is composed primarily of sandstone and siltstone. The Moenkopi Formation has been partially removed by erosion over most of this area.

3.2.3.2.7 Organ Rock Formation. The Organ Rock Formation is composed of red arkosic, poorly sorted sandstones, and siltstones. North of Indian Creek, the Organ Rock Formation merges with the underlying Cutler Formation. In the GROA, the Organ Rock Formation is approximately 49 meters (160 feet) thick. The top of the Organ Rock Formation is estimated to be 9 meters (30 feet) below the ground surface in most of the GROA.

3.2.3.2.8 Cedar Mesa Sandstone. The Cedar Mesa Sandstone conformably overlies the Elephant Canyon Formation. The contact is often gradational in the Davis Canyon site and vicinity. In the Davis Canyon GROA, the formation is approximately 198 meters (650 feet) thick.

The Cedar Mesa Sandstone is a white, light gray, tan, or pale red cross-bedded quartz sandstone with thin interbeds of reddish-brown siltstone. In the general vicinity of Indian Creek, the Cedar Mesa Sandstone changes facies and merges with the Cutler Formation. The top of the Cedar Mesa Sandstone is estimated to be 58 meters (190 feet) below the ground surface in the GROA.

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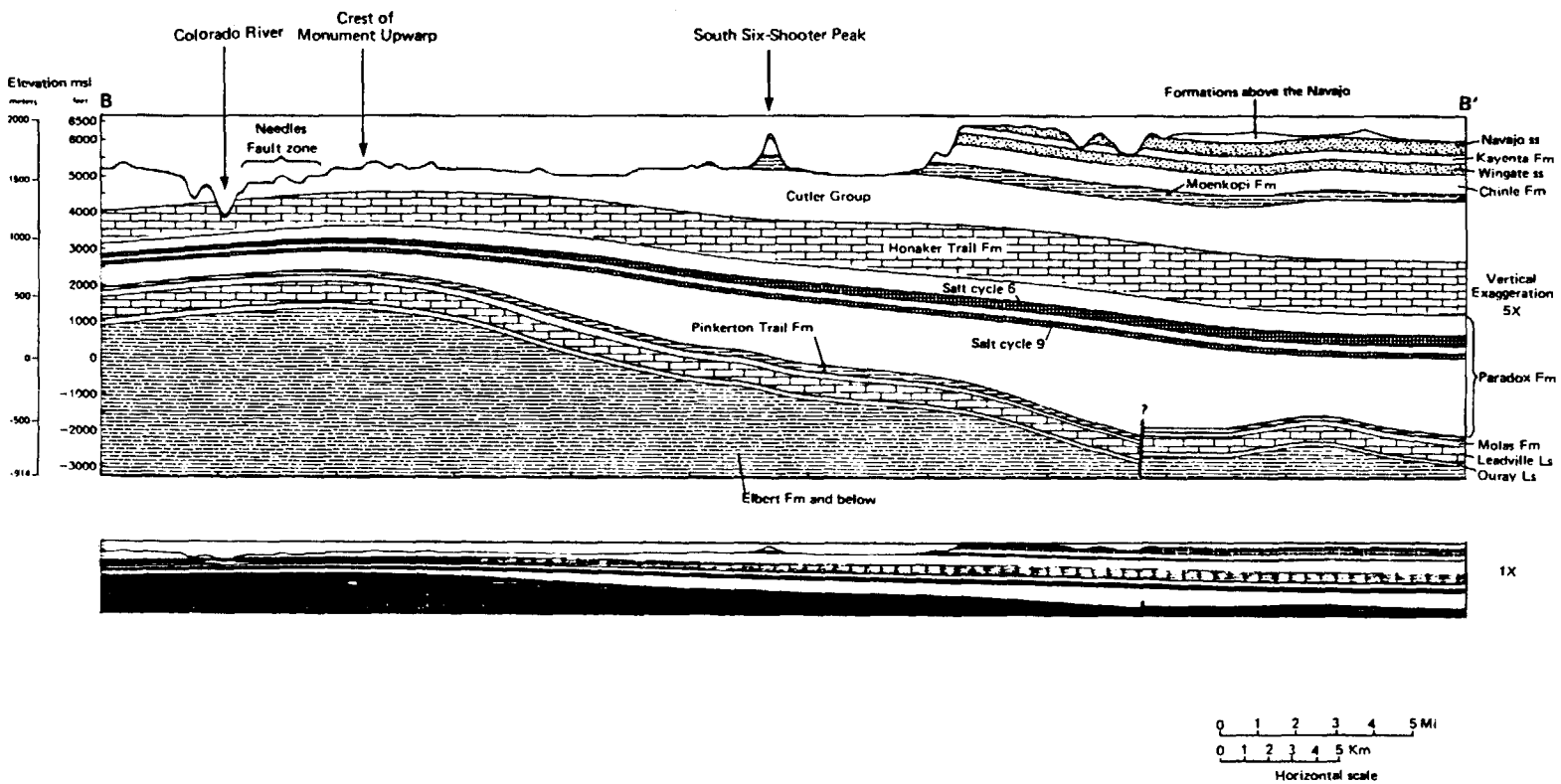
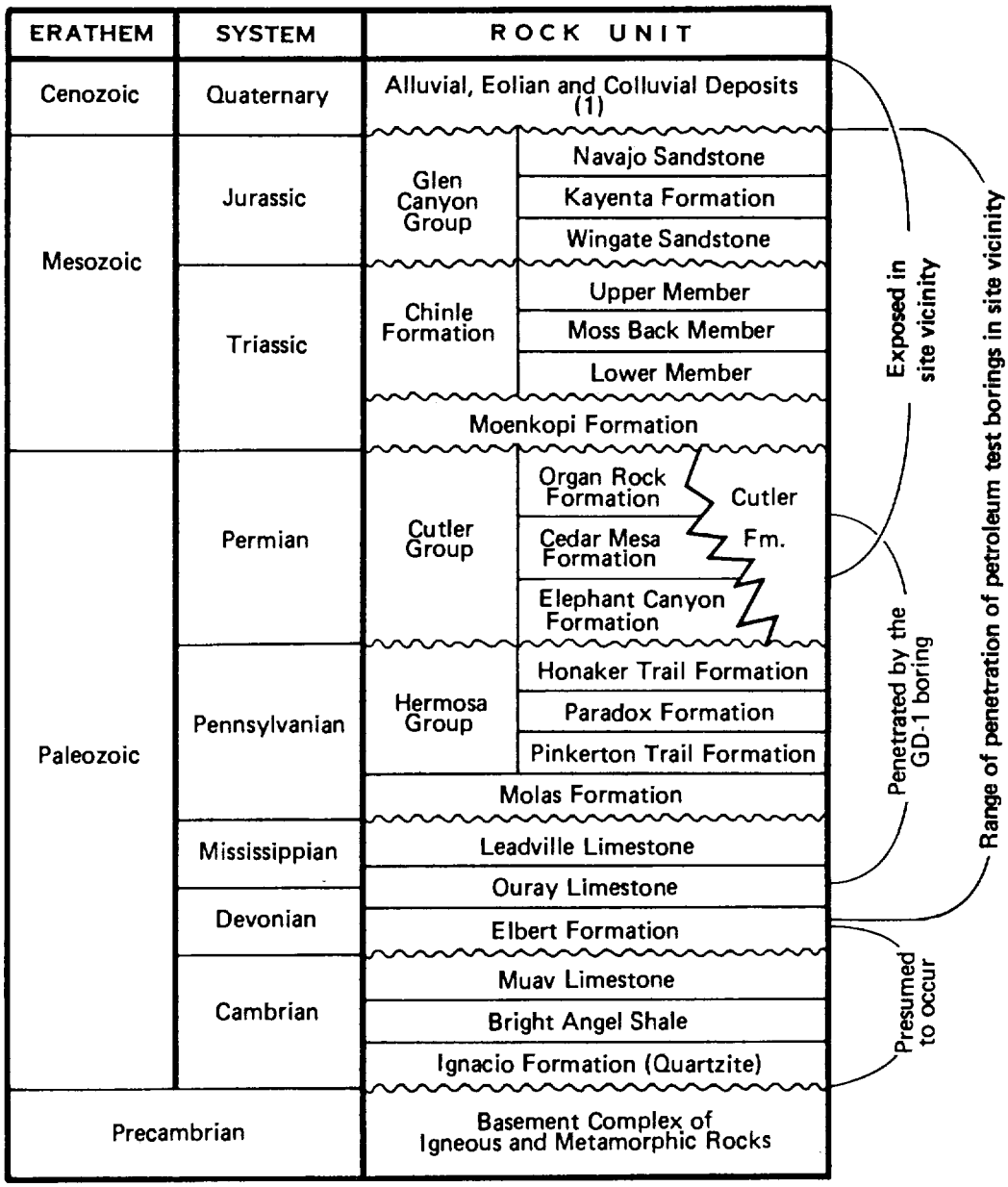
*This discussion is derived from McCleary and Romie (1985) unless otherwise noted.



Note: Refer to Figure 3-12 for location of cross section.

East-West Computer-Generated Cross Section

Figure 3-13



Explanation

(1) Unconformable on all exposed older units

——— Conformable Contact

〰〰 Unconformable Contact

Stratigraphic Column of the Davis Canyon Site

Figure 3-14

3.2.3.2.9 Elephant Canyon Formation. The Elephant Canyon Formation unconformably overlies the Honaker Trail Formation. In the GD-1 borehole it is 171 meters (560 feet) thick; in the Davis Canyon GROA it is approximately 152 meters (500 feet) thick. The formation is comprised of thinly bedded siltstone, sandstone, silty sandstone, silty claystone, and limestone. Most of the clastic materials are calcareous. The top of the Elephant Canyon Formation is estimated to be 256 meters (840 feet) below the ground surface in the GROA.

3.2.3.2.10 Honaker Trail Formation. In the GD-1 borehole the Honaker Trail Formation is 420 meters (1,379 feet) thick, and consists of limestone, sandstone, silty and sandy limestone, calcareous siltstone and claystone, oolitic limestone, dolomite, and cherty limestone. In the GROA the formation is approximately 343 meters (1,125 feet) thick. Limestone containing varying amounts of clastic material, chert, and fossils comprises approximately 85 percent of the formation. Most of the cherty limestone is in the lower third of the formation. The top of the Honaker Trail Formation is estimated to be 408 meters (1,340 feet) below the ground surface at the GROA.

3.2.3.2.11 Paradox Formation. The Paradox Formation is 881 meters (2,889 feet) thick in the GD-1 borehole; approximately 68 percent is salt (halite). The remainder is composed of anhydrite, dolomite and silty dolomite, limestone, siltstone, and shale. In the Davis Canyon GROA, the Paradox Formation is approximately 762 meters (2,500 feet) thick. The salt occurs in distinct cycles separated by interbed sequences (Hite, 1960, p. 87, Figures 1 and 2) of anhydrite, carbonate, and clastic rock. Interbeds between individual salt cycles in the Paradox Formation are particularly distinctive and can be traced over almost the entire basin (Hite, 1960, p. 86). Hite (1960, p. 86) numbered the salt cycles in the Paradox Basin from 1 (youngest) to 29 (oldest). In the GD-1 borehole the oldest (deepest) salt cycle encountered was Salt Cycle 26. Older salt cycles (27-29) were deposited to the northeast in the deeper part of the Paradox Basin. The thickness of individual salt beds in the GD-1 borehole ranges from 2 meters (6 feet) for Salt Cycle 26 to 105 meters (346 feet) for Salt Cycle 18; Salt Cycles 1 to 3, 11, 12, and 23 contain only anhydrite or were never deposited in this area. The basin never dried up during Paradox deposition; the salt is a deep water deposit precipitated from hypersaline sea water (Hite and Buckner, 1981, pp. 151, 156, 157).

The upper 17 meters (56 feet) of the Paradox Formation are a dark gray calcareous siltstone. This lithology was used to identify the top of the Paradox Formation in the GD-1 borehole. It is gradational to the overlying Honaker Trail Formation limestones, representing the change from the hypersaline environment in which the Paradox Formation was deposited to the marine environment in which the Honaker Trail Formation was deposited. The top of the Paradox Formation is estimated to be 752 meters (2,465 feet) below the ground surface at the GROA.

3.2.3.2.12 Pinkerton Trail Formation. The Pinkerton Trail Formation is composed of siltstone, shale, limestone, dolomite, and anhydrite. It is 63 meters (208 feet) thick in the GD-1 borehole and approximately 61 meters (200 feet) thick in the GROA. The top of the Pinkerton Trail Formation is estimated to be 1,574 meters (4,965 feet) below the ground surface of the GROA.

3.2.3.2.13 Molas Formation. The base of the Molas Formation is a paleosol or paleokarst formed on the Leadville Limestone surface. In the GD-1 borehole, this interval extends from the base of the formation at 1,786.5 meters (5,861.2 feet) to at least 1,768.3 meters (5,801.6 feet), which is the start of a core-loss interval; the clastic portions of this interval appear to be regolithic breccias that filled cavities in the Leadville Limestone. The upper part of the formation is composed of marine limestone and siltstone (Merrill and Winar, 1958, p. 2111, Figure 2). The Molas Formation is approximately 46 meters (150 feet) thick in the GROA and 45 meters (147 feet) thick in the GD-1 borehole. The top of the Molas Formation is estimated to be 1,575 meters (5,165 feet) below the ground surface of the GROA.

3.2.3.2.14 Leadville Limestone. The Leadville Limestone is approximately 145 meters (475 feet) thick in the GROA, and is 143 meters (470 feet) thick in the GD-1 borehole; it is composed primarily of limestone and dolomite. The top of the Leadville Limestone is estimated to be 1,620 meters (5,315 feet) below the ground surface of the GROA.

3.2.3.2.15 Ouray Limestone. The Ouray Limestone of Devonian and Mississippian age overlies the Elbert Formation. It is approximately 46 meters (150 feet) thick in the GROA and is composed of limestone with thin shale beds at the top and bottom. The top of the Ouray Limestone is estimated to be 1,765 meters (5,790 feet) below the ground surface.

3.2.3.2.16 Elbert Formation. The Elbert Formation of Devonian age unconformably overlies the Cambrian in the Davis Canyon site. It is estimated to be approximately 76 meters (250 feet) thick in the Davis Canyon GROA (McCleary et al., 1983, ONWI-485, Figure A-1) and is composed of limestone, siltstone, and sandstone with minor shale. The top of the Elbert Formation is estimated to be 1,811 meters (5,940 feet) below the ground surface.

3.2.3.2.17 Muav Limestone. The Muav Limestone, estimated to be approximately 91 meters (300 feet) thick in the GROA is composed primarily of limestone. The top of the Muav Limestone is an erosion surface (Baars, 1958, p. 100, Figure 4) and is the highest Cambrian unit in the GROA. The top of the Muav Limestone is estimated to be 1,887 meters (6,190 feet) below the ground surface.

3.2.3.2.18 Bright Angel Shale. The Bright Angel Shale, estimated to be approximately 122 meters (400 feet) thick in the GROA, conformably overlies the Ignacio Formation and is composed of shale and limestone. The top of the Bright Angel Shale is estimated to be 1,979 meters (6,490 feet) below the ground surface.

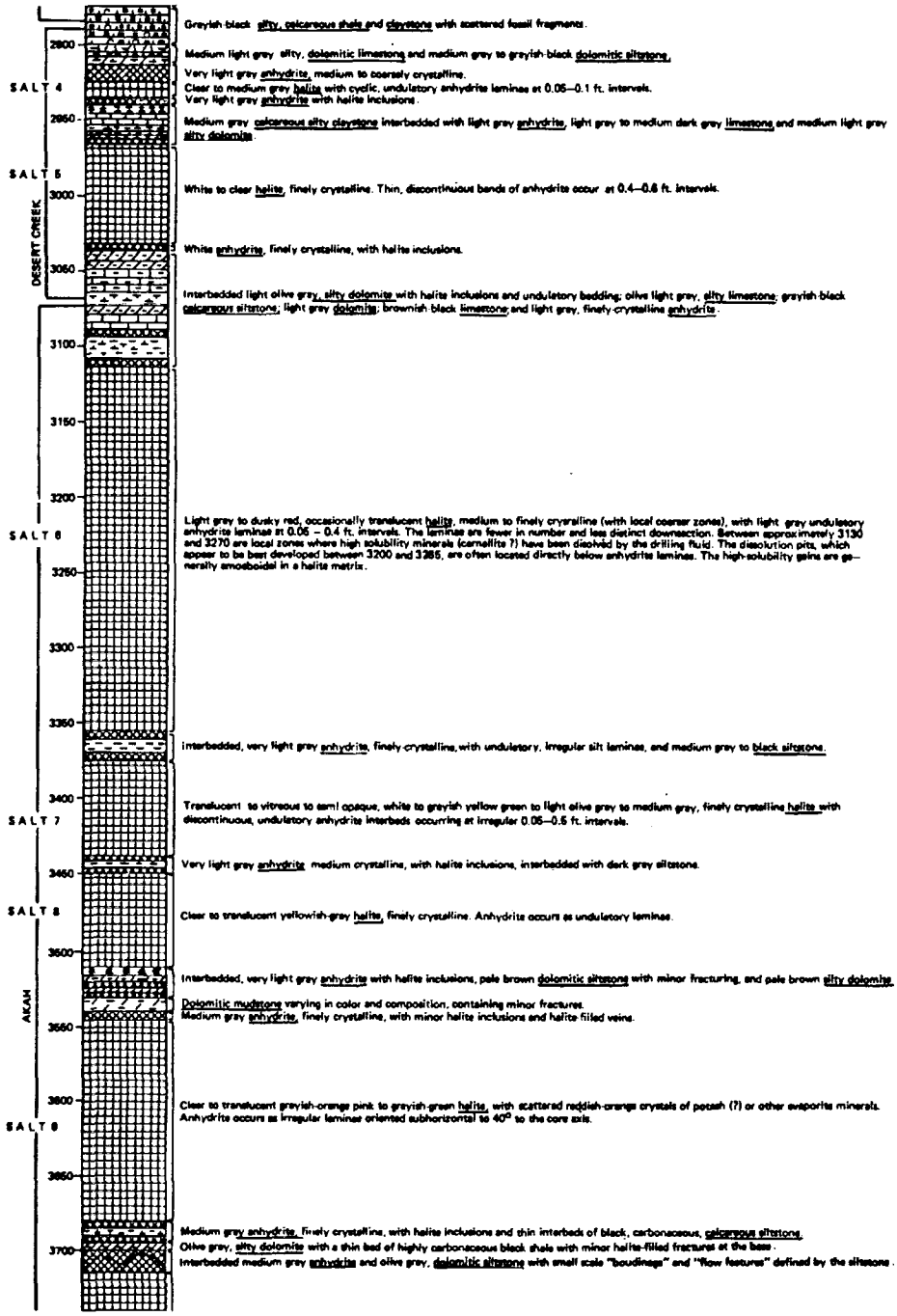
3.2.3.2.19 Ignacio Formation. The Ignacio Formation is the basal Cambrian sandstone in the GROA. It is not penetrated by any borings in the site or Davis Canyon candidate area, but is estimated to be approximately 61 meters (200 feet) thick based on regional relationships (Baars, 1958, Figure 2). The top of the Ignacio Formation is estimated to be 2,101 meters (6,890 feet) below the ground surface.

3.2.3.3 Thickness, Lateral Extent, and Characteristics of the Host Rock

The host rock for the proposed repository in Davis Canyon is the Pennsylvanian Paradox Formation. Like Pennsylvanian deposits in many parts of the world, the Paradox Formation is cyclically bedded. Hite (1970, p. 335) related the salt cycles to transgressive and regressive sea-level changes. When sea level was at maximum and fine clastics were being carried into the basin, dark shales and siltstones were deposited. During the regressive phase, first dolomite, then anhydrite, and finally halite were deposited. If salinities increased enough during the regressive phase, potash salts (more soluble than halite), were also deposited. The transgressive phase, initiated by a major rise in sea level, was relatively rapid and resulted in freshening in the evaporite basin and dissolution of the last-deposited halite on potash salts. Over this disconformity, first anhydrite, then dolomite and fine clastics were deposited (Hite, 1972, p. 335), completing the cycle. (A log of some of the salt cycles cored in the GD-1 borehole is shown in Figure 3-15.) Because of this depositional sequence, potash salts, when they are present, are generally located near the top of the salt cycle. In the GD-1 borehole Salt Cycles 18 and 13 contain sylvite (KCl) in their upper parts. Salt Cycle 6 contains carnallite, a complex hydrated potash mineral, in its middle and upper portion.

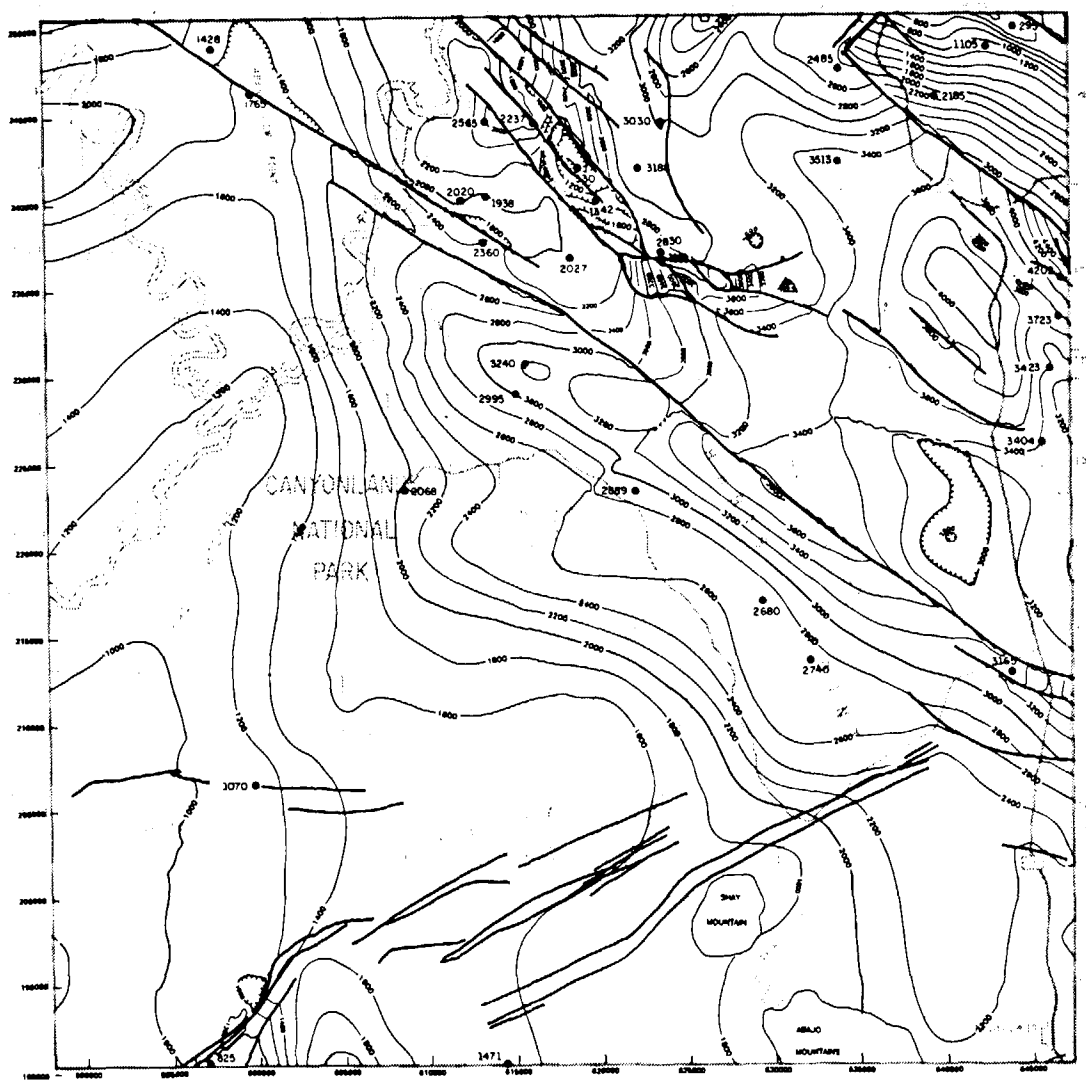
As the basin filled up, its geometry changed; each salt cycle has a somewhat different depositional extent that was probably influenced by bottom topography, particularly in the lower cycles. For example, it appears that the area of the Monument Upwarp was relatively higher than the area around Gibson Dome because the lowest (earliest) salt cycle deposited on the Upwarp was Salt Cycle 16 (wells 37, 43, and 44 on Figure 3-12), while the lowest salt cycle around Gibson Dome was 25 or 26 (wells 22, 26, and 29). The lowest salt cycle in well 27 (Figure 3-12), which is located between the dome and the Upwarp, is Salt Cycle 21. The data suggest, then, that the major thinning of the Paradox Formation south of Gibson Dome (Figure 3-16) is a depositional thinning caused by basin topography or differential subsidence.

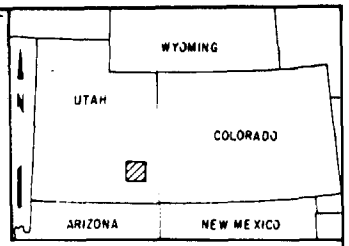
Though of relatively minor significance compared to thinning from the bottom, the Paradox Formation also thins from the top in the candidate area. In well 29 (Figure 3-12) there was salt present in Salt Cycle 4 but only anhydrite is present in well 35 and to the south. In



Portion of the Gibson Dome No.1 (GD–1) Lithologic Log

Figure 3-15





Explanation

Isopach. Contour interval: 200 feet

Well data point

2027 Thickness in feet

Faults from both Leadville and Paradox Formation Structure Contour Map

Source: McCleary and Romie, 1985.

0 5 10 MI

0 5 10 Km

Isopach Map of the Paradox Formation

Figure 3-16

general, Salt Cycles 6 through 19 have large areal extents while 1 through 5 and 20 through 29 are more restricted (Hite, 1970, p. 334, Figure 4). Figure 3-17 is an isopach map showing the interval between the top of the Paradox Formation and the top of Salt Cycle 6.

The thickness of the Paradox Formation is influenced not only by deposition but by later salt flow, and dissolution as well. Gibson Dome, for example, is indicated by approximately 200 meters (650 feet) of thickening in the Paradox Formation (Figure 3-16). Of this thickening, 60 to 75 meters (200 to 250 feet) is due to salt flow and the remainder is caused by additional deposition in the syncline on the underlying Pinkerton Trail Formation surface (McCleary and Romie, 1985, Figures A-8 and A-10). Salt flow has caused major thickness changes in the northeast part of the candidate area (Figure 3-16) where measured thickness in wells ranges from 90 to 1,281 meters (295 to 4,202 feet). Salt dissolution in Lockhart Basin has reduced the Paradox Formation thickness to only 162 meters (530 feet) (Figure 3-16). It is notable that areas of rapidly changing Paradox Formation thickness often coincide with potentially favorable petroleum exploration targets, so drill hole density is often higher in these areas. For example, Gibson Dome itself is a classic structural trap with approximately 75 meters (250 feet) of closure that attracted exploration efforts as early as 1927. Seismic reflection surveys done in the late 1950s and early 1960s suggest complex structural relationships and potential petroleum traps in the Leadville Limestone underlying Lockhart Basin, so exploration boreholes are fairly dense in this area.

There are depositional pinch outs in cycles above 5 and below 16 within the candidate area and perhaps within the site vicinity. Using the salt cycle thickness encountered in the GD-1 borehole as a guide, only Salt Cycles 6, 9, 10, 13, and 16 are 30 meters (100 feet) or more in thickness. The only two cycles that are of an adequate thickness and at an appropriate depth (less than 1,067 meters [3,500 feet], as discussed by BGI and WCC [1982, ONWI-291, pp. 4-5]) are Salt Cycles 6 and 9. Because Salt Cycle 6 is both thicker and higher in the section than Salt Cycle 9, it potentially offers more design flexibility. Therefore, this discussion is directed at Salt Cycle 6 (Figures 3-18 and 3-19).

A structure contour map on top of the Paradox Formation is shown on Figure 3-20. Major features include the Monument Upwarp, which dominates the southwestern quarter of the candidate area; Gibson Dome, just north and east of the Upwarp; Lockhart Basin, a salt dissolution feature in the north-central part of the area; and the Coyote Wash syncline, a major salt flowage feature in the northeast corner of the candidate area.

Within the Davis Canyon site vicinity, Salt Cycle 6 ranges in thickness from approximately 21 meters (70 feet) in the upper Salt Creek area to approximately 82 meters (270 feet) on the Gibson Dome structure (Figure 3-19). At the GROA in Davis Canyon, Salt Cycle 6 is expected to be approximately 61 meters (200 feet) thick. These thicknesses are based on known thicknesses of the cycle from geophysical logs of petroleum exploration borings in the candidate area (Figure 3-19); surface mapping, which provides information on the size and orientation of features such as Gibson Dome; and known depositional trends such as the southwestward thinning of both the Paradox Formation as a whole and individual salt cycles. Within the site vicinity five borings penetrate the full thickness of Salt Cycle 6. Thickness values, interpreted from geophysical logs in these borings, range from 52 to 77 meters (172 to 252 feet).

Thin undulatory anhydrite bands occur in the salt cycles of the Paradox Formation. In Salt Cycle 6, two different types of bands are present. In the upper part of the salt bed, particularly in the carnallite marker (discussed below), the anhydrite bands are approximately 0.3 centimeter (0.125 inch) thick and are composed of fairly dense, laminar anhydrite. In the lower part of the cycle the anhydrite bands are thicker, approximately 2.5 centimeters (1 inch) thick and composed of anhydrite sand in a halite matrix. Considering the Paradox Formation as a whole, the bands composed of anhydrite sand in a halite matrix are most abundant. Band spacing in Salt Cycle 6 ranges from 1 to 10 centimeters (0.4 to 4 inches). Even though the anhydrite bands are very distinctive as observed in the core, anhydrite comprises only a small percentage of the rock. For example, between the depths of 950.5 and 997.9 meters (3,118.6 and 3,274.0 feet) in Salt Cycle 6 anhydrite content ranges between 1.42 percent and 6.71 percent with an average of 2.56 weight percent (Hite, 1983, Table 1).

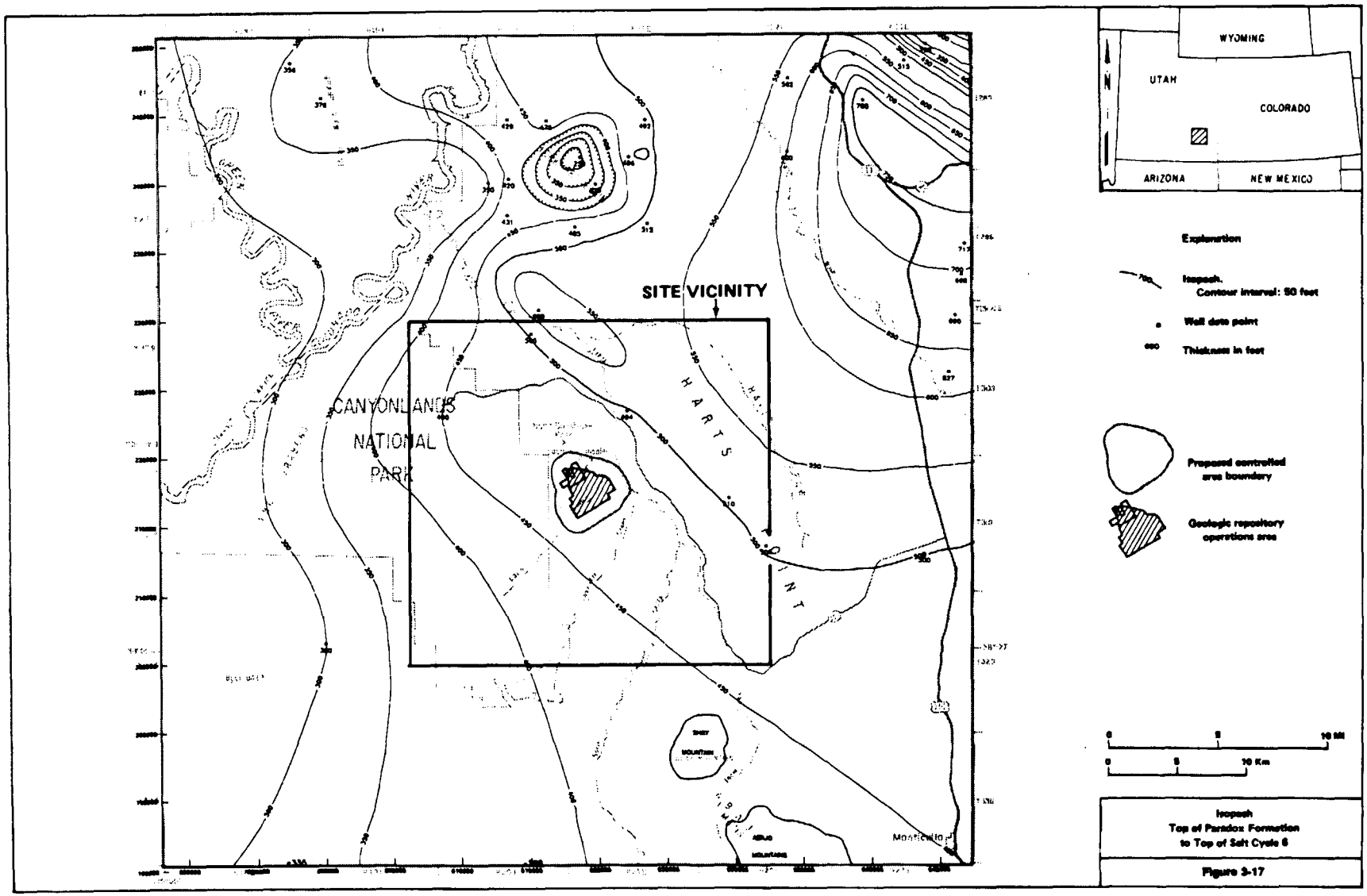
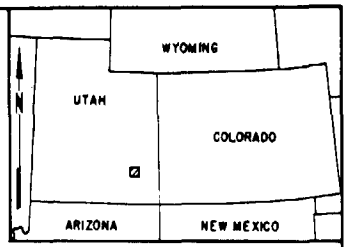

SITE VICINITY
CANYONLANDS NATIONAL PARK
HARTS POINT
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
N
Explanation
Isopach. Contour interval: 50 feet
Well data point
Thickness in feet
Proposed controlled area boundary
Geologic repository operations area
0 5 10 Mi
0 5 10 Km
Isopach
Top of Paradox Formation
to Top of Salt Cycle 6

Figure 3-17



Explanation

Contour indicating depth below ground surface (contour interval 100 feet)

Shaded area is 3500 feet or less below gound surface

Proposed controlled area boundary

Geologic repository operations area

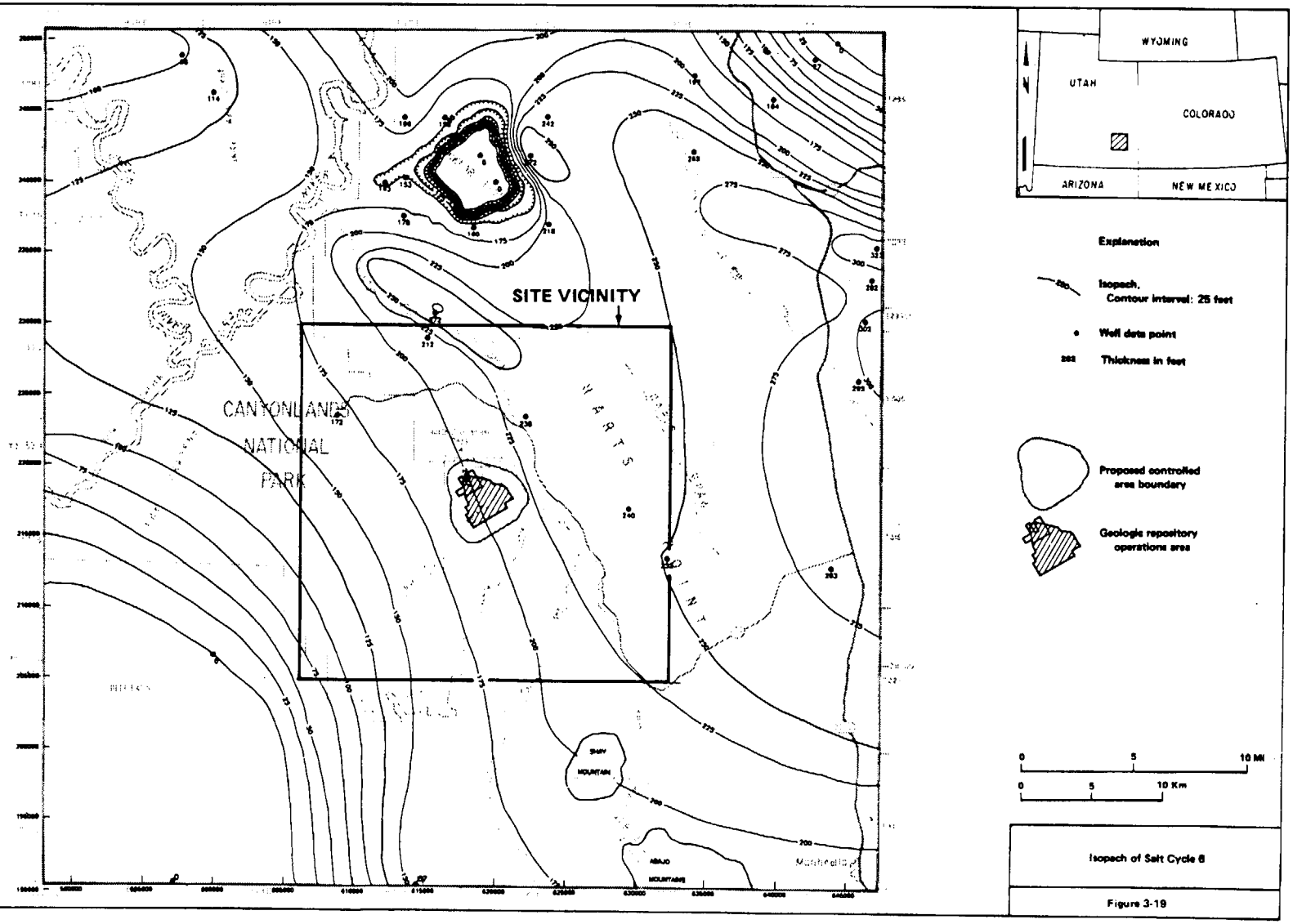
Note: Computer mapping software generates contours between very closely spaced grid cells. In some instances, numerical values in adjacent grid cells result in contours which are very angular or appear to close or cross. This appearance is an artifact of the contouring process combined with photo reduction from plot scale. Data and resulting contours are considered accurate to 125 meters in plan.

0 1 2 3 4 MI

0 1 2 3 4 5 Km

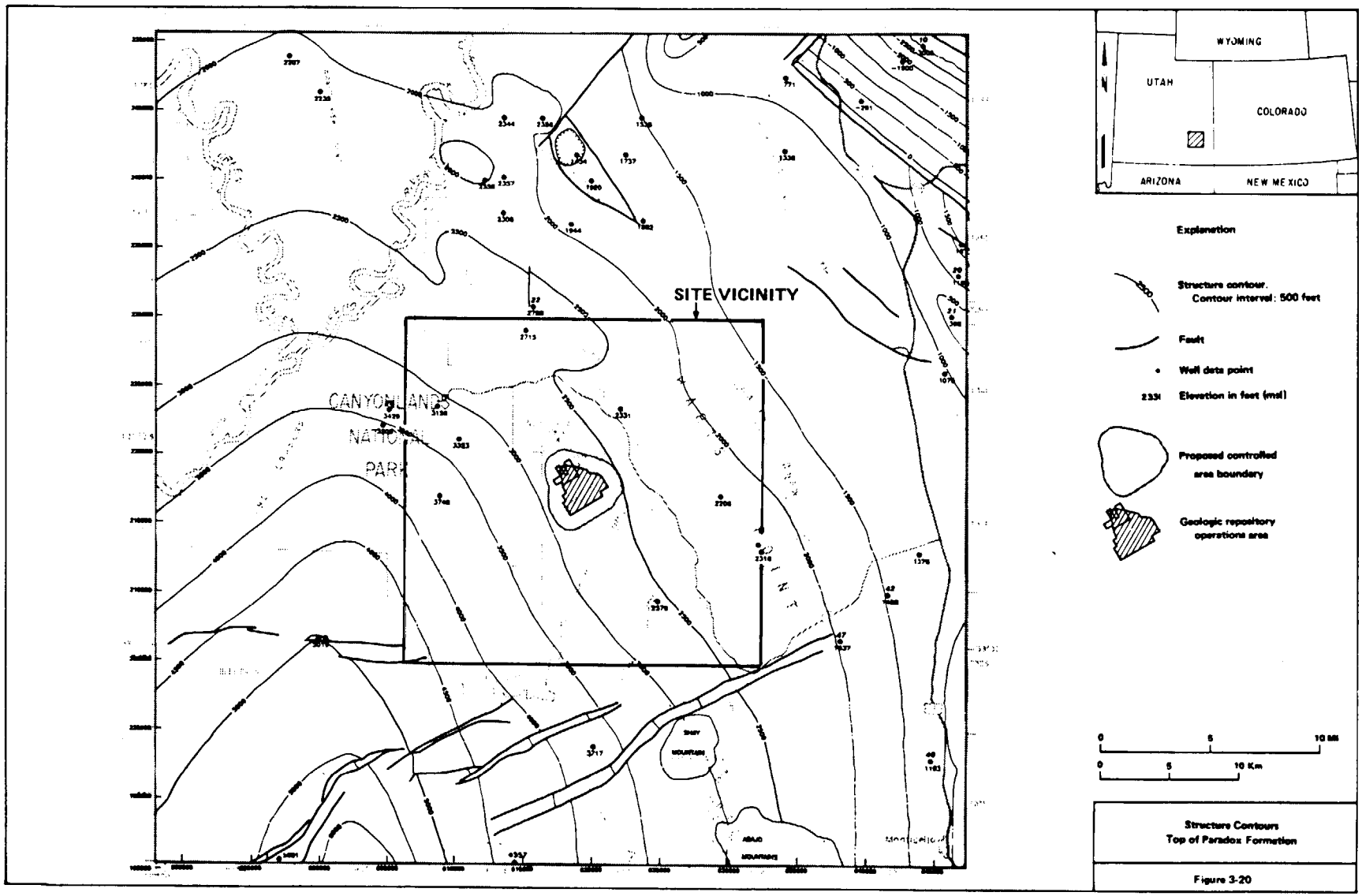
Depth to Salt Cycle 6
Davis Canyon Site Vicinity

Figure 3-18



Isopach of Salt Cycle 6

Figure 3-19



Structure Contours
Top of Paradox Formation

Figure 3-20

The carnallite marker is easily recognized on geophysical logs (gamma logs) of boreholes because the potassium in the mineral causes a slight gamma response, approximately 10 API (American Petroleum Institute) units in the GD-1 borehole. This gamma signature can be correlated between boreholes. An isopach map of the carnallite marker is presented in Figure 3-21. On the gamma log of the GD-1 borehole, the carnallite marker occurs between 975 and 995 meters (3,200 and 3,265 feet) below the kelly bushing (Figure 3-22). The carnallite content in this interval ranges from 1.63 to 7.81 percent (Hite, 1983, Table 1) and averages 4.94 percent by weight. The analysis of the GD-1 core indicates that carnallite is present from near the top of Salt Cycle 6, at (950.5 meters [3,118.6 feet]), down to, at least, the base of the geophysically defined carnallite marker. Carnallite content in the interval from 950.5 to 975 meters (3,118.6 to 3,200 feet) ranges from 0.21 to 4.62 percent and averages 2.00 weight percent. Carnallite (potassium) content below 995 meters (3,265 feet) falls off rapidly to very low values (Hite, 1983, Figure 43). The Davis Canyon site is at or near the depositional limit of potash shown by Hite (1961, p. D-136), so the carnallite content is expected to be lower there than at the GD-1 borehole. Figure 3-21, an isopach map of the carnallite marker in Salt Cycle 6, shows that the site is near the limit of carnallite deposition as detected in borehole geophysical logs. At this time, however, the exact limit of potash deposition (the zero isopach) is not well defined. In an effort to estimate the appropriate percentage of carnallite in the carnallite marker within the candidate area, a correlation was made between the intensity of the gamma response in the carnallite marker and the known carnallite content in the GD-1 borehole. As illustrated on Figure 3-23, carnallite content decreases toward the southwest.

Under expected repository thermal conditions, carnallite may undergo hydrometamorphic reactions such as dehydration and transformation to other mineral phases. The maximum amount of brine expected to be generated through carnallite dehydration is discussed in Section 3.2.7.1. Possible transformation reactions to other mineral phases and associated impacts on repository performance are discussed in Sections 6.3.1.2.2 and 6.3.1.2.3.

3.2.4 Paleontology

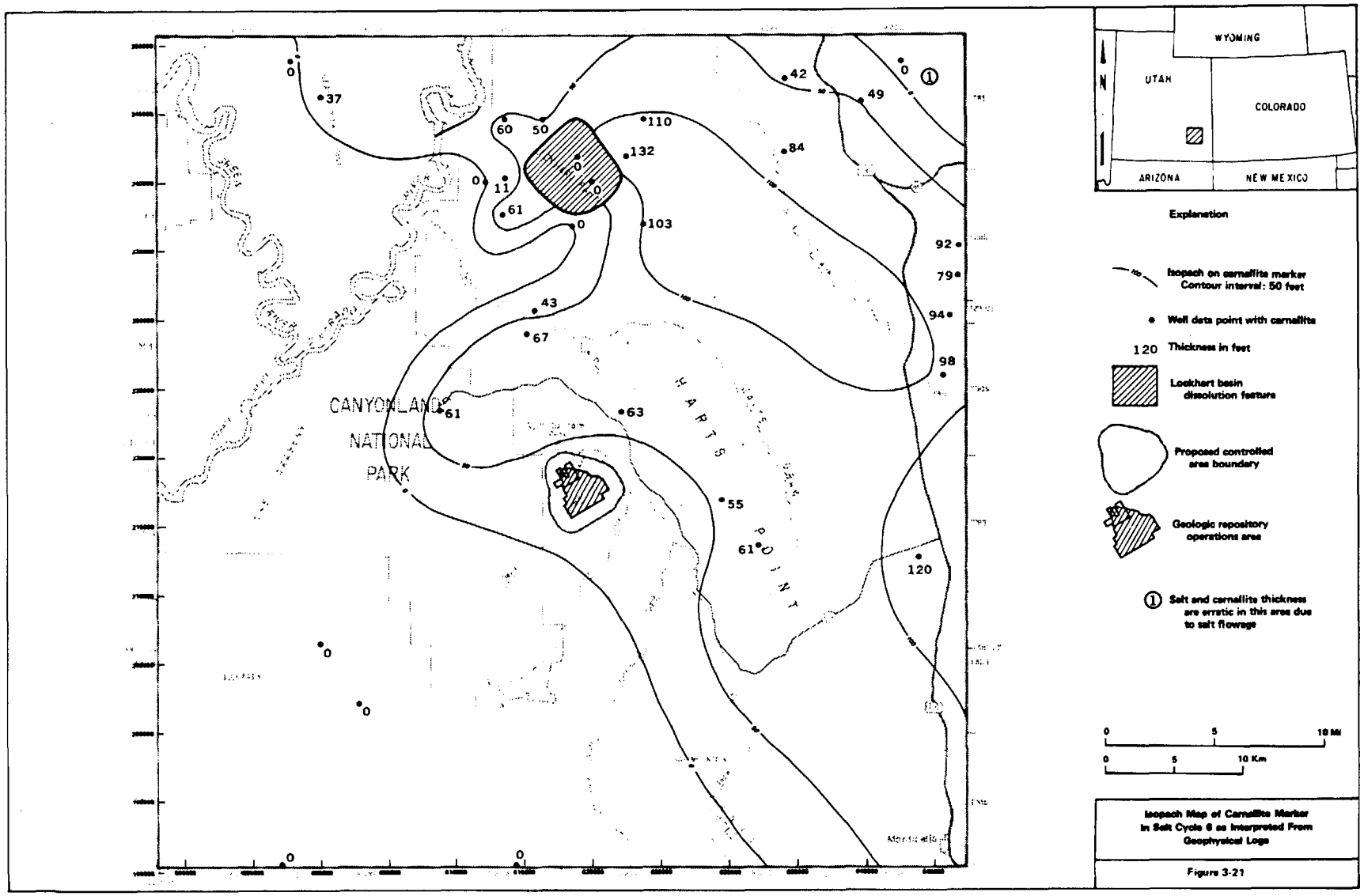
The paleontological resources in the Davis Canyon candidate area are considered in terms of the individual formations that may be impacted by exploration or construction activities. Each formation could be rated relative to its potential paleontological resources. For example, if a formation has produced a large number of important fossils, its resource potential would be high. If it has produced a low number of unimportant fossils (e.g., indistinct worm trails) its resource potential would be low. All other possibilities would be evaluated as moderate, such as a large number of low value fossils.

Within the candidate area, exposed formations range from the Pennsylvanian Paradox Formation to the Mancos Shale, plus scattered Quaternary deposits and Tertiary igneous rocks. The formations that are considered to have a high paleontological resource potential are the Dakota Sandstone, the Morrison Formation, the Chinle Formation, and the Honaker Trail Formation. The Mancos Shale and Burro Canyon Formation are considered to have a high to moderate resource potential, and the Summerville Formation and Wingate Sandstone are considered to have a low resource potential. All other formations in the area have a moderate paleontologic resource potential. These ratings are based on the work of Robison (1977), who conducted a paleontological inventory of existing data for the Bureau of Land Management, Moab district.

3.2.5 Structure and Tectonics

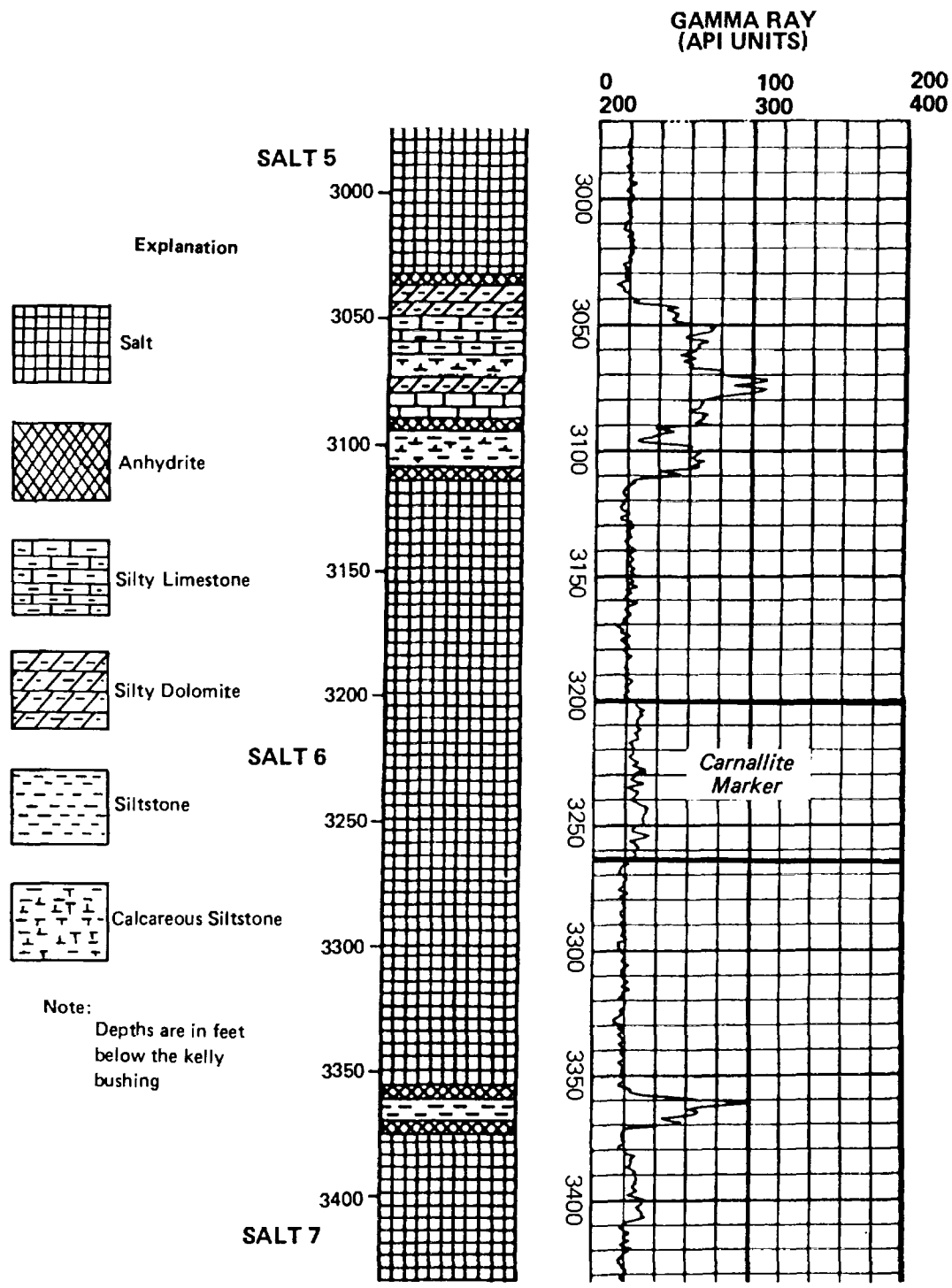
The Davis Canyon candidate area is located within the Colorado Plateau tectonic province (WCC, 1982, ONWI-290, Vol. I, p. 7-39) which has maximum dimensions of 770 and 640 kilometers (480 and 400 miles) in the north-south and east-west directions, respectively.

The Plateau interior is characterized by low heat flow, few Cenozoic magmatic centers, a thick crust, low incidence of surface faulting, a low to moderate level of seismicity, and a thick cover of Phanerozoic sedimentary rocks overlying the Precambrian crystalline basement (Thompson and Zoback, 1979, p. 149; Keller et al., 1979, p. 131). The most significant structures in the sedimentary rocks near the candidate area are monoclinal folds that possibly



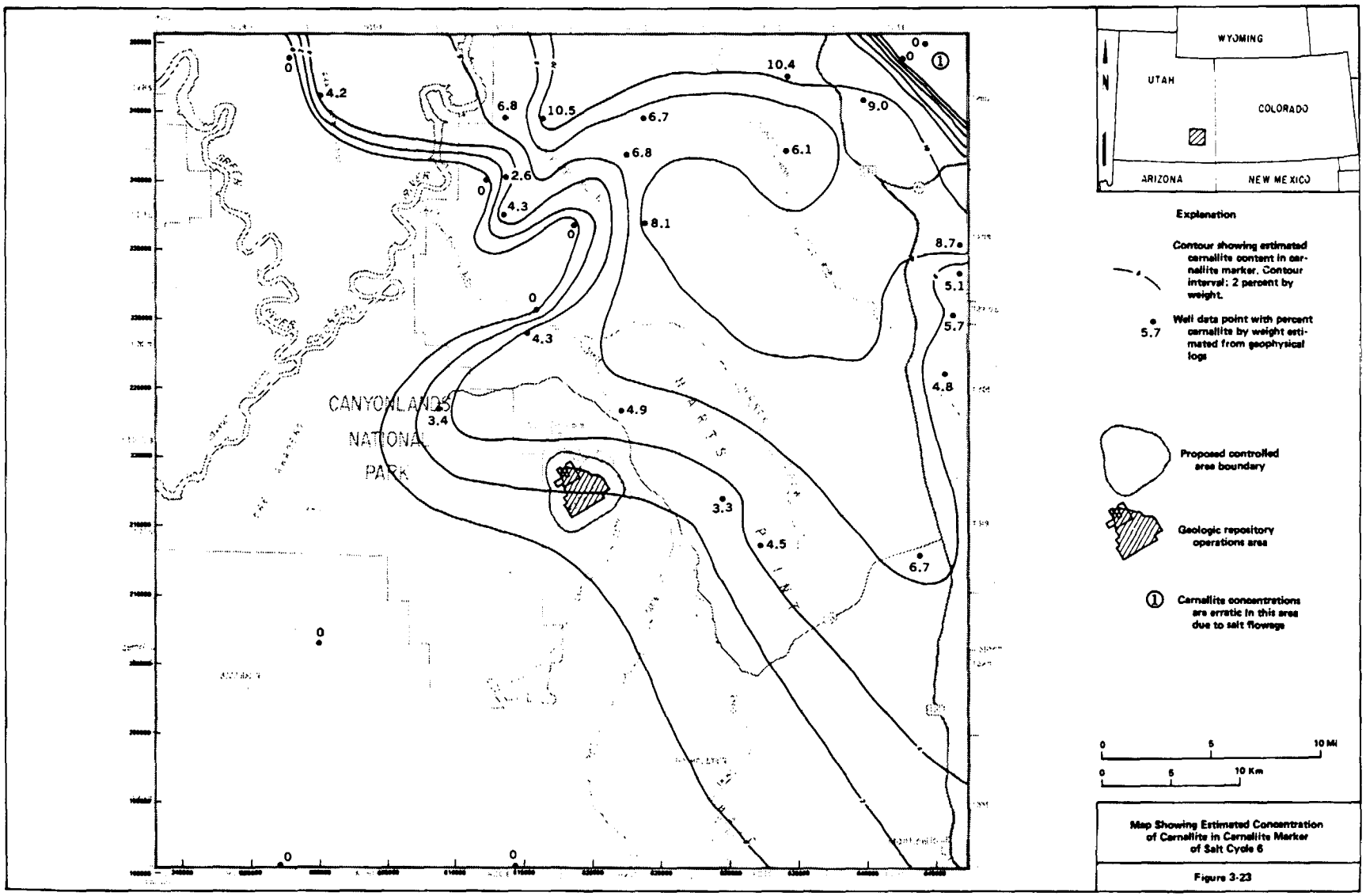
Isopach Map of Carnallite Marker In Salt Cycle 6 as Interpreted From Geophysical Logs

Figure 3-21



Portion of Gamma Ray Geophysical Log of the GD-1 Borehole Showing Carnallite Marker

Figure 3-22



Map Showing Estimated Concentration of Carnallite in Carnallite Marker of Salt Cycle 6

Figure 3-23

overlie steeply dipping reverse faults in the basement. The monoclines are thought to have formed during the Laramide orogeny in the late Cretaceous-early Cenozoic (Davis, 1978, p. 215). The salt anticline region northeast of the candidate area has had a long and complex history of salt tectonism (Cater, 1970, pp. 63-67). The Colorado Plateau is bounded on the west, south, and east sides by the Basin and Range-Rio Grande Rift stress province, a region of active late Cenozoic crustal extension characterized by high heat flow, wide spread, Cenozoic-age volcanism, and thin crust (Zoback and Zoback, 1980, p. 6132).

The Paradox Basin lies within the contemporary stress field of the Colorado Plateau interior, as described by Zoback and Zoback (1980, p. 6133). Strike-slip fault plane solutions for microearthquakes along the Colorado River indicate that the maximum principal stress is horizontal and directed east-west to northwest-southeast (Wong, 1984, ONWI-492, p. 27). These observations are in general agreement with shallower stress measurements at the GD-1 borehole (Nelson et al., 1982, ONWI-400, p. 37) and other earthquake and hydrofracture test data, cited by Zoback and Zoback (1980, p. 6133), which indicate general east-west compression. The stress orientation calculated from seismic data is similar to, but not identical with, the orientation obtained from borehole measurements.

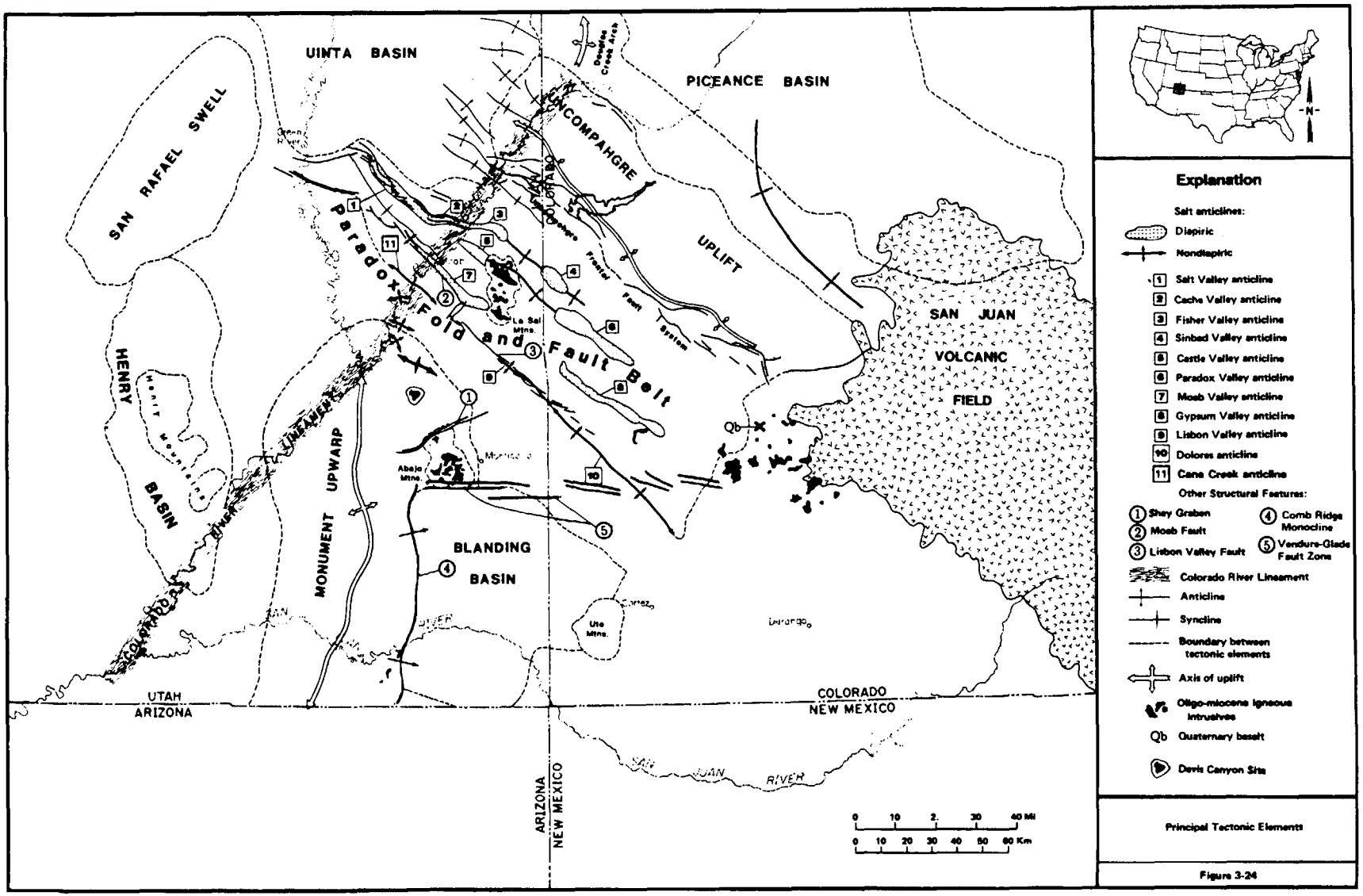
The dominant structural feature of the candidate area is the northern end of the Monument Upwarp, which is located in the western part of the area (Figure 3-24). The Upwarp is a broad, asymmetric basement fold about 180 kilometers (110 miles) long, reflected by approximately 1,200 meters (4,000 feet) of structural closure on the top of the Paradox Formation (Figure 3-20) (WCC, 1982, ONWI-290, Vol. II, p. 7-2). It lies between the Henry Basin on the west and the Comb Monocline on the east (Figure 3-24). The sinuous axis of the Upwarp typically lies within 16 to 24 kilometers (10 to 15 miles) of Comb Monocline, whereas the western flank is a long homoclinal slope that descends into the Henry Basin with no obvious structural demarcation.

The Upwarp axis plunges gently to the north within the candidate area, and has not been identified north of the confluence of the Green and Colorado Rivers. In this area the northeast flank of the Upwarp is a gently dipping, homoclinal slope that merges into the Paradox Fold and Fault Belt in a wide structural sag in the northeast part of the candidate area. The homoclinal slope terminates to the southeast at the Shay Graben system and the Abajo Mountains, an area of considerable structural complexity at the northern termination of the Comb Monocline. This monocline is thought to be a drape fold that overlies a steep, west-dipping reverse fault or zone of closely spaced faults in the Precambrian basement.

The Verdure-Glade Fault zone is a left-stepping system of normal faults and grabens that extends almost due east from the north end of the Comb Monocline. The surface faults reflect right-lateral slip during the Laramide Orogeny on a reactivated basement fault (Shawe, 1970, pp. 5, 10). This fault zone appears to have absorbed the compressional strain across the Comb Monocline and transferred the strain eastward to the Paradox Fold and Fault Belt (WCC, 1982, ONWI-290, Vol. I, p. 7-40).

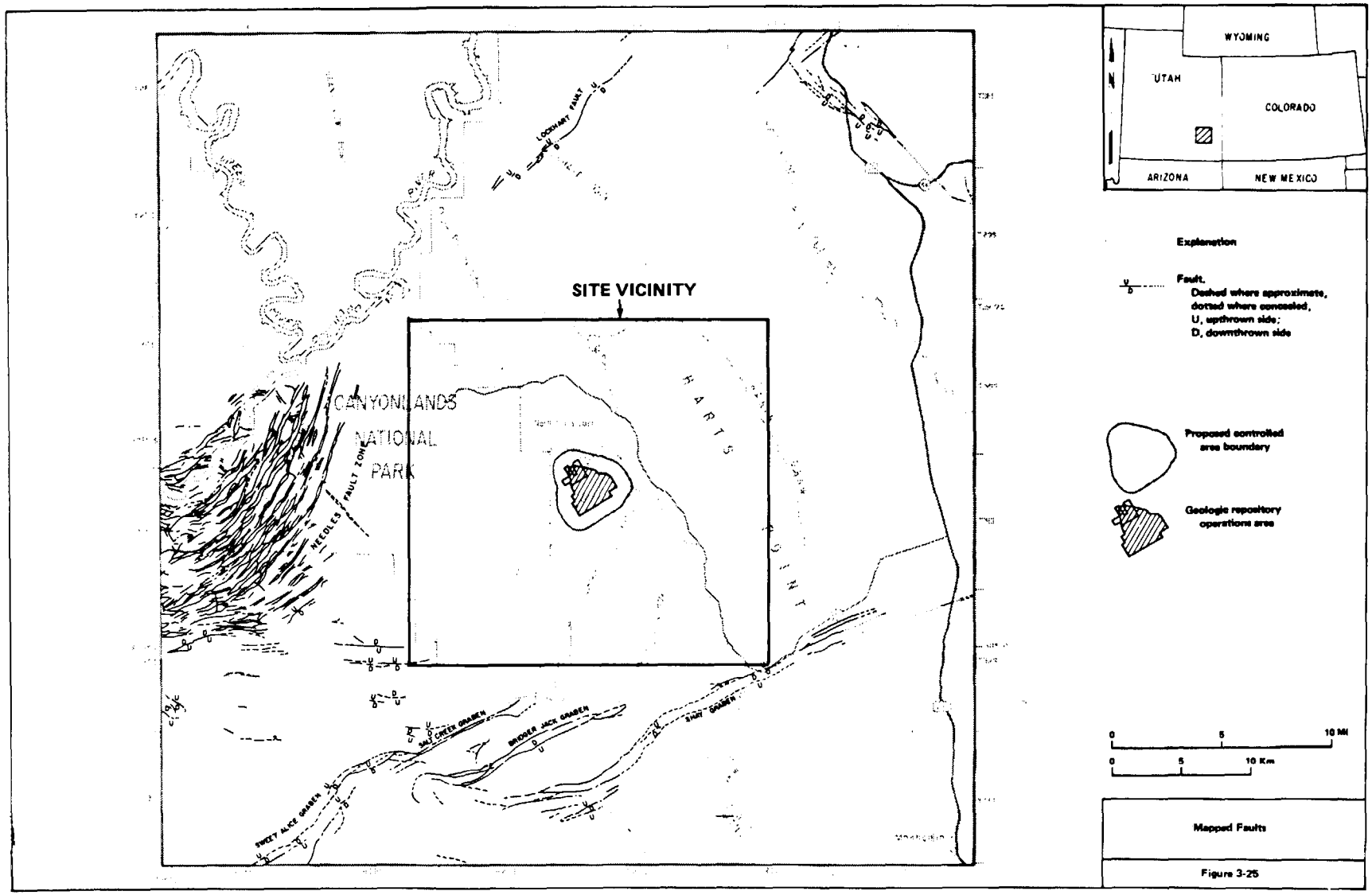
The geologic structure of the Davis Canyon site is characterized by sedimentary strata dipping northeastward off the Monument Upwarp (Figure 3-24) at gradients of approximately 1.6 degrees (29 meters per kilometer [150 feet per mile]). No faults or folds have been identified in the Permian or younger beds within or near the GROA; the nearest faults with surface expression are located approximately 16 kilometers (10 miles) west and 16 kilometers (10 miles) south of the GROA (Figure 3-25). The nearest identified fold is the Indian Creek Syncline located northeast of the site (Figure 3-10). This fold represents a broad, gentle inflection between the Monument Upwarp and Gibson Dome. It is not easily recognized in exposures in the field. The nearest prominent fold (Gibson Dome) (Figure 3-10) is located 8 kilometers (5 miles) north of the GROA.

In addition to the published regional geophysical studies by Case and Joesting (1972), proprietary aeromagnetic, gravity, and seismic reflection data that included the candidate area were purchased. The coverage of the proprietary gravity and seismic reflection data is shown on Figure 3-26; the proprietary aeromagnetic survey covers the entire candidate area.



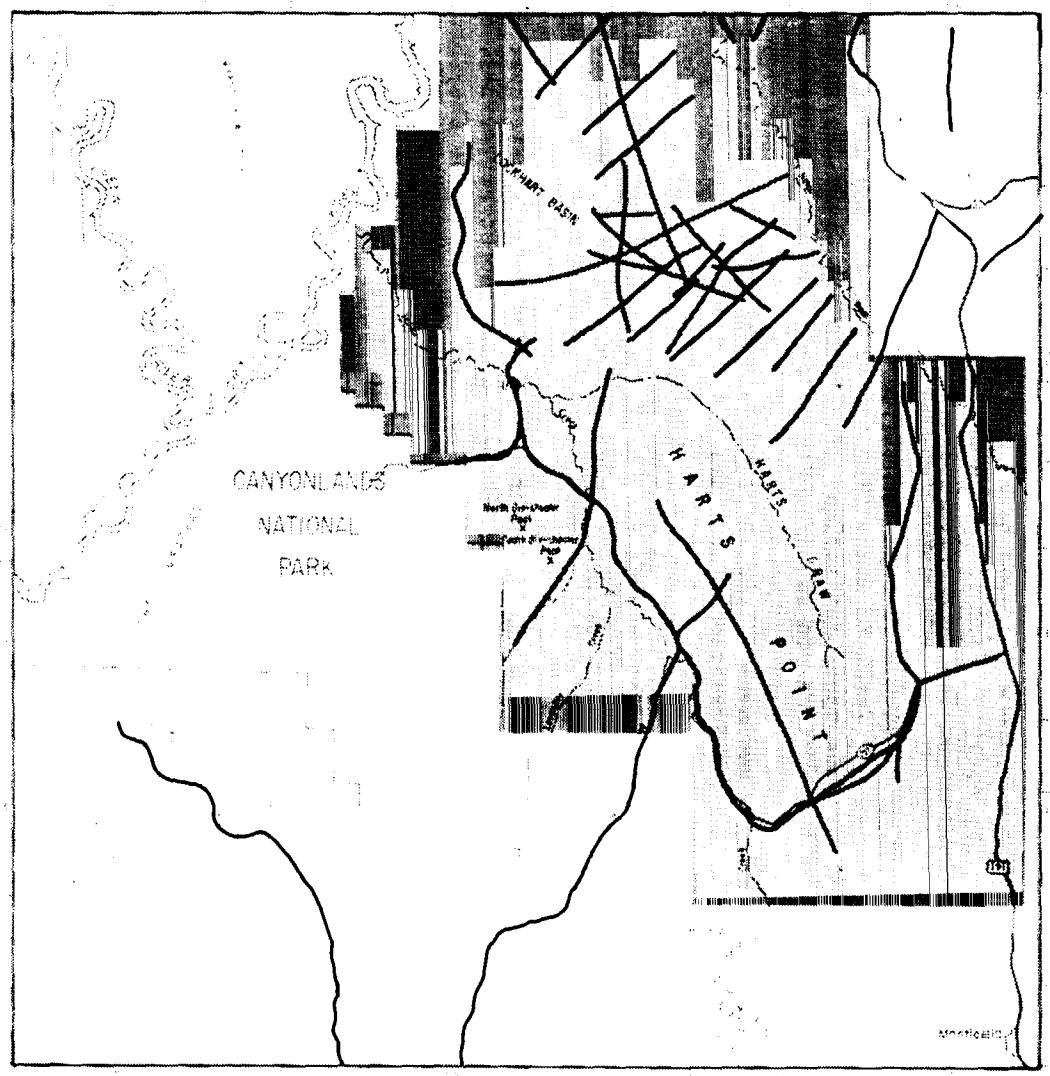
Principal Tectonic Elements

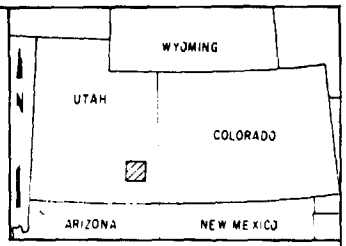
Figure 3-24



Mapped Faults

Figure 3-25





Explanation

Seismic reflection survey lines

Limit of gravity data coverage. Stations are 1 mi (1.6 km) apart within the area

0 5 10 MI

0 5 10 Km

Locations of Geophysical Survey

Figure 3-26

No significant magnetic or gravity anomalies occur near Davis Canyon (Kitcho et al., 1984, p. 27). Joesting et al. (1966, p. 8, 11) state that the sedimentary rocks of the Paradox Basin are essentially nonmagnetic, and that the magnetic anomalies in the site area are probably due to metagabbro plutons in the Precambrian basement. Numerous terminations of magnetic anomalies along the Colorado River west of the site indicate the presence of a major basement structure controlling the location of the river (Joesting et al., 1966, p. 7) (Sections 3.2.5.1 and 3.2.5.2).

The gravity field is primarily influenced by density contrasts between the Paradox Formation (specific gravity [SG] = 2.2-2.3), other Paleozoic deposits (SG = 2.6-2.7), and the Precambrian basement (SG = 2.6-3.2) (Case and Joesting, 1972, p. 5). Thickening of the salt section under Gibson Dome has produced a slight gravity low (Kitcho et al., 1984, p. 27), whereas the major salt anticlines have very large negative gravity anomalies (Case and Joesting, 1972, p. 11). Lockhart Basin is associated with a local gravity high reflecting the salt dissolution that has occurred within the basin (Kitcho et al., 1984, p. 26).

3.2.5.1 Faulting

Low-flying helicopter traverses and ground-based geologic mapping were carried out in the site vicinity and surrounding area to trace formation contacts and marker horizons in order to specifically search for evidence of faulting (Figure 3-11).

No faults with surface expression have been identified within the Davis Canyon site. Excellent exposures of Permian and Triassic rocks (210 to 280 million years old) in the site show no evidence of faulting since their deposition. Faults in the Davis Canyon candidate area that can be mapped at the surface are shown on Figure 3-25 and are discussed below.

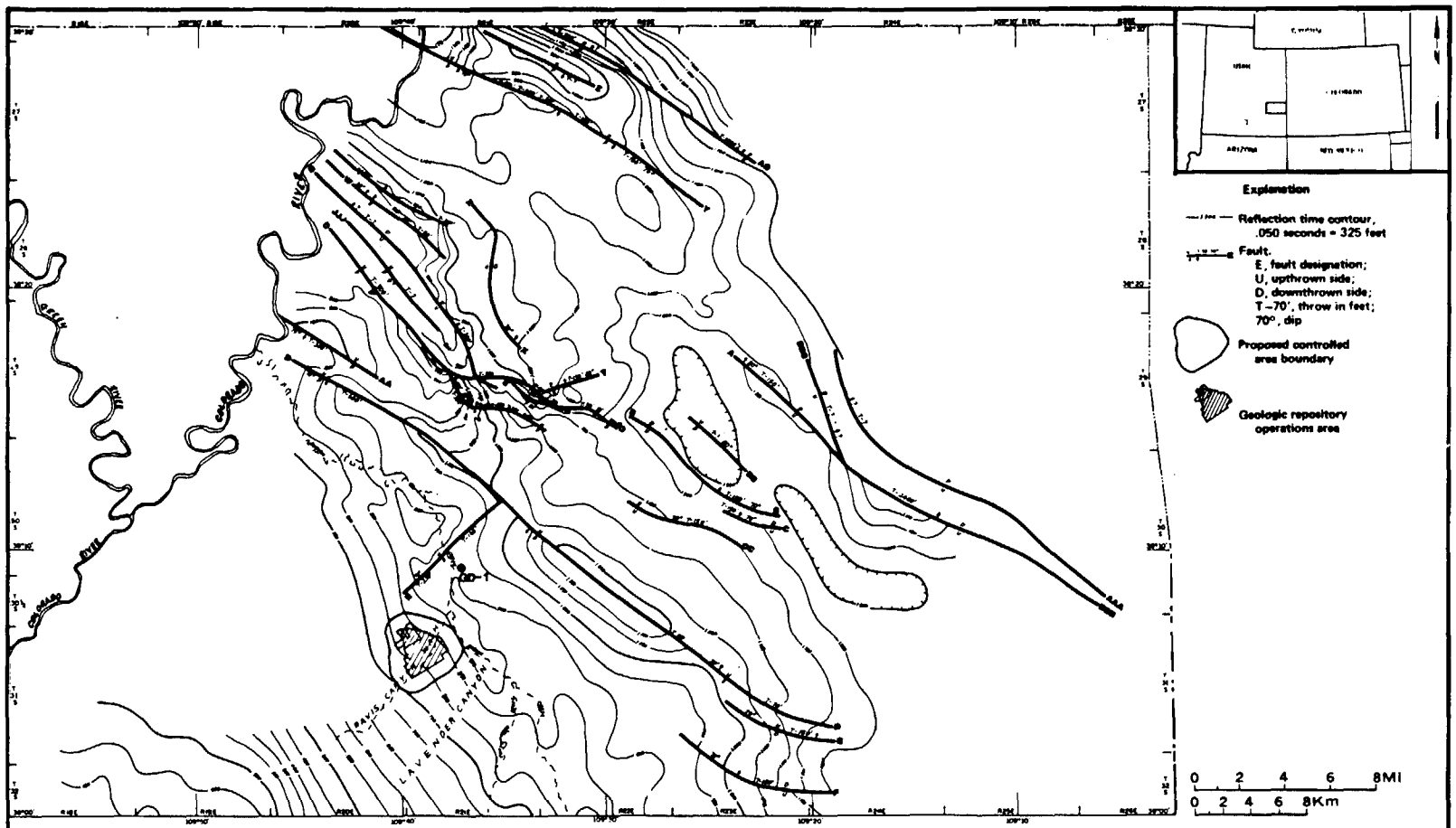
A seismic reflection line in Davis Canyon shows no evidence of faulting in the sedimentary rocks, including the Paradox Formation. However, a fault in the Precambrian basement was interpreted from this seismic line (Kitcho et al., 1985, Figure 3-1).

The closest fault to the Davis Canyon site that cuts the Mississippian Leadville Limestone is fault R, Figure 3-27, which has an interpreted maximum displacement of 80 meters (265 feet) (Kitcho et al., 1984, Figure 5-1).

The faults shown on the stucture contour map of the Paradox Formation (Figure 3-20) are derived from the interpretation of seismic reflection lines (Kitcho et al., 1984). The seismic reflection interpretation suggests that only the Shay Graben of the Shay/Bridger Jack/Salt Creek graben system displaces the top of the Paradox Formation. However, displacements are at the limit of resolution, and since all the grabens have both surface and Mississippian displacement, it was judged likely that they all displace the top of the Paradox Formation as well.

Figure 3-20 also shows a small north-south trending fault located about 4 kilometers (6.5 miles) north of the Davis Canyon site. This structure is interpreted to displace the top of the Paradox Formation solely on the basis of information from one seismic line. The estimated stratigraphic separation across the fault is 24 meters (80 feet), which is at the limit of resolution of the data. It is interpreted to extend from about the middle of the Paradox Formation through the rest of the overlying strata (Kitcho et al., 1984, p. 16). However, there is no surficial expression of the fault. Considering the available information, confidence in the fault's existence is only fair and its length and orientation are very poorly constrained because it is interpreted on the basis of one seismic line.

The Lockhart Fault (Figure 3-25) (WCC, 1982, ONWI-290, Vol. II, pp. 6-9) is the longest of several faults in Lockhart Basin and has the greatest displacement. It trends N. 25 to 61 E., dips 66 degrees southeast to vertical, and, as observed at the surface, has a maximum displacement of 73 meters (240 feet) down on the southeast. The fault is primarily a single trace that is locally surrounded by a shear zone with a width of 1.4 to 3 meters (5 to 10 feet). Vertical slickensides are present where the fault plane is exposed in sandstone. The youngest formation present in the vicinity of the fault, the Navajo Sandstone, is



Source: Kitcho et al., 1984.

Reflection Time Contours Top of Mississippian

Figure 3-27

displaced. The Cutler Formation is the oldest formation exposed in the vicinity of the fault and is also displaced.

The Lockhart Fault passes through the northern end of Lockhart Basin and to Hatch Mesa. The basin itself has collapsed approximately 335 meters (1,100 feet) because of solution of underlying salt.

At one location along the Lockhart Fault, alluvial fan deposits overlie the fault and are apparently not displaced. This Quarternary material is approximately 20,000 to 30,000 years old, based on field observations (WCC, 1982, ONWI-290, Vol. II, p. 4-5).

In contrast with other faults near the Davis Canyon site, the faults in Lockhart Basin are single traces, not graben systems. Most of the Lockhart Basin faults trend in a northeasterly direction and, with the exception of the Lockhart Fault, have small displacements of 0.3 to 6 meters (1 to 20 feet), generally to the south or southeast. Fault planes dip from 63 degrees to vertical, and most faults dip in a southeasterly direction. The faults are bleached, brecciated, and mineralized with calcite; well-developed vertical slickensides occur on fault plane surfaces. The smaller faults are expressed as zones that are 1 to 6 meters (3 to 20 feet) wide.

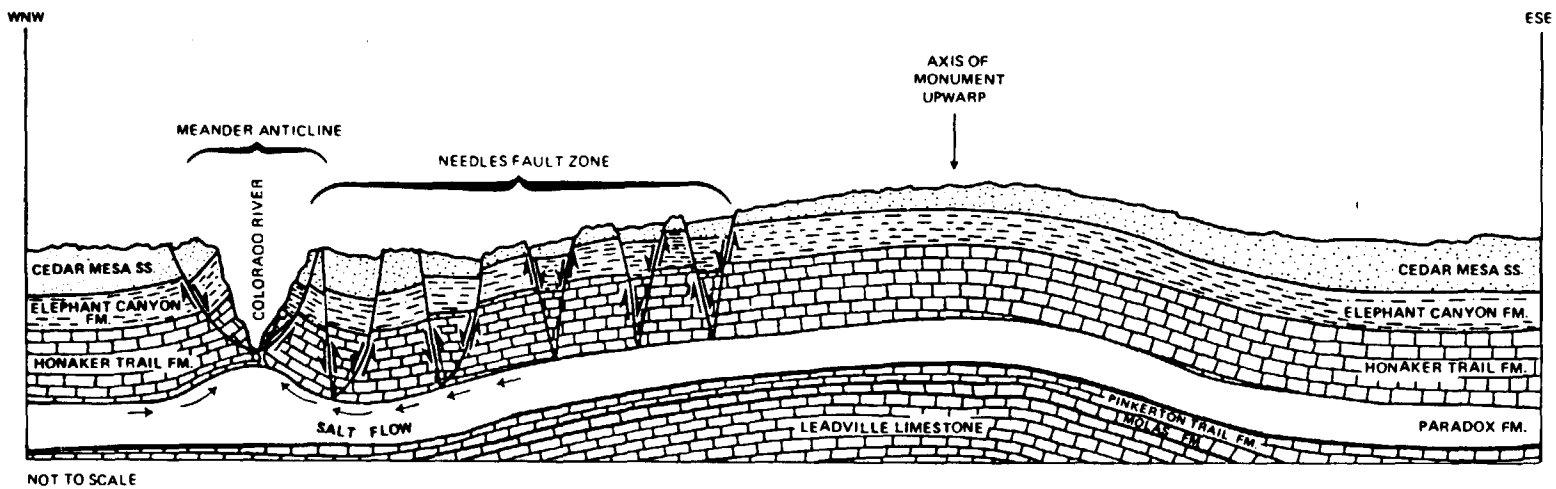
The Needles Fault zone (Section 3.2.2.2.3) is located in the western part of the Davis Canyon candidate area south of the confluence of the Green and Colorado Rivers, and is approximately 14 kilometers (9 miles) wide and 27 kilometers (17 miles) long (Figure 3-25). The fault zone was so named because of the shape of the rock spires, created by erosion, along the narrow, linear fault blocks (Baker, 1933, p. 73). The fault zone consists of an arcuate system of grabens having an average displacement of 23 to 24 meters (75 to 80 feet), and widths of 90 to 370 meters (300 to 1,200 feet) at the surface. The faults that bound the grabens in this area have average dips of 80 to 85 degrees. Displacements are highly variable along faults bounding single grabens and range from a few meters to 90 meters (300 feet) (Lewis and Campbell, 1965, p. 31). Displacement is greatest along the middle of faults bounding individual grabens in the zone and decreases toward the ends.

The major grabens consist of two or more en echelon elements with one boundary fault shared by both elements. This configuration suggests a scissor motion on the shared fault (McGill and Stromquist, 1979, p. 4548). Where these faults are exposed along the Colorado River, they occur as open or colluvium-filled fractures. Such open or colluvium-filled fissures occur along faults throughout this zone as far south as Imperial Valley, along the Colorado River. No slickensides are observed in the fault zone and no significant brecciation occurs along the fault planes. These observations, along with relict paleodrainage lines on the host blocks and a lack of bleaching or alteration along the faults, imply that the Needles faults may have been caused by different structural mechanisms or are more recent than other faults mapped in the Paradox Basin.

Faults in this zone are parallel to a dominant joint trend in the vicinity. According to McGill and Stromquist (1979, p. 4557), this strong pre-existing joint system controlled the trends of the faults in this vicinity. The faults in this zone were described by McGill and Stromquist (1979, p. 4557) as dipping steeply inward toward the graben axis and converging near the top of the Paradox Formation.

Recent theories on the origin of the Needles Fault zone emphasize gravity tectonics as the causative agent. Stromquist (1976, p. 1) proposed that canyon-cutting along the Colorado River during the late Cenozoic reduced the overburden load on the evaporites, allowing viscous evaporite material to flow down the gentle westerly dip off the Monument Upwarp and to rise beneath Cataract Canyon (Figure 3-28). Tension in the overlying strata created the grabens along preexisting joint trends (Stromquist, 1976, p. 1). Evaporites and a gentle dip toward the canyon are both required for this mechanism of graben formation.

Huntoon (1979, p. 46, Figure 5; 1982, p. 941) interpreted the grabens as the result of downdip sliding of postsalt sediments. In this case, the grabens were formed because of the creation of a free surface by the incision of the Colorado River. Both mechanisms may be



Needles Fault Zone
Schematic Subsurface Configuration
and Graben Evolution

Figure 3-28

operating; the rotated fault blocks (Figure 3-28) close to the Colorado River and open faults imply that flow of the underlying salt has pulled these blocks apart, whereas farther to the east, block rotations are not obvious, and downdip sliding may be the most important mechanism.

Hite (1982a) postulates that salt dissolution may have created the Needles Fault zone. In this case, rapid dissolution occurred as the river cut through Paradox salt at the Meander Anticline, leaving behind a residuum of mostly gypsum, which outcrops along the river. Overlying strata collapsed, creating a fracture system and connecting the overlying aquifer to the evaporites. Ground water in the strata overlying the Monument Upwarp could percolate through faults and fractures created by the collapse, and perpetuate movement of the dissolution front up the west limb of the upwarp (Section 3.2.5.6).

The progression of the Needles graben formation was from the Colorado River updip toward the southeast (Figure 3-28) (McGill and Stromquist, 1979, p. 4557). The south boundary of the Needles Fault zone marks a pinchout of evaporites (McGill and Stromquist, 1979, p. 4551). The Monument Upwarp has been a strong influence on regional dip in this vicinity, and structural events in the Needles Fault zone have been localized to an area west of the axis of the Upwarp. The Davis Canyon site is east of the axis. These interpretations, and the fact that the site exhibits a northeastern regional dip (not riverward), indicate that a Needles-type structure will not encroach on the site east or south of the Needles Fault zone.

An en echelon series of grabens (Salt Creek, Bridger Jack, and Shay Grabens) occurs along the southern margin of the Davis Canyon candidate area. The right-stepping configuration of the grabens suggests that they may have formed in response to left-lateral, strike-slip displacements at depth. Similarities to the Verdure-Glade graben system suggest that these grabens probably originated before the Abajo Mountain intrusives (Oligocene), and after deposition of the late Cretaceous Mancos Shale (Witkind, 1964, p. 104).

Shay Graben extends from South Canyon Point east of U.S. Highway 191 (U.S. 191), southwestward to Seven Sisters Butte, a distance of about 34 kilometers (21 miles). The graben generally trends N. 65 E., is an average of 0.8 kilometer (0.5 mile) wide, and includes two primary faults exhibiting dip-slip movement. Dips on the faults range from 70 to 80 degrees northwest or southeast, and are thought to converge downward (Witkind, 1964, p. 102). Displacement on the faults varies from 0.3 to 97 meters (1 to 320 feet), is greatest toward the center of the graben, and decreases toward the west and east ends (WCC, 1982, ONWI-290, Vol. II, p. 6-4).

The south fault at Shay Graben (south Shay fault) is generally better exposed than the north fault, and the middle of the structure is marked by sharply faceted spurs on the flank of Shay Mountain. The fault appears to displace a Quaternary gravel-covered pediment on the north side of Shay Mountain, implying that an episode of rejuvenation has taken place since emplacement of laccoliths in the Oligocene, and since exposure and erosion of those laccoliths. The south Shay fault has a total length of 37 kilometers (23 miles), and its ground expression is good to excellent throughout its length. Where it is exposed, the fault is expressed as a 3- to 6-meter- (10- to 20-foot-) wide shear zone, with bleaching and limonite staining.

The northeastern end of the south Shay fault (northeast of Harts Draw) is partially covered by eolian deposits and landslide debris. Where this end of the fault crosses mesa surfaces, its expression is subtle or absent. This northeastern end of the fault trends approximately N. 70 E. and dips steeply northwest to vertical. The average measurable displacement along this portion of the south Shay fault is 3 meters (10 feet), increasing to 12 meters (40 feet) at the west edge of Peter's Point.

The segment of the south Shay fault from Harts Draw to Indian Creek has good surface expression. The eastern portion of this segment is defined by a low linear topographic ridge marked by a distinct contrast in vegetation. It consists of an alignment of sheared,

brecciated, limonite-stained outcrops that locally display dip-slip slickensides. Displacement cannot be measured in the eastern portion of this segment because it is wholly within the middle to upper Navajo Sandstone.

In the western portion of this segment near Indian Creek, the Kayenta Formation is in fault contact with the Navajo Sandstone. Displacement is estimated to be 90 to 97 meters (300 to 320 feet). This segment of the south Shay fault consists of a prominent single trace surrounded by lesser shear zones several meters wide. It is brecciated, limonite-stained, and mineralized with calcite. Both the prominent trace and the associated shear zones exhibit vertical slickensides.

The segment of the south Shay fault from Indian Creek westward to North Cottonwood Creek has good to excellent expression in the form of faceted spurs and linear breaks in slope. It is primarily one fault bounded by a 6- to 30-meter- (20- to 100-foot-) wide zone of shears, having brecciation and limonitic alteration. The trend of this segment ranges from N. 65 E. to N. 45 E. Maximum displacement observed during mapping occurs at Indian Creek (98 meters [320 feet]); the displacement 10 to 16 kilometers (6 to 10 miles) west of Shay Canyon is 46 meters (150 feet).

The segment of the south Shay fault from North Cottonwood Creek to the west terminus of the fault is fairly well exposed. The trend changes from N. 45 E. to due east from North Cottonwood Creek westward. Displacement also decreases toward the west; it is 30 to 60 meters (100 to 200 feet) near North Cottonwood Creek and only a few meters at Maverick Point. From Maverick Point to Stevens Canyon, the south Shay fault trace joins the north Shay fault, converging at Stevens Canyon.

The north fault at Shay Graben (north Shay fault) extends from Peter's Point westward to Stevens Canyon, a distance of 34 kilometers (21 miles). This fault is generally poorly exposed along its entire length. The northeastern segment of the fault from Peter's Point to Indian Creek is almost completely covered by eolian deposits. Where it is exposed, the fault trace is marked by a subtle linear ridge or shear zone enhanced by vegetation such as sagebrush. The shear zones are narrow (0.3 to 1.5 meters [1 to 5 feet] wide) and are limonite stained. The low ridges are 0.3 to 3 meters (1 to 10 feet) high and consist of sheared, brecciated, and slickensided Navajo Sandstone, altered with limonite. This segment of the north Shay fault trends N. 70 to 74 E. and dips 78 degrees south. Displacement is not measurable along this segment because it is wholly confined to the middle to upper Navajo Sandstone.

The segment of the north Shay fault from Indian Creek to north Cottonwood Creek has poor surface expression; it is exposed at Indian Creek and in Shay Canyon. At Indian Creek, displacement is estimated to be approximately 46 meters (150 feet); strike and dip are not measurable at this location, where the Kayenta Formation is in fault contact with the Navajo Sandstone. At Shay Canyon, this segment of the fault trends N. 67 E. and dips 74 degrees southeast. Displacement is approximately 47 meters (160 feet). At this location the fault is expressed as a brecciated and limonite-stained shear zone, 15 meters (50 feet) wide, exhibiting vertical slickensides. The segment of the fault between Shay Canyon and North Cottonwood Creek trends N. 50 E. and dips 75 to 80 degrees southeast. Displacement is estimated to be 30 meters (100 feet).

The segment of the north Shay fault from North Cottonwood Creek to the west terminus trends N. 75 W. It is expressed as a brecciated zone 1.5 to 15 meters (5 to 50 feet) wide, where it crosses Maverick Point, with a displacement of 46 meters (150 feet). At its west terminus, where the north Shay fault plane converges with the south Shay fault plane, it trends N. 68 E. and dips 81 degrees southeast. At the point of convergence, the displacement is estimated to be 3 to 6 meters (10 to 20 feet).

Bridger Jack Graben (Figure 3-25) is 14 kilometers (9 miles) long with an overall trend of N. 65 E. (WCC, 1982, ONWI-290, Vol. II, p. 6-6). At the northeast end of the structure, the southern fault consists of several separate en echelon segments. At the southwest end of the structure, the graben is bounded and crisscrossed by several faults in a braided pattern

(Lewis and Campbell, 1965, p. 29). Greatest vertical displacement on both faults is near Cathedral Butte. At this location, which is approximately at the middle of the graben, the north fault has 114 meters (375 feet) of displacement and the south fault has a displacement of 97 meters (320 feet). Measurable surface displacement decreases to 1.5 meters (5 feet) toward both ends of the graben. Individual faults trend N. 50 to 76 E.; the north fault dips from 62 to 82 degrees southeast and the south fault dips 80 degrees north. The faults are limonite-stained zones of brecciation, and are occasionally expressed as bleached single traces with localized shear zones up to 15 meters (50 feet) wide. No slickensides were observed in either the single traces or the zones.

The oldest exposed unit displaced by Bridger Jack Graben is the Cedar Mesa Sandstone; the youngest formation displaced is the Kayenta Formation. No Quaternary cover in the vicinity of this graben can be used to evaluate its Quaternary activity.

The structural history of Bridger Jack Graben is not precisely known, but it is similar in overall characteristics (dimensions, trend, and displacement) to Shay Graben, so it may have had a similar history. This graben system and Shay Graben are en echelon. No subsurface data are available for this graben, so the subsurface configuration and pre-Permian history cannot be determined.

Salt Creek Graben (Figure 3-25) was mapped by Lewis and Campbell (1965). The graben is similar to Bridger Jack and Shay Grabens in style of faulting and amount of displacement. Salt Creek Graben forms the western component of the system of right-stepping, en echelon grabens that include Bridger Jack and Shay Grabens. Displacement on the graben is less than 6 meters (20 feet) at Salt Creek Mesa and increases to approximately 185 meters (600 feet) to the west. Near the eastern end of the graben complex, the north fault is nearly vertical, while the south fault dips steeply northward (Lewis and Campbell, 1965, p. 29).

Based on interpretation of seismic reflection data, a series of northwest-trending subsurface faults in the north-central part of the Davis Canyon candidate area were identified. Faults that were interpreted as cutting the Mississippian surface are shown on Figure 3-27. The displacement of most of these faults dies out in the lower part of the Paradox Formation, indicating that the activity of these faults ceased in Pennsylvanian time (Kitcho et al., 1984, p. 14). In support of this interpretation, these faults have no surface expression.

The northeast-trending portion of the Colorado River extending from the Grand Canyon to the Uncompahgre Uplift appears to be structurally controlled by part of an extensive Precambrian strike-slip fault system termed the Colorado Lineament (Warner, 1978, p. 161). This structural zone is interpreted to extend from northwest Arizona to Lake Superior and has an average width of approximately 160 kilometers (100 miles). The system was probably active sometime during the Penokean Orogeny (1700 to 2000 million years ago) (Warner, 1978, p. 161). The amount and sense of displacement along the Colorado Lineament are unknown; the configuration of magnetic anomalies near the southern end of the lineament are suggestive of a right-lateral strike-slip fault, several tens of kilometers long (Shoemaker et al., 1978, p. 361). Concentrated microearthquake activity extending approximately 50 kilometers (31 miles) along the river southwest from Moab appears to reflect reactivation of a fault or faults within the lineament (Wong, 1984, ONWI-492, pp. 7, 8, 27). Although the seismicity extends from near surface to a depth of 17 kilometers (11 miles) (Wong, 1984, ONWI-492, p. 8), only a few minor surface faults have been mapped in this area.

3.2.5.2 Seismicity

The historical seismicity record indicates that earthquakes in the Colorado Plateau are relatively infrequent, of small to moderate magnitude, and of diffuse distribution (Wong, 1984, ONWI-492, p. 4). By itself, the historical record is limited because it is incomplete, and some earthquake locations are inaccurate. These limitations result from the relatively short (approximately 130-year) historical record, small and sparsely distributed population and, until recently, limited seismographic coverage of the Plateau. For hazard analysis, the historical seismicity record is combined with other geologic and tectonic data to determine the seismic potential of the area.

From 1962 to the present, regional seismographic coverage of the Colorado Plateau has been adequate to detect and locate earthquakes of approximate local magnitude (M_L) 3 or greater. An epicenter map for the period 1962 to 1982 is shown in Figure 3-29. The sources of earthquake data, location techniques, detection levels, and location uncertainties have been described in a previous publication (WCC, 1982, ONWI-290, Vol. I, pp. 6-2 to 6-4).

In the historical record, earthquakes of M_L 4 or greater have occurred only rarely in the Colorado Plateau (Figure 3-29) (Wong, 1984, ONWI-492, pp. 94-121). The largest known earthquakes within the plateau were located in north-central Arizona with magnitudes of M_L 5 to 6. The largest event is believed to be the August 18, 1912, earthquake which had a maximum modified Mercalli (MM)* intensity of VII-VIII and was reported north of Flagstaff (DuBois et al., 1981, pp. 85-89). In contrast, two major zones of seismicity occur along the margins of the Colorado plateau: the Intermountain Seismic Belt, along the northwest margin, and the Rio Grande rift along the southeast margin (Figure 3-29). For each of the two neighboring zones, geologic evidence of the historical seismicity record attests to the occurrence of M_L 6 to 7.5 earthquakes.

The largest historical earthquake that may have occurred in the Utah portion of the Paradox Basin was an event on July 30, 1953, with maximum reported MM intensity V felt in Green River (Wong, 1984, ONWI-492, p. 7). Also, the earthquake epicenter could have been north or west of Green River, outside the Paradox Basin. No earthquakes have been reported in the Davis Canyon site vicinity during historical times.

A source of earthquakes of possible significance to the Davis Canyon site is the area in the vicinity of Capitol Reef-Henry Mountains, located approximately 80 kilometers (50 miles) southwest of the site and outside the Paradox Basin (Figure 3-29). Although seismicity has been known there only since 1978, the area represents the most macroseismically** active area observed to date within the Colorado Plateau interior, with the exception of mining-induced seismicity near the Book Cliffs-eastern Wasatch Plateau. Although the largest earthquake was only a M_L 3.6, the seismicity in the Capitol Reef-Henry Mountains region (including the epicentral area of a M_L 3.5 earthquake that occurred southeast of Hanksville on May 3, 1983) may represent an occurrence of Basin-and-Range extensional tectonism. Some analyses of seismic data to determine earthquake focal mechanisms suggest a faulting mode similar to that of the Basin and the Range. Because large earthquakes (M_L 6 to 7) have occurred in the extensional Intermountain Seismic Belt, and extensional focal mechanisms have been observed near Capitol Reef-Henry Mountains, the Capitol Reef-Henry Mountains region may represent a potential source for similar large earthquakes.

A program of microearthquake monitoring was initiated in the Utah portion of the Paradox Basin in mid-1979. The results indicate a general pattern of widespread, small-magnitude seismicity with some clustering of events in space and time (Figure 3-30) (Wong, 1984, ONWI-492, p. 11). The events occur in the upper crust, both in the Phanerozoic section and the Precambrian basement. A few microearthquakes have been observed in the vicinity of the Shay Graben faults (Figure 3-30); however, the uncertainty of their locations precludes correlating these events definitely with the Shay Graben faults.

The microearthquake pattern includes a linear cluster of seismicity 50 kilometers (31 miles) long aligned along the Colorado River from its confluence with the Green River northeastward to Moab. At its nearest point, the cluster is 17 kilometers (11 miles) from the Davis Canyon site. More than half of the 700 events located by the microearthquake network through 1984 are associated with this cluster (Figure 3-30). From the microearthquake monitoring, the largest earthquakes observed to date within the Paradox Basin were two approximately M_L 3 events that occurred in the Colorado River seismicity cluster and in the Potash-Shafer Basin area on January 22 and February 10, 1984 (Wong et al., 1985). Focal depths of

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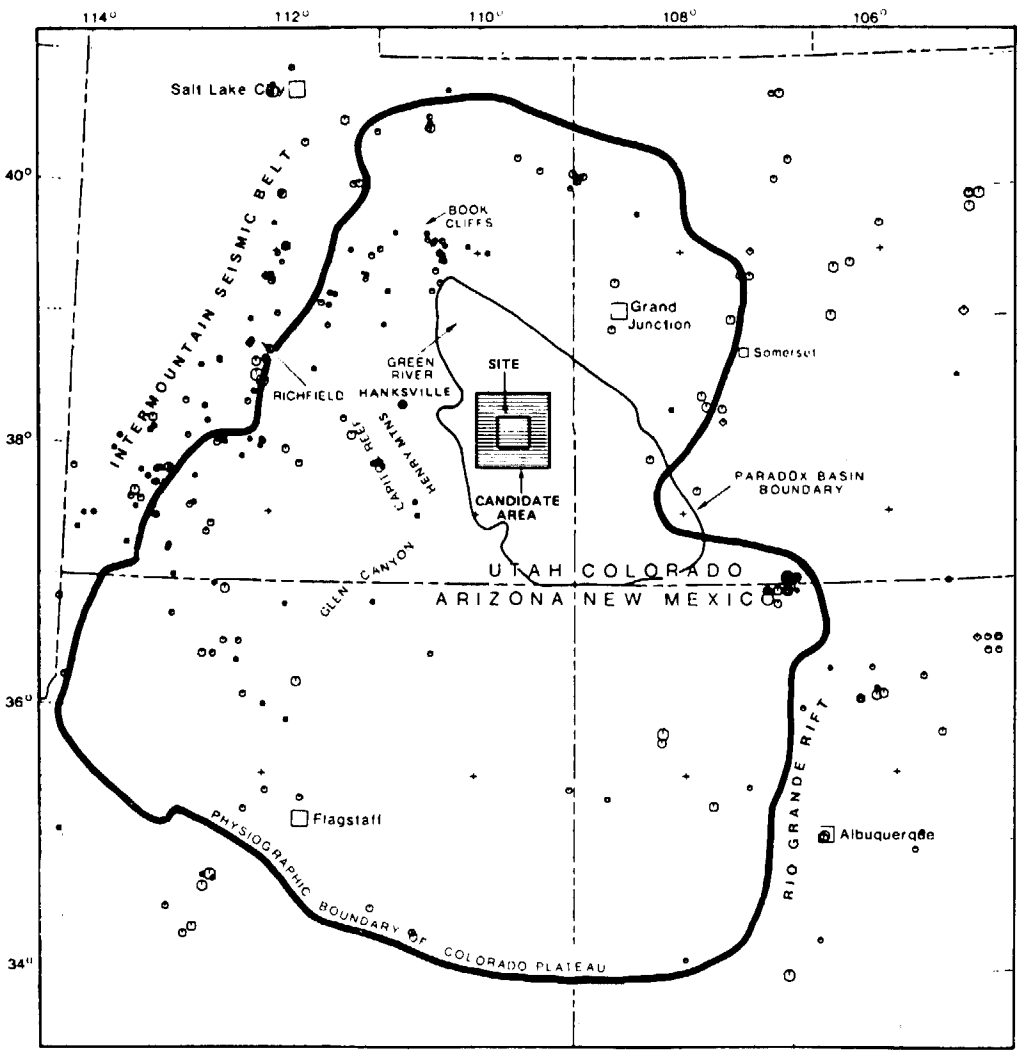
* See Wood and Neumann (1931) for description of intensities.

** Magnitude greater than 3.



Explanation

INTENSITY

XII
XI
X
IX
VIII
VII
VI
V
IV

MAGNITUDE

8.0
7.0
6.0
5.0
4.0
3.0

Note: Magnitude symbols are on a continuous nonlinear scale

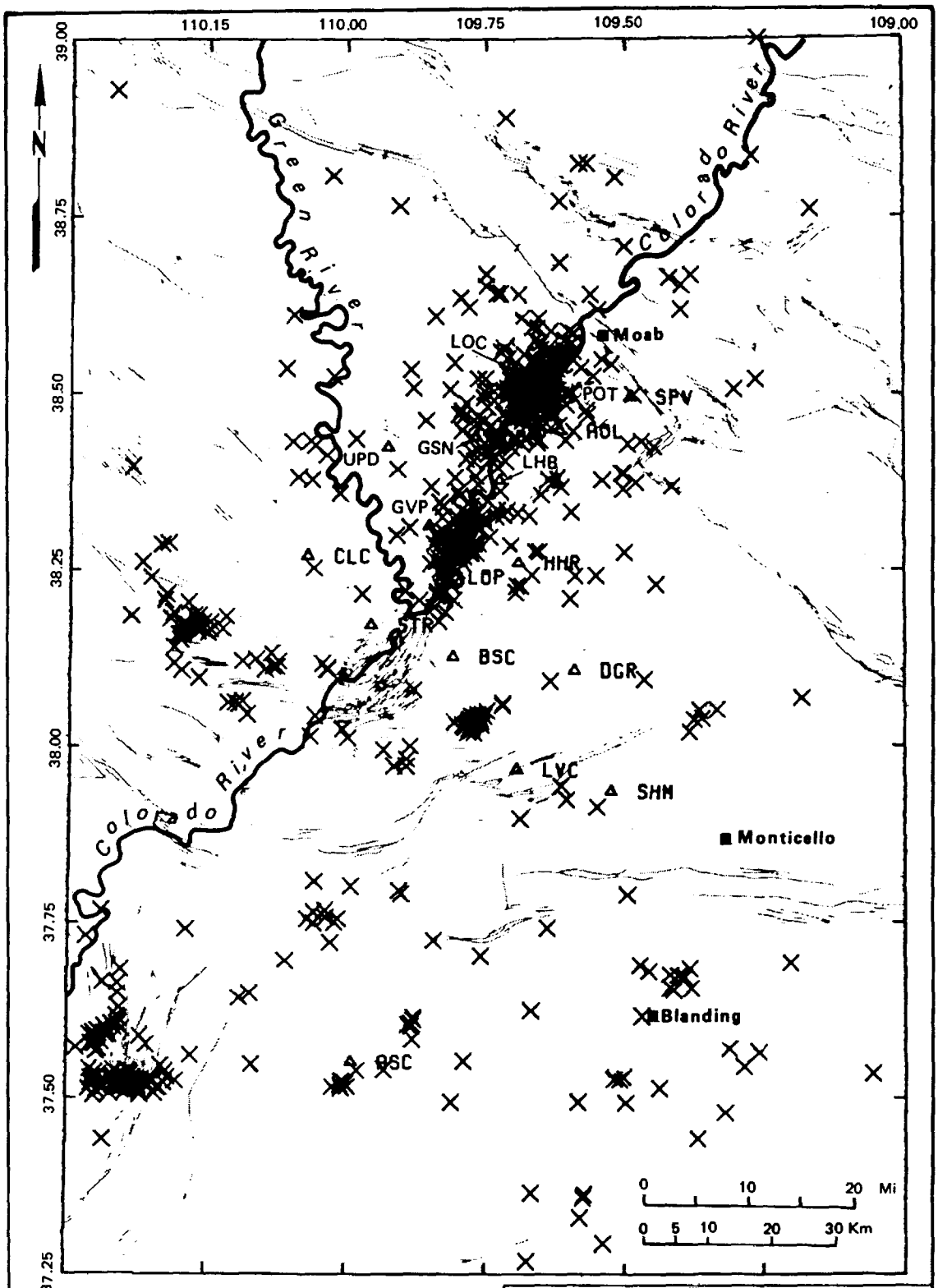
Sources: WCC, 1983; Sanford et al., 1981; Dubois et al., 1981; Hadsell, 1968; Newton et al., 1976; Los Alamos National Laboratory, 1981-1983; University of Utah, 1983.

0 15 30 60 90 120 MI

0 50 100 150 200 Km

Seismicity of the Colorado Plateau 1962 to 1982

Figure 3-29



Explanation

- △ Seismograph station, with station code
- × Earthquake
- Fault; dashed where approximately located, dotted where concealed

Seismicity of the Paradox Basin
July 1979-1984

Figure 3-30

the events in the cluster range from near-surface to 17 kilometers (11 miles). Fault plane solutions suggest a zone of multiple and complex strike-slip faulting. Aeromagnetic data suggest that the southern portion of this zone is underlain by a northeast-trending basement fault that may be part of the Colorado lineament of Warner (1978, p. 161).

Mining-induced seismicity is known to occur at the Book Cliffs coal mines and suspected to occur at the potash mine near Moab (Wong, 1984, ONWI-492, pp. 92-118). Although too distant to directly influence the seismic exposure of the Davis Canyon site, the seismicity of the Book Cliffs and the eastern Wasatch Plateau area is significant because it appears to be induced by underground coal mining. The area is the most seismicially active area within the Colorado Plateau and has displayed intense, sometimes hazardous, seismicity. Because the possibility of mining-induced seismicity is important for siting large underground structures, studies are being performed to understand the local geologic and tectonic conditions. At the Cane Creek potash mine located southwest of Moab, induced seismicity appears temporally related to mine activity. Both of these regional examples have unique local tectonic characteristics that are not present at the Davis Canyon site. The coal mines at Book Cliffs are at the edge of a high plateau and in a "ridge and canyon" topography that can affect the near-surface stress fields. The deep canyons provide free surfaces that are in the vicinity of the mines and extend to the mine levels. The potash mine near Moab is in the crest of a young anticline with faulting recognized at the surface. The induced events at Cane Creek are thought to be related to subsidence of overlying rocks as the product is removed from the mine.

3.2.5.3 Igneous Activity

No volcanic or intrusive igneous rocks are exposed within the Davis Canyon site. The closest exposures of igneous rocks are found on Shay Mountain, approximately 19 kilometers (12 miles) southeast of the geologic repository operations area. These rocks have not been radiometrically dated, but are presumed to be the same age as the rest of the Abajo Mountains intrusive complex (Oligocene).

The La Sal Mountains lie northeast of the Davis Canyon site (Figure 3-24), and consist of three stocks (North La Sal, Middle Mountain, and South Mountain) and associated laccoliths arranged in a north-south line. South Mountain is closest to the site; its nearest exposures are approximately 43 kilometers (27 miles) northeast of the site. Radiometric dates from the La Sal Mountains range from 23 to 26 million years before present (BP) for the intrusive rocks (Stern et al., 1965, p. 1503).

The closest known Quaternary volcanic center is located on Specie Mesa in the San Miguel Mountains of Colorado, 127 kilometers (79 miles) east of the site (see Qb on Figure 3-24) (Bush et al., 1960, p. 463; Luedke and Smith, 1978). This center, which includes a 0.8-kilometer (0.5-mile) long north-south oriented basaltic dike, is probably part of the Rio Grande rift Basin and Range stress province of Zoback and Zoback (1980, p. 6132).

3.2.5.4 Uplift, Subsidence, and Folding

The Colorado Plateau, Paradox Basin, and the candidate area have been undergoing steady uplift through much of the Cenozoic. Regional subsidence has not been detected in the candidate area or Paradox Basin. Local subsidence has occurred over dissolution features such as Lockhart Basin and the salt anticlines. The last phase of uplift of the Colorado Plateau amounted to approximately 1,800 meters (6,000 feet) in the last 10 million years. Evidence for this uplift includes the 10-million-year old basalt flows that cap Grand Mesa 160 kilometers (100 miles) northeast of the site that now stands 1,500 to 1,800 meters (5,000 to 6,000 feet) above the Colorado River (Marvin et al., 1966, p. 81). Because these flows are locally overlain by river gravel derived from a distant source (Yeend, 1969, p. 44), the difference in elevation between the mesa top and the river is probably close to the amount of regional uplift of this part of the Colorado Plateau. A slightly lesser amount of drainage incision has occurred 135 kilometers (85 miles) west of the site at Boulder Mountain. The surface of the mountain is a volcanic plateau that was apparently low-lying during the Miocene, because the down-faulted equivalent to the west is locally overlain by fluvial

deposits of the Sevier River Formation (Williams and Hackman, 1971; Rowley et al., 1981, p. 592). The mountain now stands 1,200 to 1,500 meters (4,000 to 5,000 feet) above the headwaters of the Fremont River, suggesting a comparable amount of plateau uplift since the deposition of the Sevier River Formation in the late Miocene.

The details of the past 10 million year uplift history are not well understood due to the sparsity of late Tertiary deposits. Sparse data in the Paradox Basin area indicate that most of the uplift and resultant downcutting by the Colorado River system took place before the Quaternary. Cater (1966, p. 88; 1970, pp. 48, 71) described early Pleistocene gravels along West Creek near Gateway, Colorado, 2.4 to 4.8 kilometers (1.5 to 3 miles) upstream from the Dolores River. (Gateway is approximately 48 kilometers (30 miles) southwest of Grand Junction, Colorado.) These gravels were deposited by the ancestral Gunnison River before rise of the Uncompahgre Uplift diverted it to its present course. The gravels indicate 30 to 60 meters (100 to 200 feet) of downcutting (and, by inference, uplift) has taken place at this location since they were deposited (Cater, 1966, p. 91).

Richmond (1962, p. 1) mapped early Pleistocene river gravel (older, Harpole Mesa Formation) on rock benches that are about 75 meters (250 feet) above the Colorado River, upstream from Moab. These deposits support Hunt's (1969, p. 60) estimate of 150 meters (500 feet) of uplift of the Colorado Plateau in the last 2 million years.

Fluvial deposits 240 to 410 meters (800 to 1,350 feet) above and west of the Green River, upstream from the confluence with the Colorado River, have Stage V calcic soil profiles (caliche); the highest deposits are paleomagnetically reversed and are at least 730,000 (and perhaps 2 million) years old (WCC, 1982, ONWI-290, Vol. I, p. 3-18). The lower Green River terraces have not been studied, but based on the low elevation of similar early Pleistocene terrace deposits near Moab and Gateway, they may be early Pleistocene as well.

The average uplift rate for the Paradox Basin during the late Pleistocene was no greater than 0.6 meter (2 feet) per 1,000 years, based on the deposits west of the Green River, and probably was close to 0.1 meter (0.3 foot) per 1,000 years based on the deposits near Moab and Gateway.

The presence of over 38 meters (125 feet) of alluvium below the bed of the Colorado River just downstream from the junction with the Green River (Baker, 1933, p. 94) indicates that little or no bedrock erosion is occurring at this locality. Evidence presented by WCC (1982, ONWI-290, Vol. I, p. 3-26) indicates that limited stream incision has occurred in the Paradox Basin during the Holocene. These relationships imply limited vertical crustal movement during this time.

The late Quaternary uplift rate is probably close to the rate of downcutting of the Colorado River. The river is free of bedrock rapids, and there is no evidence to indicate that the long-term uplift rate exceeds the rate at which the river can deepen its canyons.

No first-order geodetic or gravity surveys that have been repeated are available from the candidate area or site. A third-order leveling survey was conducted by the U.S. Geological Survey (USGS) within the candidate area along Utah 211 between U.S. Highway 163 and Cottonwood Creek. The survey line continues southwest along Cottonwood Creek to Elk Ridge, where it connects with several other third-order survey lines. This line has not been repeated. The closest first-order leveling survey to the candidate area follows U.S. 163 approximately 24 kilometers (15 miles) east of the site. The survey was conducted by the National Geodetic Survey (NGS) in the 1930s and has not been repeated.

The closest repeated leveling line follows a second-order NGS line along Utah 46 and Colorado Route 90 between La Sal Junction, Utah, and Naturita, Colorado. This line begins at a point approximately 25 kilometers (16 miles) northeast of the site and proceeds east. A 27-millimeter up-to-the-east change over 103 kilometers (64 miles) between 1934 and 1938 was observed along the length of this line. This value is probably not significant for a second-order survey. Several other relatively short, detached lines of repeated leveling occur

within the Colorado Plateau; no studies are available for these lines (Brown and Reilinger, 1980, p. 132).

The site strata are characterized by a gentle northeasterly dip off the axis of the Monument Upwarp. The strata exposed at the site and geologic repository operation area do not appear to be affected by folding, except north of the site where part of the Gibson Dome is present (Section 3.2.5.5). An indistinct syncline (Indian Creek Syncline) has been interpreted by Huntoon et al., (1982) to be located south of the Gibson Dome fold (Figure 3-10). This syncline is broad, indistinct, and is an extremely subtle feature in the surface exposures. The syncline is formed by the slight change in dip from the regional northeasterly dip off the Monument Upwarp to the gentle southwesterly dip of the southwest flank of Gibson Dome (see structure contours on Figure 3-33) (Section 3.2.5.7).

Generally, two types of folds are observed within the candidate area: folds related to broad basement uplifts (i.e., the Monument Upwarp), and, folds resulting from salt flow (discussed in Section 3.2.5.5). Inter- and intrastrata folding of lesser magnitudes (i.e., lesser wavelength and amplitude) possibly occurs within the evaporite section of the candidate area and site. However, insufficient information exists to do more than speculate about this type of folding at present.

Potter and McGill (1978, p. 952) mapped numerous valley anticlines in and just east of the Needles Fault zone that they interpreted to reflect conditions of excess horizontal compressive stress. Fold amplitudes range from 1 to 5 meters (3 to 15 feet), wavelengths from 2 to 60 meters (6 to 100 feet), and lengths generally a few tens of meters. However, some of the folds are as much as 600 meters (1,968 feet) long. The folds occur only on valley floors where a thin-bedded sequence a few meters thick at the contact between the Elephant Canyon and Cedar Mesa Formations crops out. Most of the anticlinal axes are oriented perpendicular to the Needles Fault zone and were interpreted by the authors (Potter and McGill, 1978, p. 953) to be perpendicular to the horizontal maximum stress in the vicinity of the Needles Fault zone. The axes of the anticlines, which occur in the Salt Creek drainage, trend for the most part north to northeast (Huntoon et al., 1982). These anticlines are approximately perpendicular to the regional maximum horizontal stress as interpreted from earthquake focal mechanism studies (Wong, 1984, ONWI-492, p. 30). The valley anticline nearest the Davis Canyon site is located 10 kilometers (6 miles) to the southwest (Huntoon et al., 1982).

3.2.5.5 Salt Flow and Diapir Development

Within the Paradox Basin, the salt of the Paradox Formation occurs in three geometric configurations: diapiric or pierced anticlines, nondiapiric anticlines that have not penetrated the overlying stratigraphic section, and areas of bedded salt where local minor deformation related to salt flow may be present (Figure 3-9).

The salt anticline region lies northeast of the site, and includes five major folds: (1) Salt Valley - Sinbad Valley; (2) Castle Valley - Paradox Valley; (3) Moab Valley; (4) Gypsum Valley; and (5) Lisbon Valley - Dolores anticlines (Figure 3-24). The locations of the anticlines are controlled by faults in the subsalt rocks, with as much as 1,500 meters (5,000 feet) of structural relief (Cater, 1970, p. 51). The thickened salt cores of the anticlines lie on the downthrown northeast sides of the subsalt faults. The stratigraphic evidence of the growth history of the anticlines is described in Section 3.2.3.1. The salt anticline cores exhibit a progressive change in structural style with increasing proximity to the Uncompahgre Uplift (Shoemaker et al., 1958, p. 54). The cores of southwesternmost anticlines (Cane Creek and Lisbon Valley - Dolores) are relatively low and wide and do not penetrate the overlying Honaker Trail Formation (Hite, 1968, pp. 326-328). Anticlines in an intermediate position (Moab Valley, Gypsum Valley, Castle Valley - Paradox Valley) have high ridge-like salt cores that penetrate overlying deposits as young as the Middle Jurassic San Rafael Group (Shoemaker et al., 1958, p. 54) (Section 3.2.3.1). The anticlines closest to the Uncompahgre Uplift are dominated by discrete, elliptical, structurally independent salt cells (cupolas) that rise from deeply buried ridge-like masses (Shoemaker et al., 1958, p. 54). Shoemaker et al. (1958, p. 54) consider the variation in structure to have been a consequence

of progressively greater depth of burial and more intense compressive forces to the northeast toward the Uncompahgre frontal fault system.

Most authors agree that thickening of the anticlinal cores began late in the history of salt deposition or during Honaker Trail Formation deposition, as a result of tectonic compression (Section 3.2.3.1). The most rapid growth of the anticlines took place in the Early Permian during deposition of the Cutler Group; over half of the structural relief on the anticline cores was acquired at this time (Shoemaker et al., 1958, p. 42; Cater, 1970, Plate 1). Although sedimentary loading and lateral flow of salt from the intervening synclines was the major factor in driving the rise of salt anticlines during Permian and later time, tectonic compression also continued to play a role. Shoemaker et al. (1958, p. 52) and Elston et al. (1962, p. 1877) suggest that pulses of anticlinical growth (recorded by angular unconformities along their margins) coincided with pulses of compression and rise of the Uncompahgre Uplift, which in turn were followed by floods of arkosic sediment derived from the uplift, and thus more rapid loading of the synclines.

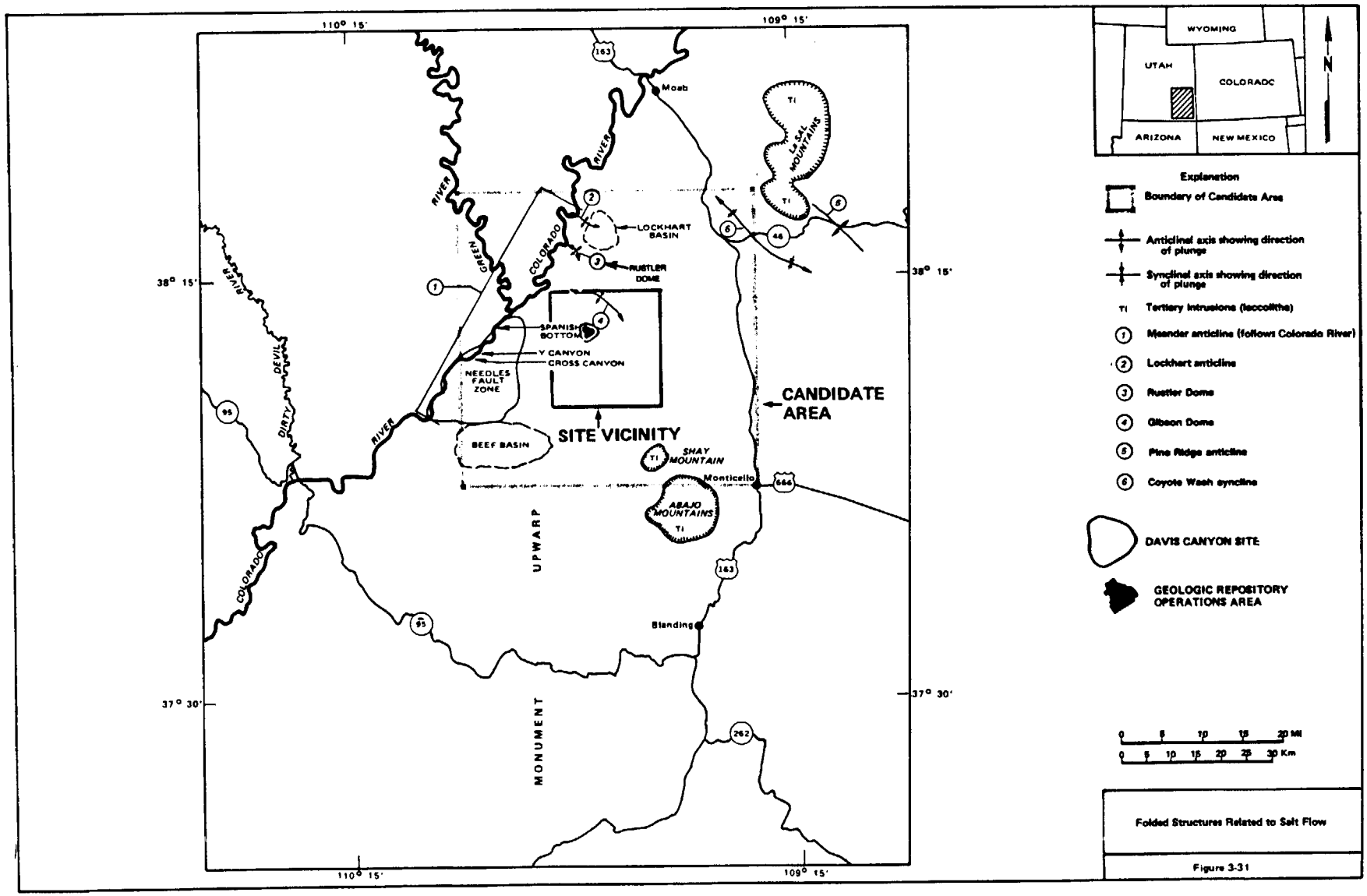
The last major episode of folding to affect the salt anticlines occurred during the Laramide Orogeny in the latest Cretaceous-Eocene. The Laramide folds, as recorded in Cretaceous deposits, are much broader than the salt cores and apparently were the result of deep-seated compression along the structures beneath the anticlines (Cater, 1970, p. 65). Two episodes of post-Laramide collapse of the overlying sedimentary rocks into the salt cores were inferred by Cater (1970, p. 65). The first episode may have been a consequence of crustal relaxation following Laramide compression. The best evidence for this is in Gypsum and Paradox valleys, where mineralized faults in foundered blocks indicate that these blocks subsided when the salt cores were deeply buried (Cater, 1970, p. 57; Shawe, 1970, p. 9). The second episode followed uplift and deep erosion of the Colorado Plateau in the Miocene-Pliocene; this episode is still continuing (Cater, 1970, p. 65).

The only anticlines to exhibit upward movement during the Quaternary are Fisher Valley, where a thick sequence of early Pleistocene deposits appears to have been trapped behind a salt cupola (Colman, 1983, p. 240) and Dolores anticline, where terraces along the Dolores River have anomalous dips (Shawe, 1970, p. 8).

The candidate area includes the Coyote Wash syncline (Figure 3-31), a major salt flow structure related to the adjacent Pine Ridge anticline (located to the northeast, out of the candidate area) (WCC, 1982, ONWI-290, Vol. II, p. 6-27). Most of the remainder of the Davis Canyon candidate area is an area of bedded salt. Minor salt flowage has occurred locally to produce the Gibson Dome, Rustler Dome, Lockhart anticline, and Meander anticline structures (Figure 3-31). Structural closure of these features ranges from 15 meters (50 feet) for Rustler Dome (Hite and Lohman, 1973, p. 52) to approximately 122 meters (400 feet) for the Meander anticline (Huntoon, 1982, p. 946).

Gibson Dome is located approximately 8 kilometers (5 miles) north of the site and trends northwest along Indian Creek. The mapped length of the fold is approximately 29 kilometers (18 miles) (Huntoon et al., 1982), extending from the Colorado River to Harts Point. At the surface, the limbs of the fold dip 1 to 5 degrees. Hite and Lohman (1973, p. 47) estimated that structural closure of Gibson Dome is 61 meters (200 feet). It has been interpreted, on the basis of well logs and seismic reflection profiles, that the salt section thickens across the fold axis, whereas the underlying Mississippian age strata appear to form a gentle syncline (Kitcho et al., 1984, p. 16).

An upper-bound estimate for the growth rate of Gibson Dome can be made using a very conservative scenario. This scenario assumes that the dome is entirely a late Cenozoic feature that resulted from differential loading and flow of salt from under the Chinle-Navajo cliff. If it is assumed that the cliff retreated back from the crest of the dome during the last major phase of canyon cutting along the Colorado River (which began at least 700,000 years ago, Section 3.2.5.4), and that growth of the dome only took nine-tenths of the available time (a conservative assumption), then an uplift rate of 1 meter (3 feet) per 1,000 years would be sufficient to create the 61 meters (200 feet) of closure on Gibson Dome. Continued growth at this rate would produce 9 meters (30 feet) of uplift in the next 10,000 years, an



Folded Structures Related to Salt Flow

Figure 3-31

insignificant value which is probably several orders of magnitude more rapid than the actual growth rate when the dome formed.

Some evidence suggests that Gibson Dome formed before the present drainage pattern was established. Indian Creek flows lengthwise along the strongly jointed axis of the dome. Quaternary uplift of the dome would have tended to cause the creek to slip off axis and down-dip on the Cutler Formation sandstones, rather than entrench itself along the axis of maximum uplift.

Indian Creek syncline is not a significant structure. As mapped, the syncline lies along a vague zone where the northeast dip on the flank of the Monument Upwarp passes imperceptibly into the southwest dip, along the flank of Gibson Dome.

Several small diapiric structures appear on the crest of the Meander anticline in the Colorado River near Cataract Canyon (Huntoon et al., 1982). These structures are probably related to the formation of the Meander anticline and the Needles Fault zone.

3.2.5.6 Dissolution

The geologic setting (Paradox Basin) of the Davis Canyon site contains a number of dissolution features. The crests of the major salt anticlines in the Paradox fold and fault belt have collapsed and are now expressed as alluvium-floored linear valleys. The alluvium overlies cap rock composed of the insoluble material left behind as salt was dissolved from the anticlinal cores. Within the candidate area (southwest of the fold and fault belt) there are two known dissolution features, Lockhart Basin and Beef Basin, and two potential dissolution features, the Needles Fault zone and the Shay/Bridger Jack/Salt Creek graben system.

Evidence for dissolution in the geologic setting includes downwarped or infolded strata, breccia pipes, positive-gravity anomalies, disruption of seismic reflection patterns, faulting, presence of ground water with high sodium chloride content, and absence of all or part of the salt section of the Paradox Formation interpreted from geophysical logs of boreholes (Gupta et al., 1985, BMI/ONWI-567).

The largest and best expressed dissolution feature in the candidate area is Lockhart Basin. Information from geophysical logs of petroleum exploration borings, gravity surveys, seismic reflection surveys, and surface mapping indicates that all or part of the salt has been removed from the Paradox Formation over an area of approximately 23 square kilometers (9 square miles). Both the cause and the timing of the dissolution in Lockhart Basin are in question. There is a system of northwest-trending faults underlying Lockhart Basin with sufficient displacement to juxtapose the Leadville Limestone aquifer and the Paradox Formation salt (Kitcho et al., 1984, pp. 14-15). While this relationship is not known to be causative, the presence of the dissolution zone over the fault system suggests that they may be related. The Lockhart Fault, a northeast-trending feature mapped at the surface, bounds the northwest side of the dissolution zone. Seismic reflection data indicate that the fault displaces the stratigraphic section above the salt, the top of the salt, and perhaps one of the salt interbed reflectors; it does not extend through the entire salt section and is interpreted to be a tensional feature related to salt dissolution rather than a causative feature.

The timing of the dissolution at Lockhart Basin is also uncertain. Thickened or thinned stratigraphic units can sometimes be used to help bracket times of salt flow or dissolution. Examination of isopach maps indicates a thick area adjacent to the south side of Lockhart Basin, in the Honaker Trail Formation of Pennsylvanian age. This suggests that there may have been salt flowage from this area northward into the ancestral (predissolution) Lockhart anticline during Honaker Trail deposition (McCleary and Romie, 1985, p. 74). No conspicuous thickening or thinning is shown on other isopach maps near Lockhart Basin (McCleary and Romie, 1985, Appendix A) up through the Jurassic Navajo Sandstone, the youngest unit exposed in the area. This suggests that dissolution occurred sometime in post-Jurassic time. It seems probable that dissolution began in the mid-Tertiary when the area of the Colorado Plateau was uplifted following withdrawal of the Cretaceous seas. Quaternary alluvial or colluvial deposits exposed in a stream cut in Lockhart Basin appear to be ponded on the southeast

(basin) side of the Lockhart Fault suggesting that dissolution was occurring at the time of their deposition. However, the present configuration of deposits could also be explained by differential erosion of more and less resistent bedrock units (less resistant on the southeast side of the fault), and subsequent ponding of sediments in the flattened portion of the stream profile. The current rate of dissolution, if any, is not known.

A number of breccia pipes are present in the Lockhart Basin (Huntoon and Richter, 1979, pp. 45-53). These pipes of resistant, cemented breccia project as small hills above the surrounding country rock, which is often gently infolded for a few hundred feet around the pipes. The exact origin of the breccia pipes is uncertain. They are probably related to dissolution of salt because their occurrence is confined to the area of salt dissolution.

Beef Basin, located approximately 23 kilometers (14 miles) southwest of the geologic repository operations area, is the other known dissolution feature in the candidate area. This feature is very poorly defined. Salt is apparently absent from two boreholes in the basin (McCleary and Romie, 1985, p. 60), but the exact configuration of the basin is unknown because the geographic distribution of petroleum exploration borings is very uneven. However, geophysical logs from drill holes north and east of the basin show undisturbed evaporite sections. The basin is outside the area of the gravity survey; the seismic reflection line through the basin was not interpretable; and only one stratigraphic unit (the Cedar Mesa sandstone) is exposed in the area, making it difficult to assess the amount of downwarping.

Of the two potential dissolution features in the candidate area, the Needles Fault zone is considered to be the most likely area where dissolution is occurring. There are a large number of open or colluvium-filled fractures that could act as conduits for meteoric or ground water to reach the salt of the Paradox Formation (Section 3.2.5.1).

Saline spring samples were taken from the banks of the Colorado River in Cataract Canyon, adjacent to the Needles Fault zone (WCC, 1982, ONWI-290, Vol. II, pp. 9-8, 9-9). Though the sodium chloride concentration is relatively low, it suggests that salt is currently being dissolved beneath the Needles Fault zone. There is no borehole, gravity, or seismic reflection information presently available for the Needles Fault zone, so the subsurface configuration of the zone is unknown.

The Shay/Bridger Jack/Salt Creek graben system is considered to be an area of potential dissolution only because these faults may be through-going features (Kitcho et al., 1984, pp. 10-11) that could possibly provide pathways for meteoric or ground water to reach Paradox Formation salt. There are no surface indications of dissolution in or near the graben system and seismic reflection lines across the grabens do not indicate dissolution. A petroleum exploration borehole (well No. 45; Figure 3-12) was drilled between the Shay and Bridger Jack Grabens in the southern part of the candidate area. The hole penetrated the salt section but no geophysical logs were run through this section so no evaluation of salt dissolution was possible. Examination of the drilling history of this well (Placid Oil Company, No. DU-2, USA) indicates that while some unusual drilling conditions were encountered in the upper part of the hole and at the very bottom of the hole, the drilling in the salt section was normal. The thickness of the salt section, estimated from drill cuttings, is about what would be expected in this area based on the Paradox Formation isopach map of the candidate area (Figure 3-16).

At the bottom of the hole (822 meters [2,695 feet]), a cavity, approximately 3 meters (10 feet) in height, was encountered in the Leadville Limestone resulting in a loss of circulation. It is not known at this time if this feature is related to the paleokarst developed on the Leadville Limestone or is part of the present ground-water flow system. As estimated from drill cuttings, this opening is approximately 43 meters (140 feet) below the top of the Leadville Limestone. It is hypothesized that the cavity occurred at this location because of probable increased fracturing in the area between the Shay and Bridger Jack Grabens or its proximity to the Abajo Mountains recharge area.

Another possible cause of the cavity would be an interformational karst within the Leadville Limestone. This karst was investigated in the Lisbon Valley oil field by Fouret

(1982). At that location there is evidence of large vugs and solution channels beneath solution breccias (Fouret, 1982, p. 61). It is not known how extensive the interformational karst is. In the core from the GD-1 borehole, about 18 meters (60 feet) of paleosol or paleokarst, consisting of clasts of resistant limestone in a red, clayey siltstone matrix, is encountered at the interface between the Molas Formation and the underlying Leadville Formation (WCC, 1982, ONWI-388, Vol. I, p. 47). The Molas Formation is an aquitard that helps to seal off the Leadville Formation from the overlying formations.

The probability of a cavity within the Leadville Limestone stopping upward and allowing hydrologic interconnection between the Leadville and Paradox Formations is unknown. However, the probability is assumed to be low since there is no known evidence for such an occurrence in the geologic setting.

An indicator of dissolution in the geologic setting is ground water rich in sodium chloride. High-TDS (total dissolved solids) sodium-chloride water has been encountered in both the upper and lower hydrostratigraphic units in the candidate area. In the upper hydrostratigraphic unit, high-TDS water was encountered in the GD-1 borehole in the lower portion of the Honaker Trail Formation. Six different hypotheses for the origin of this water were examined by McCulley et al. (1984). It was concluded that the high-TDS water is probably an admixture of evaporated sea water and ancient meteoric water (McCulley et al., 1984, pp. 39-52), although one possible interpretation is that the brine may have resulted from salt dissolution (Section 3.2.7.2).

The high-TDS water in the Leadville Limestone is most likely the product of salt dissolution (Section 3.3.2.1; McCulley et al., 1984, p. 52). It is probable that most of the salt is entering the Leadville Limestone flow system in areas of known salt dissolution, such as Lockhart Basin, and in the fold and fault belt to the northeast of the candidate area. This hypothesis is supported by the distribution of concentrations of TDS in the lower hydrostratigraphic unit (Figure 3-32) which, though the data are somewhat sparse and erratic, tends to be lower to the southwest of the fold and fault bed. Little dissolution is expected in the bedded salt portion of the basin, which includes the Davis Canyon site, because the Paradox Formation is overlain and underlain by very low permeability strata (Section 3.3.2.1). Dissolution may occur at specific localities in the bedded salt area where the normal stratigraphic sequence has been disrupted by faulting, such as in Lockhart Basin or at the Needles Fault zone.

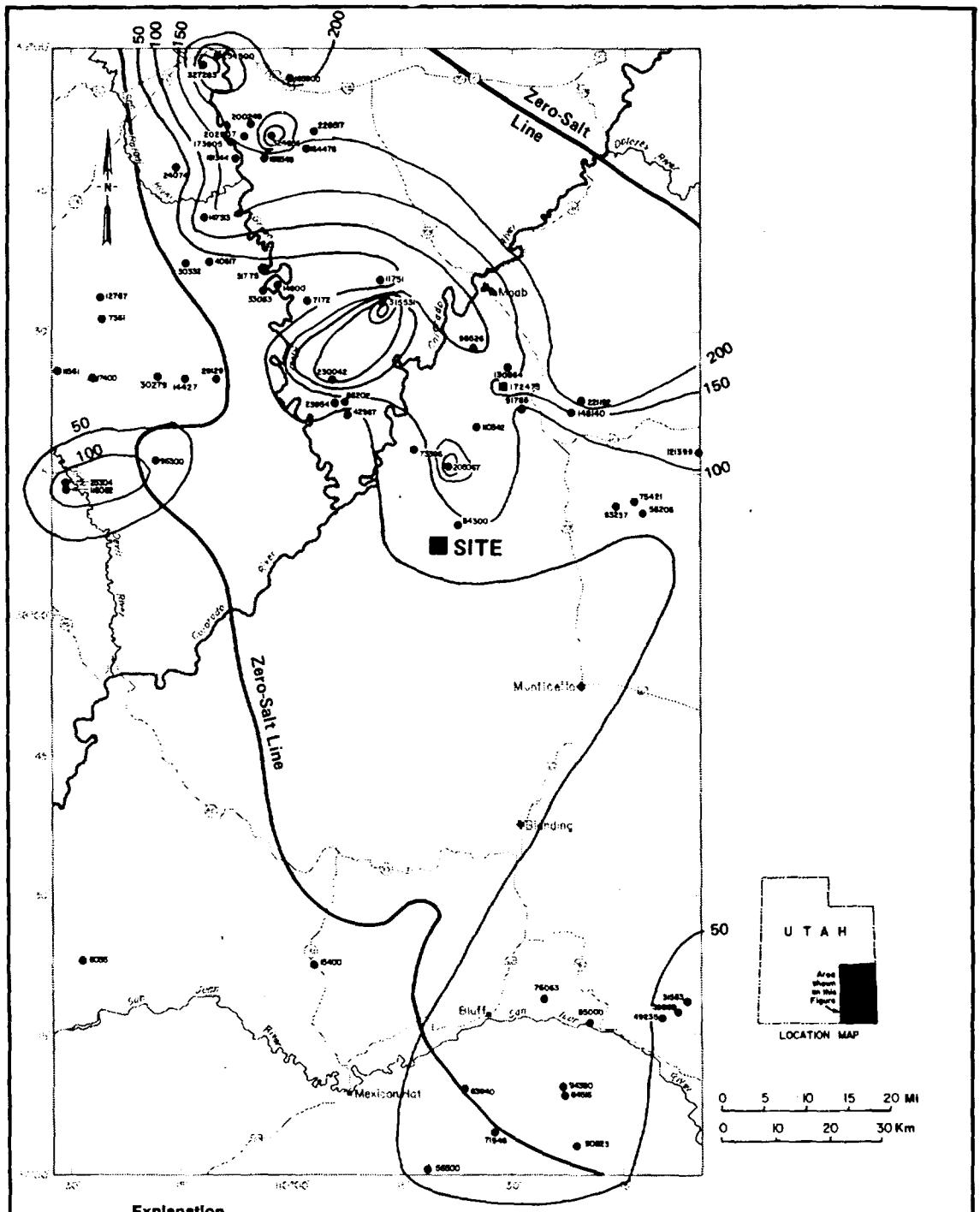
Salt crusts near springs and seeps can be indicators of dissolution. Salt crusts from two seeps north of Salt Creek pocket were analyzed and it was concluded that they represented leaching of finely disseminated salts in the adjacent Cedar Mesa Sandstone by shallow ground water and concentration by evaporation (Section 3.3.2.1).

3.2.5.7 Jointing

A joint is a surface of fracture or parting in a rock without displacement (Bates and Jackson, 1980, p. 334). Figure 3-33 summarizes the joint orientations and densities in the site vicinity, as observed on 1:12,000 aerial photos. Each area delineated on Figure 3-33 (A, B, C, and D) has a characteristic pattern of joint orientation and density.

Area A is on the northern edge of the site vicinity at Gibson Dome. Most joints in the area are closely spaced and trend N. 50 W. to N. 75 W., closely paralleling the axis of Gibson Dome (Figure 3-34). Joints here are interpreted to be a result of extension over the crest of Gibson Dome, a salt flow structure. The depth of jointing is unknown, but is not likely to extend into or below the domed Paradox Formation salt. There is no evidence at the surface or in well logs of two boreholes located at the crest of the dome that joints have acted as conduits for ground water to reach the salt, causing dissolution.

Areas B and C, in the southwest portion of the site vicinity, are moderately to highly jointed (Figures 3-35, 3-36). Joint density increases toward the crest of the Monument Upwarp, which is west of the site vicinity (Figure 3-24). A prominent set of joints in these areas trends northeast, approximately perpendicular to the structural contours of the Upwarp



Explanation

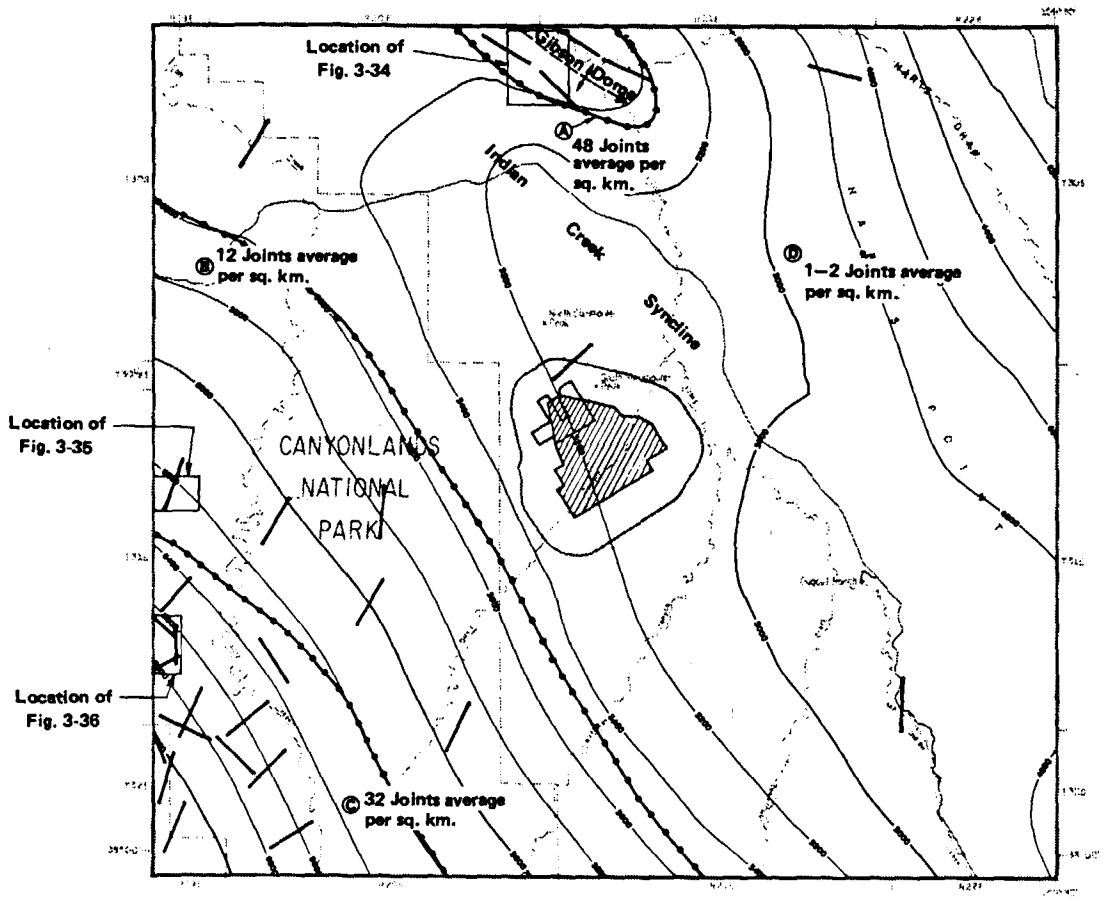
Approximate boundary of the saline facies in the Paradox Formation; also referred to as the zero salt line

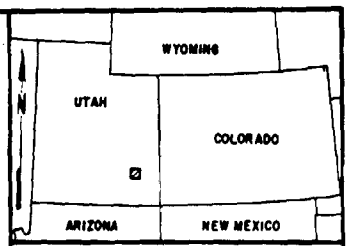
Data Point

Contour Interval 50,000 ppm TDS

Concentrations of Total Dissolved Solids Lower Hydrostratigraphic Unit

Figure 3-32





Explanation

- Outline of area classified by joint trend and density
- Ⓐ Area descriptor referenced in text
- Symbol representing local predominant joint trends
- Anticline. Trace of axial plane and direction of plunge. Dashed where approximately located
- 5000 Structure contour on top of Cutler Group. Contour interval 500 ft.
- Proposed controlled area boundary
- Geologic repository operations area

0 1 2 3 4 MI

0 1 2 3 4 5 km

Predominant Joint Trends and Density in the Site Vicinity

Figure 3-33

N

NOTE: See Figure 3-33 for Image Location.

Representative Jointing Associated with the Gibson Dome Structure

Figure 3-34

NOTE: See Figure 3-33 for Image Location.

Example of Prominent Northeast Trending Joints in the Southwestern Quarter of Site Vicinity

Figure 3-35

NOTE: See Figure 3-33 for Image Location.

Example of Curvilinear Jointing Pattern in Southwestern Corner of Site Vicinity

Figure 3-36

(Figure 3-33). In area C, where the jointing pattern is most complex, joints are generally relatively short, close together, curvilinear, and usually parallel to cliffs and steep slopes. The topography may be the result of preferential erosion along the joints, or the joints may have developed due to stress relief resulting from erosion or structural processes. The short, dense, curved nature of the joints in area C suggests that they are secondary joints (Rogers, 1982, pp. 16-18) formed in response to topography or accelerated unloading, rather than primary joints which form in a rock unit while it is in a wholly continuous state.

Jointing in area D is low density and there is no preferred orientation. Many joints are parallel or perpendicular to cliff faces. Joints in this area are probably secondary.

More than 90 percent of the joints observed in aerial photos are in the Cutler Group, and most of those are in the Cedar Mesa Member of the Cutler, a massive quartz sandstone which outcrops over most of the western third of the site vicinity, shown on Figure 3-33. Joints are also well-developed in the Wingate Sandstone. Prominent, near-vertical Wingate cliffs exhibit columnar jointing which does not extend into underlying or overlying units. Joints are also seen in the limited outcrops of Navajo Sandstone and Moss Back Member of the Chinle Formation. Joints in the Moss Back most often trend northeast and are very closely spaced. Joints in both the Moss Back and Chinle do not appear to extend into units above or below those formations.

Air photo analysis does not provide adequate information to evaluate the age of jointing, its sequence, or its vertical continuity. Horizontal or low-angle joints are not observable on the photographs and neither are vertical joints in units, like the Wingate, which form cliffs or steep slopes with little outcrop in plan view. The density and trends of joints in the Wingate cannot be adequately assessed from air photos because they are vertical and, therefore, are seldom visible except in the few areas where the overlying units are eroded away.

3.2.6 Rock Characteristics

3.2.6.1 Geomechanical Properties

Standard laboratory tests were used to determine the mechanical properties of salt and nonsalt strata. These tests included triaxial compression, uniaxial (unconfined) compression, creep, and Brazilian (indirect tension) tests (Pfeifle et al., 1983, ONWI-450; Nelson et al., 1982, ONWI-400). Laboratory tests also measured rock index properties, including point load strength, abrasion resistance, and Schmidt Hammer rebound hardness (WCC, 1982). All tests were conducted on samples from the GD-1 borehole. Preliminary engineering property test results are presented in Table 3-5 for salt and nonsalt rocks. Paradox Basin salt is relatively pure, although thin laminae of anhydrite occur, and some thin layers of salt have a high content of carnallite ($KMg \cdot Cl_3 \cdot 6H_2O$) (Section 3.2.3.3). Carnallite and other impurities, such as kerogen, are discussed in detail in Section 3.2.7, Geochemistry. Thus far, laboratory tests of mechanical properties at ambient and elevated temperatures have not demonstrated any deleterious effects of these inclusions or discontinuities (Nelson et al., 1982, ONWI-400, p. 54; Pfeifle et al., 1983, ONWI-450, p. 30). It is recognized that, although the range in rock properties at a single location might be adequately represented by the GD-1 laboratory test data, the range in such properties over a larger area of the site might be greater. The properties of intact rock play a role in predicting rock mass behavior needed by the designers and constructors of underground openings. However, large-scale exploratory excavations and in situ testing are needed to fully assess rock mass behavior and the significance of rock discontinuities, such as fractures, joints, and other anisotropies.

Heterogeneities in the host rock are mineralogic variations (kerogen and carnallite), anhydrite bands, and potentially the presence of brine and gas pockets. Kerogen also exists in small quantities in the dolomite bed between Salt Cycles 5 and 6. Significant amounts of hydrocarbons will not be generated in the kerogen-bearing interbed overlying Salt Cycle 6 because the maximum temperature reached in the interbed will not be sufficient. Furthermore, the heat impact from the emplaced waste lasts only about 1,000 years, after which the temperature of the salt will have returned almost to its initial temperature. This heating

Table 3-5. Summary of Rock Characteristics

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
141.9 (465.7) Arkosic Sandstone Cutler/Cedar Mesa	2.61	100		36		2.50[d]	40.8	1.96	57.0
145 (475) (R) Sandstone Cutler/Cedar Mesa		92.3 ± 4.4	-7.8 ± 1.5	18.6 ± 0.6	0.48 ± 0.05				
158.1 (518.8) Sandstone Cutler/Cedar Mesa	2.63	107		39		3.08[d]	46.6	1.64	59.6
183 (600) (R) Silty Sandstone Cedar Mesa		78.6 ± 6.6	-5.7 ± 0.8	17.6 ± 1.0	(b)				
188.8 (619.3) Sandstone Cedar Mesa	2.33	52		12		1.32[d]	41.6	5.14	94.2
218.4 (716.4) Sandy Siltstone Elephant Canyon	2.58	90		25		3.20[d]	47.1	1.07	48.8
244 (800) (R)[c] Silty Sandstone Elephant Canyon		40.5 ± 3.0	-2.9 ± 0.1	7.0 ± 0.3	0.40 ± 0.08				

Table 3-5. Summary of Rock Characteristics
(Page 2 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
245.7 (806.1) Cross-bedded Ss Elephant Canyon	2.59	112		21		2.43[d]	47.9	2.24	71.7
268.6 (881.2) Silty Ss with Sandy Siltstone Elephant Canyon	2.64	160		41		0.37[d]	42.4	1.98	59.8
291.0 (954.6) Silty Sandstone Elephant Canyon	2.62	69		34		2.91	36.1	0.77	31.6
305.1 (1001.0) Sandstone Elephant Canyon	2.06	21		10		0.63	23.0	0.08[e]	6.3
305.9 (1003.6) Sandstone Elephant Canyon	2.08	25		9		0.50	25.3	0.08[e]	7.4
306.8 (1006.5) Sandstone Elephant Canyon	2.04	16		21		0.43	22.1	0.04[e]	4.6
308.2 (1011.1) Siltstone Elephant Canyon	2.63	79		17		0.52[d]	35.2	0.47	24.1

Table 3-5. Summary of Rock Characteristics
(Page 3 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
309.9 (1016.6) Siltstone Elephant Canyon		Sample fractured during coring				1.24	30.6	0.20	13.6
310.6 (1019.0) Sandy Siltstone Elephant Canyon	2.59	93		23		0.44[d]	39.5	1.05	40.5
317.6 (1041.9) Siltstone Elephant Canyon	2.63	77		18		0.27[d]	31.6	0.32	17.8
320 (1050) (R)[c] Siltstone Elephant Canyon		69.3 ± 6.1	-6.4 ± 1.1	13.8 ± 0.7	0.23 ± 0.03				
327.7 (1075.1) Sandy Siltstone Elephant Canyon		Core arrived broken				2.41	26.2	0.32	14.9
340.4 (1116.7) Sandy Siltstone Elephant Canyon	2.63	89		21		0.72[d]	33.4	0.44	22.3
350 (1150) (R) Sandstone Elephant Canyon		79.1 ± 5.8	-4.0 ± 2.3	31.4 ± 10.0	(a)				

Table 3-5. Summary of Rock Characteristics
(Page 4 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
356.6 (1170.0) Sandstone Elephant Canyon	2.54	85		23		2.07[d]	36.1	0.57	27.2
372.9 (1223.4) Sandstone Elephant Canyon	2.31	44		12		1.48[d]	29.1	0.39	18.1
379.4 (1244.7) Stylolitic Limst. Honaker Trail	2.68	70		34		0.96[d]	39.6	1.48	48.2
381 (1250) (R) Sandy Limestone Honaker Trail		100.4 ± 12.2	-5.5 ± 0.7	32.8 ± 3.1	0.25 ± 0.05				
388.6 (1274.8) Silty Limestone Honaker Trail	2.64	88		49		2.92[d]	46.1	1.08	48.0
401.4 (1317.0) Silty Limestone Honaker Trail	2.60	139		3		2.32	43.1	1.28	48.8
424 (1390) (R)[c] Shale Honaker Trail		61.8 ± 5.3	-7.1 ± 1.1	10.0 ± 0.9	0.11 ± 0.02				

Table 3-5. Summary of Rock Characteristics
(Page 5 of 15)

Depth m(ft) Description(a) Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
436.1 (1430.9) Calcareous Siltstone Honaker Trail	2.63	90		19		2.28	42.7	0.76	37.2
448.3 (1470.9) Silty Limestone Honaker Trail	2.51	62		13		2.25	27.6	0.32(f)	15.6
464.5 (1524.1) Silty Limest. w/ Siltstone Honaker Trail	2.55	83		17		1.30(d)	35.1	2.65	57.2
466 (1530) (R) Limestone Honaker Trail		98.7 ± 2.8	-6.5 ± 1.3	20.2 ± 0.7	0.42 ± 0.04				
475.5 (1560.2) Silty Limestone Honaker Trail	2.62	117		29		2.85	38.7	2.11	56.3
480.1 (1575.0) Silty Fossiliferous Limestone Honaker Trail	2.66	123		59		4.99	40.6	1.71	53.0

Table 3-5. Summary of Rock Characteristics
(Page 6 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
485.1 (1591.5) Silty Fossiliferous Limestone Honaker Trail	2.67	130		67		5.24	46.1	3.41	85.0
487.8 (1600.5) Oolitic Limestone Honaker Trail	2.62	77		52		2.75	39.5	0.52	28.3
524.7 (1721.3) Limestone Honaker Trail	2.61	146		29		4.41	36.9	0.96	36.2
533 (1750) (R) Limestone Honaker Trail		207.2 ± 16.7	-10.0 ± 0.1	51.5 ± 4.6	0.27 ± 0.03				
546.8 (1793.8) Silty Limestone Honaker Trail	2.65	125		39		4.15	36.8	0.55	27.4
554.4 (1819.0) Calcareous Limestone Honaker Trail	2.65	103		32		3.08	38.5	0.97	37.9
560.5 (1839.0) Coarse-grained Sandstone Honaker Trail	2.18	16		6		0.81	19.2	0.97[e]	18.9

Table 3-5. Summary of Rock Characteristics
(Page 7 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
565 (1855) (R) Siltstone with Limestone & Ss Honaker Trail		89.1 ± 3.9	-6.8 ± 1.0	27.5 ± 1.9	0.43 ± 0.09				
566.7 (1859.1) Clayey Siltstone Honaker Trail	2.67	57		15		0.25[d]	32.2	0.28	17.0
574.8 (1885.7) Limestone and Silty Limestone Honaker Trail	2.71	112		57		3.23	41.6		Disc broken
581.6 (1908.0) Coarse-grained Sandstone Honaker Trail	2.39	38		10		0.23	23.8	0.21	10.8
								0.16	9.6
588.8 (1931.7) Silty Shale Honaker Trail	2.64	83		26		2.01	38.9	0.49	27.1
596.6 (1957.2) Limestone Honaker Trail	2.64	141		49		2.77[d]	45.2	1.91	62.5
614.6 (2016.3) Limestone Honaker Trail	2.65	146		48		6.12	49.1	3.58	92.9

Table 3-5. Summary of Rock Characteristics
(Page 8 of 15)

Depth m(ft) Description(a) Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
622.2 (2041.4) Silty Limestone Honaker Trail	Sample fractured during coring					4.19	49.9	1.98	70.1
628.1 (2060.6) Limestone Honaker Trail	2.64	149		46		5.51	46.3	1.42	55.2
640 (2100) (R) Silty Limestone Honaker Trail		135.8 ± 8.5	-10.0 ± 1.2	43.1 ± 0.6	0.27 ± 0.02				
650.7 (2134.7) Limestone Honaker Trail	2.64	193		47		4.84	45.2	2.94	77.5
653.7 (2144.7) Fossiliferous Limestone Honaker Trail	2.66	137		58		5.18	47.1	1.34	54.6
654.7 (2148.1) Fossiliferous Limestone Honaker Trail	2.67	177		54		5.32	44.4	4.84	97.6
657.4 (2156.7) Cherty Limestone Honaker Trail	2.68	139		64		3.59	44.8	2.77	74.6

Table 3-5. Summary of Rock Characteristics
(Page 9 of 15)

Depth m(ft) Description(a) Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
657.5 (2157.2) Cherty Limestone Honaker Trail	2.67	154		64		2.72	46.1	1.76	61.2
659.3 (2163.0) Cherty Limestone Honaker Trail	2.60	104		26		3.57	42.3	0.74	36.5
660.6 (2167.2) Cherty Limestone Honaker Trail	2.52	83		18		2.39	37.4	0.36	22.5
661.4 (2169.9) Silty Limestone Honaker Trail	2.62	137		33		3.92	35.7	2.03	50.9
665.6 (2183.6) Cherty Limestone Honaker Trail	2.70	129		63		5.94	46.3	1.90	63.9
670 (2200) (R) Cherty Limestone Honaker Trail		185.0 ± 24.5	-9.0 ± 1.0	60.9 ± 1.8	0.34 ± 0.06				
683.1 (2241.2) Cherty Fossiliferous Limestone Honaker Trail	2.66	131		53		5.58	45.5	3.14	80.6

Table 3-5. Summary of Rock Characteristics
(Page 10 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
699.6 (2295.3) Limestone Honaker Trail	2.67	198		60		6.77	48.9	3.74	94.6
701 (2300) (R) Limestone Honaker Trail		205.9 ± 15.3	-16.9 ± 5.9	60.3 ± 2.4	0.26 ± 0.04				
720.9 (2365.2) Cherty Silty Limestone Honaker Trail	2.63	197		42		4.32	42.7	2.53	67.9
736.3 (2415.6) Silty Limestone Honaker Trail	2.64	203		50		2.75	48.7	1.74	64.3
745.6 (2446.1) Calcareous Siltstone Honaker Trail	2.61	198		48		3.43[d]	45.6	2.50	72.1
750.2 (2461.2) Limestone Honaker Trail		Sample fractured during coring				6.20	48.9	1.75	64.7
764.9 (2509.6) Siltstone Honaker Trail		Sample fractured during coring				3.65[d]	35.0	0.43	22.8

Table 3-5. Summary of Rock Characteristics
(Page 11 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
774.3 (2540.4) Silty Limestone Honaker Trail	2.68	216		68		6.87	51.9	3.47	96.6
777 (2550) (R) Cherty Limestone Honaker Trail		174.0 ± 12.0	-15.1 ± 1.2	46.6 ± 3.7	0.29 ± 0.02				
782.9 (2568.6) Silty Limestone Honaker Trail	2.66	121		57		4.34[d]	44.1	0.60	34.2
789.7 (2590.9) Cherty Limestone Honaker Trail	2.65	164		58		3.56	47.0	1.82	63.4
795.6 (2610.4) Silty Limestone Honaker Trail	2.70	157		46		5.64	39.8	Broken abrasion disc	
804.2 (2638.4) Calcareous Siltstone Paradox	Sample fractured during hardness test					0.25[d]	32.5	1.27	36.6
804.6 (2639.9) Calcareous Siltstone Paradox	Sample too short for uniaxial test					0.72[d]	24.1	1.36	28.1

Table 3-5. Summary of Rock Characteristics
(Page 12 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
821.6 (2695.4) Silty Limestone Paradox	2.63	112		32		3.06[d]	31.5	0.60	24.3
830.1 (2723.4) Anhydrite Paradox	2.91	117		61		4.30	42.9	1.19	46.8
831 (2725) (R) Anhydrite Paradox		146.6 ± 6.8	-10.7 ± 0.7	65.0 ± 3.1	0.40 ± 0.04				
836.0 (2742.8) Dolomitic Limestone Paradox	2.69	179		46		4.55	35.7 44.5	2.86	60.4 75.3
845.7 (2774.6) Calcareous Siltstone Paradox		Sample fractured during coring				0.70[d]	22.7	0.60	17.5
851.2 (2792.5) Silty Limestone Paradox	2.62	135		31		4.21	33.7	1.13	35.7
860.8 (2824.2) Anhydrite Paradox	2.93	117		63		4.57[d]	38.2	0.86	35.5

Table 3-5. Summary of Rock Characteristics
(Page 13 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
874.8 (2870.1) Silty Dolomite Paradox	2.60	135		35		5.68	39.4	1.44	47.3
876 (2875) (R) Silty Dolomite Paradox		114.8 ± 7.1	-8.7 ± 1.2	24.2 ± 1.8	0.41 ± 0.04				
877.1 (2877.5) Silty Dolomite Paradox	2.53	91		26		2.92	33.7	0.70	28.2
895.5 (2938.0) Anhydrite and Salt Paradox	2.73	81		63		4.30	39.6	1.09	41.3
933.8 (3063.6) Anhydrite and Salt Paradox	2.88	89		43		-	32.2	0.59	24.6
934 (3065) (R) Anhydrite Paradox		72.3 ± 19.0	-5.7 ± 0.2	36.9 ± 12.2	0.43 ± 0.08				
936.7 (3073.2) Dolomitic Ss Paradox	2.52	56		17		1.28	19.3	1.84	26.1

Table 3-5. Summary of Rock Characteristics
(Page 14 of 15)

Depth m(ft) Description[a] Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion H_A	Abrasion H_{Total}
945.3 (3101.5) Anhydrite Paradox	2.93	64		48		2.20	30.6	0.50[f]	21.5
947.0 (3107.1) Siltstone Paradox			Sample fractured during coring			0.71	12.5		
977.2 (3206.0) Halite w/ Carnallite (Salt 6) Paradox			Sample fractured during coring			0.86		1.15[e]	
986.2 (3235.5) Halite w/ Carnallite (Salt Paradox			Sample fractured during coring			1.52	1.85	0.99	
1007.6 (3305.8) Halite w/ Anhydrite (Salt 6) Paradox	2.19	31		25		1.05		1.02	

Table 3-5. Summary of Rock Characteristics
(Page 15 of 15)

Depth m(ft) Description(a) Formation	Bulk Density (g/cc)	Uniaxial Compressive Strength (MPa) ± Standard Deviation	Indirect (Brazilian) Tensile Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio	Point Load Strength Index (P/D^2 [MPa])	Schmidt Rebound Hardness (H_R)	Abrasion	
								H_A	H_{Total}
1012.9 (3323.1) Halite w/ Anhydrite (Salt 6) Paradox	2.15	30		23		1.21		1.16	
1049 (3442) (R) Anhydrite Paradox		49.4 ± 21.4	-5.8 ± 0.4	25.0 ± 11.9	0.44 ± 0.17				

Note: MPa = Megapascal = 145 pounds per square inch.
GPa = Gigapascal = 145,000 pounds per square inch.
g/cc = grams per cubic centimeter = 62.43 pounds per cubic foot.
P/D_2 = Point-load at failure/(sample number)2.
H_R = Schmidt Hammer Rebound Number.
H_A = Reciprocal of weight loss of sample, in grams.

(a) Samples designated with an "(R)" in the first column indicate test results from Pfeifle et al., 1983, ONWI-450. All other test results are from WCC, 1982.
(b) No value reported because of nonlinear nature of stress-strain curve.
(c) Insufficient number of specimens available to complete original test matrix.
(d) Short core in point load test.
(e) Soft sample for abrasion test; linear extrapolation to 800 revolutions.
(f) Sample broken and glued for abrasion test.

Sources: Nelson et al., 1982, ONWI-400; Pfeifle et al., 1983, ONWI-450; WCC, 1982.

period is short relative to the natural heating episodes that produce natural gas and petroleum. Therefore, the amount of any additional overpressuring caused by heat from the emplaced waste is expected to be of minor effect.

A carnallite horizon lies within Salt Cycle 6 (Section 3.2.3.3). This horizon consists of minor quantities of carnallite and is also discussed in Section 3.2.7. The carnallite marker bed is expected to be located at least 9.1 meters (30 feet) from the repository, and at this distance the maximum temperature to which the carnallite will be exposed is 90 to 120 C (194 to 248 F). In this temperature range, hydrometamorphic reactions such as dehydration and phase transformation are possible, but melting is not expected. Carnallite begins to dehydrate at 90 C (194 F) and melts at 265 C (509 F) (Connor, 1983; Weast, 1984). Kieserite, which occurs in low quantities in Cycle 6 with the carnallite, begins to both dehydrate and melt at approximately 365 C (689 F) (Connor, 1983). Under hydrous conditions, carnallite may undergo phase transformations, but the expected products are minerals with higher melting points (Braitsch, 1971). Brine formation also accompanies the transformation reactions, but the low permeability of Cycle 6 halite suggests that brines resulting from carnallite decomposition or dehydration would probably remain in place and not migrate. Carnallite transformation reactions are accompanied by a small change in volume (Section 6.3.1.2.2). Therefore, although the data do not permit definitive conclusions, compelling evidence for geochemical processes that significantly decrease isolation does not exist (Sections 6.3.1.2.2 and 6.3.1.2.3).

In general the salt is relatively pure; however, numerous closely spaced thin laminae of anhydrite occur. Based on testing and direct observations these laminae do not represent planes of weakness. Only minute traces of gas were detected when drilling the GD-1 borehole. No brine pockets were detected. The basis for this evidence is limited (1 hole); therefore, the possibility of existence of such features (i.e., brine and gas pockets) has not been ruled out, since they are known to occur in the region.

In situ stress-strain, short-term creep, and state-of-stress for a number of salt cycles were measured in borehole GD-1 (Nelson et al., 1982, ONWI-400). The in situ data indicate short-term closure (creep deformation) rates in the borehole of 4.4×10^{-9} sec^{-1} at 988 meters (3,240 feet) in Salt Cycle 6 and 1.6×10^{-9} sec^{-1} at 1,105 meters (3,625 feet) in Salt Cycle 9. At 1,483 meters (4,865 feet) (Salt Cycle 19), the closure rate was approximately 42×10^{-9} per second. Nelson et al. (1982, ONWI-400, p. 18) noted that the Salt Cycle 6 creep rate is comparable to the borehole closure rate measured at a similar depth in the Asse salt mine in Germany. The GD-1 tests were conducted at in situ borehole temperature at each test depth, which ranged from 37 to 43 C (99 to 110 F). Laboratory testing of salt samples for creep properties demonstrates that creep rate increases with temperature (Pfeifle et al., 1983, ONWI-450, p. 40; Nelson et al., 1982, ONWI-400, p. 76). Laboratory creep data differ according to sample variability, stress level, and loading path (compression loading or extension unloading) (Nelson et al., 1982, ONWI-400, p. 80). These factors and other problems in scaling from the typical small laboratory sample sizes and short test times to the large size of the actual underground opening and long length of construction (and operation) period, together with the unknown influence of rock discontinuities, make predictions of creep closure of modeled data with laboratory data uncertain.

A material model for the thermomechanical behavior of the repository horizon salt is required for design and performance assessment calculations. The material model gives the relationship between load quantities such as stress and stress rate and deformation quantities such as strain and strain rate. The thermomechanical behavior of salt deviates markedly from the typical linear-elasticity, Mohr-Coulomb failure model that is often assumed to represent the material behavior of many brittle rocks. This deviation increases substantially as the temperature increases and therefore is especially important for the elevated temperatures associated with disposal of high-level nuclear waste.

The total deformation of salt can be divided into three components: elastic deformation, thermal expansion, and inelastic deformation. The elastic deformation and thermal expansion are readily modeled by the classical generalized Duhamel-Neumann form of Hooke's Law

(Sokolnikoff, 1956). The elastic constants (e.g., Young's modulus, E, and Poisson's ratio, n) are readily evaluated from unload-reload cycles performed on specimens that are deformed in triaxial compression (Pfeifle et al., 1983, ONWI-450). The coefficient of linear thermal expansion, $alpha_L$, is determined by measuring the change in specimen dimensions that corresponds to a specified change in specimen temperature (Yang, 1981). Following are the values and standard deviations for Young's modulus, Poisson's ratio, and the coefficient of thermal expansion for Cycle 6 salt and Cycle 6 carnallite at Paradox Basin:

	Cycle 6 Salt	Cycle 6 Carnallite Marker Horizon
Young's modulus	E = 26.9 ± 3.2 GPa	E = 29.8 ± 3.3 GPa
Poisson's ratio	n = 0.31 ± 0.06	n = 0.36 ± 0.04

Coefficient of linear thermal expansion, $alpha_L$ $(42 \pm 3) \times 10^{-6}$ per K (for both salt and carnallite horizon samples)

The elastic and thermal expansion contributions to salt deformation, although important for calculating thermal stresses resulting from waste-generated heat, are often insignificant when compared to the large inelastic deformations that are produced by the stresses, temperatures, and times of interest for nuclear waste isolation. The inelastic deformation is primarily viscoplastic (i.e., ductile behavior in which the stress depends not only on the strain, strain history, and temperature, but also on the rate of strain). Over the range of temperature of interest, the viscoplastic behavior is strongly temperature dependent.

The inelastic deformation has been modeled using the exponential-time model (Senseny, 1985). This is a semiempirical model based on first-order kinetics and incorporates both transient and steady-state deformation. Stress and temperature dependence of the deformation is incorporated using a functional form that assumes that deformation results from a diffusion controlled micromechanism, which is expected to be operable at the stresses and temperatures expected for a nuclear waste repository. Values for the inelastic parameters in the exponential-time constitutive model have been determined for the Paradox Cycle 6 salt (Senseny, 1985). Although this model poorly reproduces the laboratory data from which it was derived, it does predict strain rates approaching steady-state conditions fairly well, and is adequate for preliminary repository design and performance assessment calculations since long-term behavior can be modeled with some confidence. However, based on comparisons of predicted and measured strains, the transient part of the exponential-time model requires substantial revision. Therefore, short-term behavior cannot be accurately predicted with this model. Additionally, more tests need to be performed so that the uncertainty associated with the parameter values can be reduced. The uncertainty in the model results from both salt variability and lack of fit of the model.

Failure of salt over the stress and temperature ranges of interest can be either brittle or ductile. Failure under either mode is defined to occur when peak stress is reached. At low mean stress and low temperature, brittle failure is observed; at higher mean stress and temperature brittle failure is suppressed and the salt undergoes very large deformations without fracturing. For example, triaxial compression tests performed using Cycle 6 salt at 24 C (75 F) and at a constant stress rate of 2.5×10^{-2} megapascals (MPa) per second show that brittle failure is suppressed at confining pressures greater than about 5 MPa and that the test is stopped at about 12 percent specimen shortening when the limits of the apparatus are reached (Pfeifle et al., 1983, ONWI-450). This shortening corresponds to a true strain of about 14 percent, and there is no evidence of fracture. The hardening modulus (rate of change of true stress with respect to true strain in the plastic range), however, is very low so that the stress when the test is stopped is close to the peak stress.

The envelope of Mohr's circles at the end of the tests is characterized by a nonlinear Mises-Schleicher law that empirically assumes an exponential decay in the mean stress dependence of the shear strength: $J_2' = K + alpha\ [1-exp(-beta J_1)]$, where:

J_2' = the second invariant of the deviator stress
J_1 = the first invariant of stress
K,alpha,beta = fitting parameters.

This Mises-Schleicher model was chosen instead of a similar Mohr-Coulomb model because the manner in which the Mises-Schleicher model incorporates the influence of the intermediate principal stress is thought to be more appropriate for ductile behavior. Following are the values of the Mises-Schleicher parameters for Cycle 6 salt and Cycle 6 carnallite at Paradox Basin; included are the uncertainties in the parameters' values:

	Cycle 6 Salt	Cycle 6 Carnallite Marker Horizon
k	= 2.2 ± 0.7 MPa	1.5 ± 1.0 MPa
alpha	= 48.2 ± 2.4 MPa	47.1 ± 2.7 MPa
beta	= 0.013 ± 0.001 MPa^{-1}	0.015 ± 0.002 MPa^{-1}

The uncertainty results from both material variability and lack of fit of the model.

State of stress computations, based on the hydraulic fracturing test results from GD-1 and elastic model analysis, were made by Nelson et al. (1982, ONWI-400, p. 25). The present interpretation of the existing stress measurements is based in part on the research of Boyce et al. (1984) and Carter and Hansen (1983).

Boyce et al. (1984) demonstrated in a series of laboratory experiments on Avery Island salt that conventional hydraulic fracturing testing and analysis techniques determined minimum stress to within 15 percent for applied hydrostatic stress conditions on a salt sample, but overestimated minimum stress by as much as 60 percent for applied nonhydrostatic stress conditions. Their results show that although the hydraulic fracturing results in salt were not time-dependent (breakdown pressures did not decrease for boreholes pressurized for up to 64 hours before hydraulic fracturing), measurement data were otherwise inconsistent with elastic behavior, and were insensitive to the range of nonhydrostatic stress conditions (maximum horizontal stress 0-20.7 MPa, minimum horizontal stress 0-13.84 MPa) applied to the test specimens.

Carter and Hansen (1983) describe research results which indicate that the subgrain size of a salt sample is a function of the maximum stress difference ever imposed on the sample in past time. Their subgrain size data for Paradox Basin rock salt correspond to a maximum stress difference of approximately 2.5 MPa different than the present assumed vertical stress, and consequently can be interpreted to infer a near-hydrostatic stress condition in Paradox salt.

In the in situ testing for stress by Nelson et al. (1982, ONWI-400, p. 39) the minimum horizontal stress was analyzed as approximately equal to the lithostatic pressure of the overburden. This result is interpreted to be correct to within approximately 15 percent in view of the inferred hydrostatic stress condition based on research by Carter and Hansen (1983) and Boyce et al. (1984) using the same conventional analysis techniques as did Nelson et al. (1982, ONWI-400). It is noted that the analyses results by Nelson et al. (1982, ONWI-400, p. 39) show that maximum in situ stress is also approximately equal to lithostatic pressure, if the pore pressure component in the conventional hydraulic fracturing equation is assumed to be equal to lithostatic pressure. If, however, pore pressure is equated to a lesser value (i.e., the variation of hydrostatic head of drilling mud with depth), then the calculated in situ stress values indicate strongly anisotropic conditions. In the present instance this anisotropic condition would be of the order of 1.5:1 (maximum horizontal stress to minimum horizontal stress). There does not appear to be any reliable pore pressure measurement data for salt under high confining (consolidation) pressure, but considering the relatively impermeable nature of salt, its plasticity, low porosity, and low moisture content, the assumption of pore pressure equal to lithostatic pressure does not appear unreasonable. Consequently, it has been concluded with some uncertainty that maximum horizontal stress is equal to minimum horizontal stress, which is equal to vertical overburden pressure. In other words, an isotropic stress condition equal to lithostatic pressure is assumed to exist in the salt at the Davis Canyon site.

An uncertainty relative to the stress measurements is that they apply only to salt strata within the Paradox Formation. There may be stress anisotropy, and a maximum in situ stress that is greater than lithostatic pressure in the sedimentary rock overburden above the salt is likely. Such stress conditions are indicated by the presence of valley anticlines observed west of the site area (Section 3.2.5.4). A high maximum in situ stress may produce stress concentrations around the excavations that exceed the available strength of the rock near the walls, where confining pressures are low. This can lead to a disturbed zone of fractured rock surrounding such openings.

3.2.6.2 Thermal Properties

In situ temperature data were obtained to a depth of 1,920 meters (6,300 feet) in GD-1; a temperature range of 34 to 43 C (93.2 to 109.4 F) for the Paradox Formation (899 to 1,600 meters [2,950 to 5,250 feet]) was measured. The surface temperature was 15 C (59 F). The measurements are representative of in situ thermal equilibrium conditions (Sass et al., 1983a, p. 3). Room temperature determinations of thermal conductivity of the Paradox Formation by Sass et al. (1983b, p. 14) were consistent with published values for these evaporites (approximately 6 watts per meter per degree Kelvin [W/m-K]).

Thermal properties of salt and nonsalt rocks in the Paradox Basin were determined from laboratory tests of core from the Salt Valley DOE-3 and GD-1 boreholes (Table 3-6). Test procedures are described in a report of investigations (Lagedrost and Capps, 1983, BMI/ONWI-522). Thermal properties investigated include thermal expansion, thermal conductivity, and specific heat capacity. The thermal conductivity data of Lagedrost and Capps (1983, BMI/ONWI-522, p. 62) were analyzed by Tammemagi et al. (1985, ONWI-364) as a function of temperature. Some of the earlier analyses results are presented in Wagner et al. (1985, BMI/ONWI-512, p. 58).

Other thermal effects that are potentially important in salt are thermally induced brine migration and thermal decrepitation. Laboratory and field tests have shown that when a heat source is placed in a salt deposit, brine trapped in salt has a tendency to move toward the heat source. No data on brine migration are yet available for the Paradox Formation, but an average brine inflow of 0.5 to 3.0 milliliters (0.001 to 0.01 ounce) per day was reported for field experiments at Project Salt Vault in Kansas (Carter and Hansen, 1983, p. 317).

Thermal decrepitation involves fracturing and disintegration of the salt upon heating. This phenomenon has occurred in some salts at temperatures of 240 to 400 C (464 to 752 F) (Bradshaw et al., 1968, p. 651). In laboratory tests, Paradox Cycle 6 salt has been tested up to 450 C (842 F) without decrepitation (Senseny, 1982, ONWI-9[82-4]).

3.2.6.3 Natural Radiation

Naturally occurring radioactivity is observed in small amounts within the Davis Canyon site vicinity and is generally limited to the Moss Back Member of the Chinle Formation. Examination of borehole gamma ray logs shows minor amounts of naturally occurring radiation within the potash zones of the Paradox Formation and scattered in small silt and clay zones throughout the stratigraphic section (WCC, 1982, ONWI-290, Vol. II). A spectral gamma (NURE-Bendix KUT) log of the GD-1 borehole showed the radiation to be minor in these occurrences (WCC, 1982, ONWI-388, Vol. I. pp. 52-54, Figure 4-1; Vol. IV, Figure E-3).

3.2.7 Geochemistry

3.2.7.1 Host Rock Chemical Properties

At the GD-1 borehole the Salt Cycle 6 host unit is approximately 73 meters (241 feet) thick. The thickness of Salt Cycle 6 is expected to be approximately 61 meters (200 feet) at the Davis Canyon geologic repository operations area (GROA) (Section 3.2.3.3). Thin wave-like anhydrite bands in Salt Cycle 6 occur at intervals of 3 to 9 centimeters (0.1 to 0.3 foot) and range in thickness from 0.3 centimeter to 2.5 centimeters (0.125 to 1 inch). Generally, the

Table 3-6. Summary of Thermal Properties of Paradox Cycle 6 Salt[a]

Borehole	Number of Samples	Density ($\times 10^3$ kg/m^3)	Heat Capacity (J/kg·K)	Coefficient of Linear Expansion ($\times 10^{-6}$ K^{-1})
Salt Valley DOE-3	4	2.17 (0.01)	907 (2)	41.6 (1.8)
GD-1	4	2.20 (0.04)	929 (4)	45.4 (1.5)

(a) Average values are given with standard deviations in parentheses.

Source: Tammemagi et al., 1985, ONWI-364.

primary mineral constituents of Salt Cycle 6 are halite (78.7 to 96.4 weight-percent), anhydrite (1.4 to 6.7 weight-percent), carnallite (0.2 to 7.8 weight-percent), and kieserite (less than 0.01 to 4.1 weight-percent) (Hite, 1983, Table 1).

Halite samples from Salt Cycle 6 have organic carbon contents ranging from 0.05 to 0.51 percent, demonstrating the organically rich nature of the Paradox saline facies relative to most other salt deposits (Hite, 1983, Table 3). The organic carbon content of the interbed immediately above Salt Cycle 6 ranges from 0.07 to 1.46 weight-percent (Hite, 1983, Table 3). In Salt Cycle 6, the presence of chevron growth features (Roedder, 1984) and distinctive bromine (Br) profiles with high Br concentrations in the upper parts of the cycle (Hite, 1983, Figures 8 and 9) suggest that no outside ground water has affected the salt cycles at GD-1. An influx of outside ground water would be expected to have modified the Br profiles and the chevron features.

Salt Cycle 6 includes a carnallite-containing marker bed, defined here as that portion of the unit having a potassium content in excess of 0.05 weight-percent, which is approximately 46 meters (150 feet) thick in the upper part of the horizon (Hite, 1983, Figures 43, 45). Based on regional subsurface gamma logs, the thickness of the carnallite marker bed is assumed to decrease considerably in the site area (Hite, 1982b). Based on the gamma log of GD-1, the carnallite marker is 20 meters (66 feet) thick (Section 3.2.3.3).

The carnallite marker bed consists of a mixture of halite, carnallite, kieserite, anhydrite, sylvite, magnesium-borates, magnesite, polyhalite and trace amounts of quartz, goethite, biotite, muscovite, anatase, rutile, talc, and clay minerals (Hite, 1982b; 1982, ONWI-9[82-1]); 1983; Conner, 1983; Bodine and Rueger, 1984; Fukui and Hopping, 1984). Detailed clay mineralogical analyses of Cycle 6 by Padan et al. (1984) show well-ordered chlorite and saponite mixed-layer clays in anhydrite-rich zones. In halite-rich samples, serpentine, Al-talc, and chlorite type mixed-layer clays are found.

The host salt contains small amounts of brine as fluid inclusions and intergranular water in halite, and as hydration water in clay minerals, carnallite, and kieserite. Kieserite and polyhalite begin to dehydrate at 365 and 300 C (689 and 572 F), respectively, and thus will not release water under expected maximum repository temperatures of 250 C (482 F) (Conner, 1983). Most of the water content in Cycle 6 salt is present as hydration water in carnallite and kieserite; essentially all of the water released from Salt Cycle 6 high potassium zones at 200 C (392 F) and less will be from carnallite (Conner, 1983). Available data on the water content of halite, clay, and carnallite in Cycle 6 salt permit the calculation of the maximum amount of brine that will be available for migration to and corrosion of a waste package. The calculations are presented in detail below and summarized in Table 3-7:

1. Water in Halite: Most water in Salt Cycle 6 is present in hydrous minerals such as carnallite (Conner, 1983). For this analysis the amount of fluid inclusion and intergranular water in halite is conservatively assumed to be 0.5 weight-percent. Halite comprises approximately 90 percent of Cycle 6 strata (Hite, 1983). Hence, 0.45 weight-percent water can be derived from the halite source.

2. Water in Clays: The total clay content of Cycle 6 Salt is low, and most clays are concentrated in thin anhydrite interbeds (Weaver and Padan, 1983). If it is conservatively assumed that anhydrite comprises 10 percent of Cycle 6 salt (Weaver et al., 1982a; Padan et al., 1984; Hite, 1983) and clay minerals comprise 10 percent of the anhydrite interbeds (Weaver et al., 1982a; Padan et al., 1984; Hite, 1983), then Cycle 6 salt contains 1.0 weight-percent clay. The clay water content is conservatively estimated to be 15.0 weight-percent and is likely more on the order of 7 percent or less (Weaver et al., 1983; Padan et al., 1984; Conner, 1983). Therefore assuming total dehydration of clay, 0.15 weight-percent water can be derived from Cycle 6 clays.

3. Water in Carnallite: Average carnallite water content obtained from two different sources are in reasonably good agreement. Hite (1983) reports that 1.26 weight-percent water is the total theoretical yield from dehydration of the upper section

of Salt Cycle 6 at 200 C (392 F). Hite (1982b) reports that the mean carnallite content of the upper section of Cycle 6 is 2.39 weight-percent. Carnallite is 38.9 percent water by weight. Therefore total dehydration of a rock bearing 2.39 percent carnallite can yield 0.93 weight-percent water. The higher, more conservative, value of 1.26 weight-percent water is used in the following calculations.

4. Sum of Water from Halite, Clays, and Carnallite: 0.45, 0.15, plus 1.26 weight-percent water from halite, clays, and carnallite, respectively, equals 1.86 total weight-percent water.

5. Conversion from Weight-Percent Water to Volume-Percent Water: Assuming a density of water of 1.00 grams per cubic centimeter and average density of Cycle 6 salt (mostly halite) of 2.16 grams per cubic centimeter (Weast, 1984), then 1.86 weight-percent water converts to 3.93 volume-percent water.

6. Conversion from Volume-Percent Water to Volume-Percent Brine: The volumetric expansion of water upon saturation with halite at 90 C (194 F) is readily calculated from density and halite solubility data given in Seidell (1919) and is equal to 18.6 percent. This accounts for both the thermal expansion of water from 25 to 90 C (77 to 194 F) as well as the volumetric expansion of water upon saturation with halite. Assuming 19 percent expansion, then 3.93 volume-percent water converts to 4.68 volume-percent brine.

Therefore, the maximum amount of brine expected to be available for migration toward and corrosion with waste packages at the Davis Canyon site is 4.7 volume percent, which is lower than the 5.0 volume percent brine value assumed for the waste package corrosion calculations in Section 6.4.2.3.2. The above calculations are based on conservative approximations of the total amount of water available from the halite, clay, and carnallite sources.

It is unlikely that all of the fluid inclusion and intergranular water will migrate to the waste package at repository temperatures. The migration of intergranular water may be blocked, and molecular water may remain trapped in halite even at high temperatures despite long periods of heating (Roedder and Bassett, 1981). Clays will release only absorbed and interlayer water at temperatures less than 300 C (572 F); loss of lattice hydroxyl groups generally occurs at temperatures exceeding 400 C (752 F) (Grim, 1968). In addition, carnallite loses water in stages with increasing temperature, and the amount of water that will be released from carnallite dehydration in the repository thermal environment is expected to be significantly less than its total theoretical yield. For example, Conner (1983) indicates that carnallite will release little or no water at temperatures less than 90 C (194 F). The first four waters of hydration are lost from 90 to 150 C (194 to 302 F), and complete dehydration does not occur until approximately 185 C (365 F) (Conner, 1983). If the above brine availability calculations reflected realistic as opposed to conservatively estimated values for clay (7.5 instead of 15 weight-percent water content) and carnallite (loses only 4 waters of hydration instead of all 6), then the total amount of brine available for waste package corrosion would be 3.45 volume-percent (Reference Case B in Table 3-7).

The permeability of the halite matrix is probably such that water evolved from the carnallite will remain in the immediate vicinity of the carnallite. Therefore, the brine available for waste package corrosion may be restricted to fluid inclusions and intergranular water in halite as well as absorbed and interlayer water in clays, in which case the total brine volumes would amount to only about 1.34 volume-percent (Reference Case C in Table 3-7).

Site-specific compositional data for Cycle 6 brines are not available. If similar to Waste Isolation Pilot Plant (Brine A in Table 6-11) and expected Palo Duro Basin, Texas (Hubbard et al., 1984) brines, then Paradox Basin thermally migrating brines would be expected to be relatively high in magnesium and potassium in addition to sodium and chloride.

Table 3-7. Paradox Cycle 6 Brine-Content Calculations for Davis Canyon Site (Conservatively Overestimated and Two Reference Cases)

Data and Calculations	Conservatively Overestimated Case A	Reference Case B	Reference Case C
1. Water in Halite			
a. Weight percent water in clay-free halite	0.5	0.5	0.5
b. Percent halite in Cycle 6 strata	90[a]	90[a]	90[a]
c. Weight percent water from halite (1a x 1b x .01)	0.45	0.45	0.45
2. Water in Clay			
a. Weight percent water in clay	15.0[c,d,e]	7.5[c,d,e]	7.5[c,d,e]
b. Percent clay in Cycle 6 strata	1.0[a,b,c]	1.0[a,b,c]	1.0[a,b,c]
c. Weight percent water from clay (2a x 2b x .01)	0.15	0.075	0.075
3. Water in Carnallite			
a. Total theoretical water yield at 200° C (weight percent)	1.26[a]	0.84[a,e,f]	0.0[a,e,g]
4. Total Weight Percent Water from Halite, Clay and Carnallite (1c + 2c + 3a)	1.86	1.365	0.525
5. Conversion to Volume Percent Water			
a. Weight water (grams) per 100 grams Cycle 6 strata (4)	1.86	1.365	0.525
b. Density water	1.00[h]	1.00[h]	1.00[h]
c. Volume water (cubic centimeters) per 100 grams Cycle 6 strata (5a divided by 5b)	1.86	1.365	0.525
d. Weight rock (grams) per 100 grams Cycle 6 strata (100-5a)	94.14	98.635	99.475
e. Density rock	2.16[h]	2.16[h]	2.16[h]
f. Volume rock (cubic centimeters) per 100 grams Cycle 6 strata (5d divided by 5e)	45.435	45.664	46.053
g. Volume water plus rock (cubic centimeters) per 100 grams Cycle 6 strata (5c + 5f)	47.295	47.029	46.578
h. Volume percent water (5c divided by 5g)	3.93	2.90	1.13
6. Conversion to Volume Percent Brine			
a. Volumetric expansion of water upon saturation with halite at 90° C (percent)	19[i]	19[i]	19[i]
b. Total volume percent brine (5h + [.01 x 6a x 5h])	4.68	3.45	1.34

(a) Hite, 1983.
(b) Weaver et al., 1982a.
(c) Padan et al., 1984.
(d) Weaver et al., 1983.
(e) Conner, 1983.
(f) Carnallite assumed to release only 4 of its 6 waters of hydration.
(g) Carnallite assumed to release none of its 6 waters of hydration.
(h) Weast, 1984.
(i) Seidell, 1919.

Brines could also form by dissolving salt in the unlikely event that the repository is flooded by external water. The composition of these types of brines is relatively well known in that they represent the water soluble fraction of the salt rock. Such intrusive brines are expected to be of low-magnesium and low-potassium type, with compositions similar to that of the Permian Basin No. 1 and No. 2 brines in Table 6-11. The compositions of these Permian Basin brines in Table 6-11 are in relatively good agreement with that of an experimentally produced composite Paradox Basin dissolution brine as reported by Pederson et al. (1984).

3.2.7.2 Hydrochemistry

Because of the diverse lithologies and sources of water (WCC, 1982, ONWI-290, Vol. II, pp. 9-6 to 9-10), several chemically different types of water can be expected in the upper hydrostratigraphic unit (Section 3.3.2). Available data suggest that much of the water in the upper part of this unit is of the calcium-bicarbonate type and is relatively low in total dissolved solids (TDS). This water type probably represents an active flow system close to recharge areas, where calcium and bicarbonate are picked up from the soil zone as precipitation infiltrates downward. The carbonate strata in this unit probably also contribute calcium and bicarbonate ions to the recharging water, which is undersaturated with respect to calcite.

Deeper in the upper unit, sodium-chloride type water with higher concentrations of TDS becomes more prevalent. High-TDS/sodium chloride water was produced from the Honaker Trail and Elephant Canyon Formations at the GD-1 borehole; relatively low-TDS/sodium chloride water flows from springs in several areas (WCC, 1982, ONWI-290, Vol. II, pp. 9-6, 9-10). The two prevalent water types, calcium bicarbonate and sodium chloride, may suggest the presence of two separate hydrostratigraphic units within what is presently defined as the upper hydrostratigraphic unit.

Water chemistry data available from the upper hydrostratigraphic unit indicate a general trend from dilute calcium bicarbonate type water in the shallow subsurface to the sodium chloride-type brines in the lower part of the upper unit. These trends have been interpreted (McCulley et al., 1984, pp. 52, 67) to be a result of short travel distances of meteoric water in the shallow subsurface, whereas deeper in the upper unit the ground water of meteoric origin is mixing with and diluting ancient evaporated sea water, which has been altered by rock-water interactions. Five alternate interpretations are also discussed by McCulley et al. (1984). One of these interpretations is that the brine may have resulted from salt dissolution (Section 3.2.5.6).

Hydrogeochemical data from the middle hydrostratigraphic unit, containing salt beds, were not obtained at GD-1. Low permeabilities and extremely low flow rates precluded the collection of representative formation water during drill stem and long-term testing at GD-1 (WCC, 1982, ONWI-290, Vol. II, pp. 9-11; Thackston et al., 1984, ONWI-491). As a result of low permeabilities, the flow rates of each of the tests were less than 0.06 cubic meters per day (2.3 cubic feet per hour) during the initial flow periods, diminishing in the second flow period. Test interval thicknesses ranged from approximately 15 to 60 meters (50 to 200 feet).

Although the regional geochemical data base contains analytical results of water reportedly from the middle hydrostratigraphic unit, these results are not validated owing to the lack of information on the sample collection procedures. Many of these data points are from the fossiliferous carbonate beds in the southeastern part of the Paradox Basin, which are the stratigraphic equivalents of some of the salt cycles at the site. However, the flow regime and concomitant water chemistry in these two areas are probably different, because the isolating influence of the relatively impermeable interbeds and salt sequence in the Davis Canyon candidate area creates different conditions than the more permeable fossiliferous limestones to the southeast, many of which are not overlain by salt units. Therefore, these data are probably not representative of conditions at the site.

Concentrated and overpressurized brines have been encountered in the Paradox Basin, often occurring in clastic units between the Paradox salt beds (Mayhew and Heylmun, 1966, pp. 226-234). All of the reported occurrences are away from the Davis Canyon site and from stratigraphically deeper zones.

Water in the lower hydrostratigraphic unit in the candidate area is of the sodium chloride type, with TDS values ranging from approximately 80,000 to over 300,000 milligrams per liter. Chlorine to bromine and sodium to chloride ratios in water from the lower unit at GD-1 suggest that this salinity is related to salt dissolution (WCC, 1982, ONWI-290, Vol. II, pp. 9-14). Much of the dissolution is interpreted to occur in the folded and faulted area of the Paradox Basin east of the Davis Canyon site (e.g., along the Moab and Lisbon faults) or in Lockhart Basin (see Section 3.2.5.6).

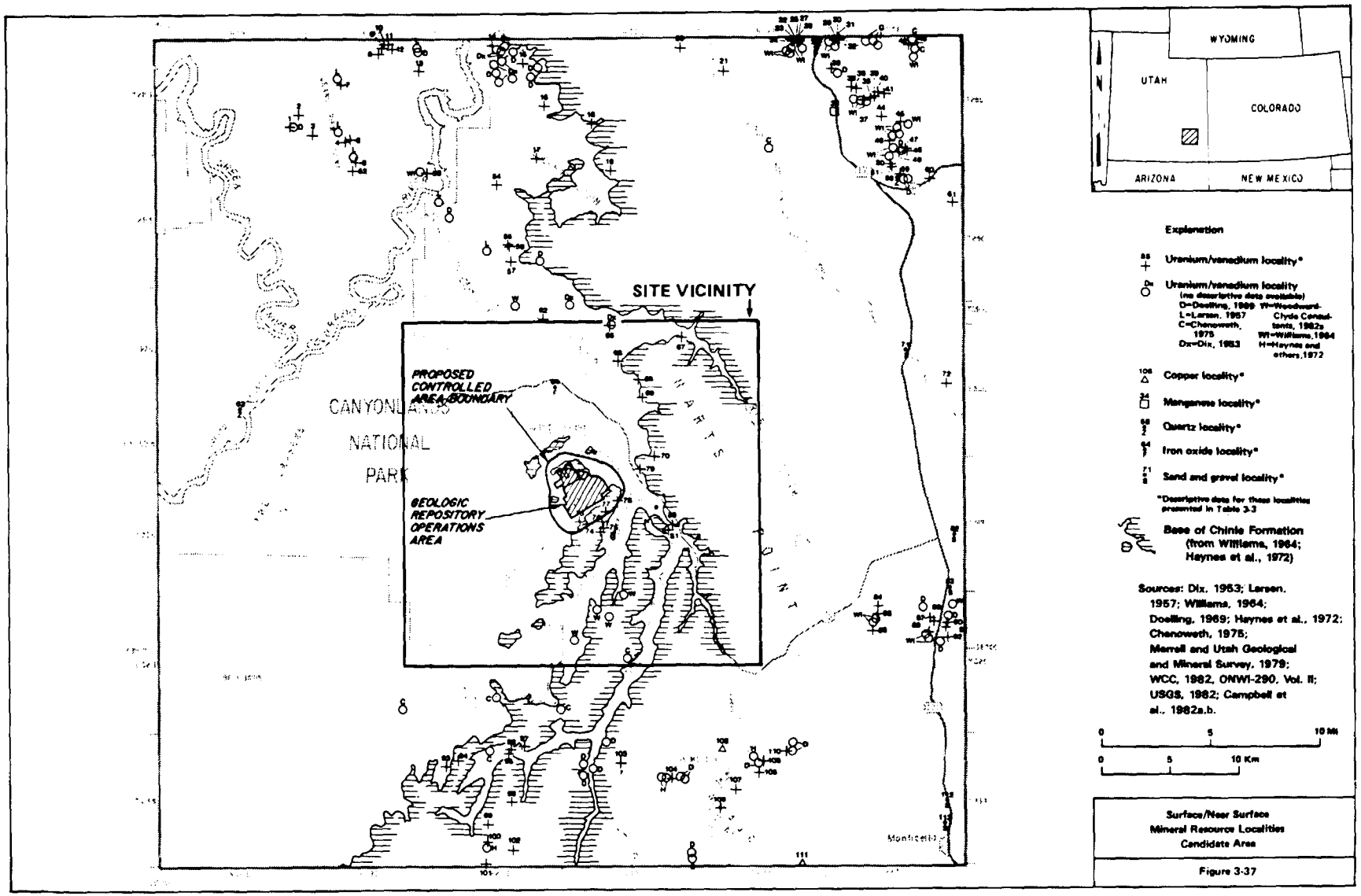
Ground water in the lower hydrostratigraphic unit below the host salt consists of brines containing methane (1.14 to 5.43 volume-percent), ethane (0.3 to 0.6 volume-percent), and sulfide (30 to 80 milligrams per liter) and is therefore considered to be chemically reducing (McCulley et al., 1984; WCC, 1982, ONWI-290, Vol. II, pp. 9-15). Platinum electrode Eh measurements range from -80 to -240 mV for lower hydrostratigraphic unit formation fluids (McCulley et al., 1984). Sulfate and sulfide redox couple calculations yield Eh values of -113 to -143 mV, which are in good agreement with measured Eh (McCulley et al., 1984). Measured and calculated Eh values are within the stability field of pyrite, which is present in both the Paradox Formation and Leadville Limestone in limited concentrations. Microbially mediated reduction of sulfate to sulfide actively occurs in the Leadville Limestone (McCulley et al., 1984). Measured Eh and calculated values for the sulfur redox couple are not in agreement with calculated values from the iron and arsenic redox couples; however, iron and arsenic speciation in the lower hydrostratigraphic unit samples analyzed was believed to have been strongly skewed by analytical interferences (McCulley et al., 1984). Lindberg and Runnels (1984) point out that obtaining reliable Eh measurements in ground water is problematic; however, the presence of redox-sensitive species such as sulfide and methane can provide at least a qualitative guide to the redox status of water. At these lower redox potentials expected in the lower hydrostratigraphic unit, redox-sensitive radionuclides such as uranium, neptunium, plutonium, and technicium, are expected to be stable in their lower oxidation states (Cleveland et al., 1983; Cleveland, 1979a, b; Bondietti and Francis, 1979; Langmuir, 1978).

Of the drill-stem test fluids collected from the Leadville Limestone at GD-1, only one sample contained no detectable drilling-fluid contamination. The total organic carbon concentration of this sample as measured in two different laboratories was 15 (McCulley et al., 1984) and 12.8 milligrams per liter (Means et al., 1983, ONWI-448). Sample volumes available were insufficient for detailed organic geochemical analysis; however, McCulley et al. (1984) report the presence of short-chain aliphatic acids in this and other drill-stem test fluids containing low but detectable drilling-fluid contamination. While available organic geochemical data on deep Paradox Basin brines are insufficient to reach definitive conclusions, if short-chain aliphatic acid anions are the principal organic species present, then significant radionuclide complexation would not be expected (Means and Hubbard, 1985, BMI/ONWI-578).

3.2.8 Mineral Resources

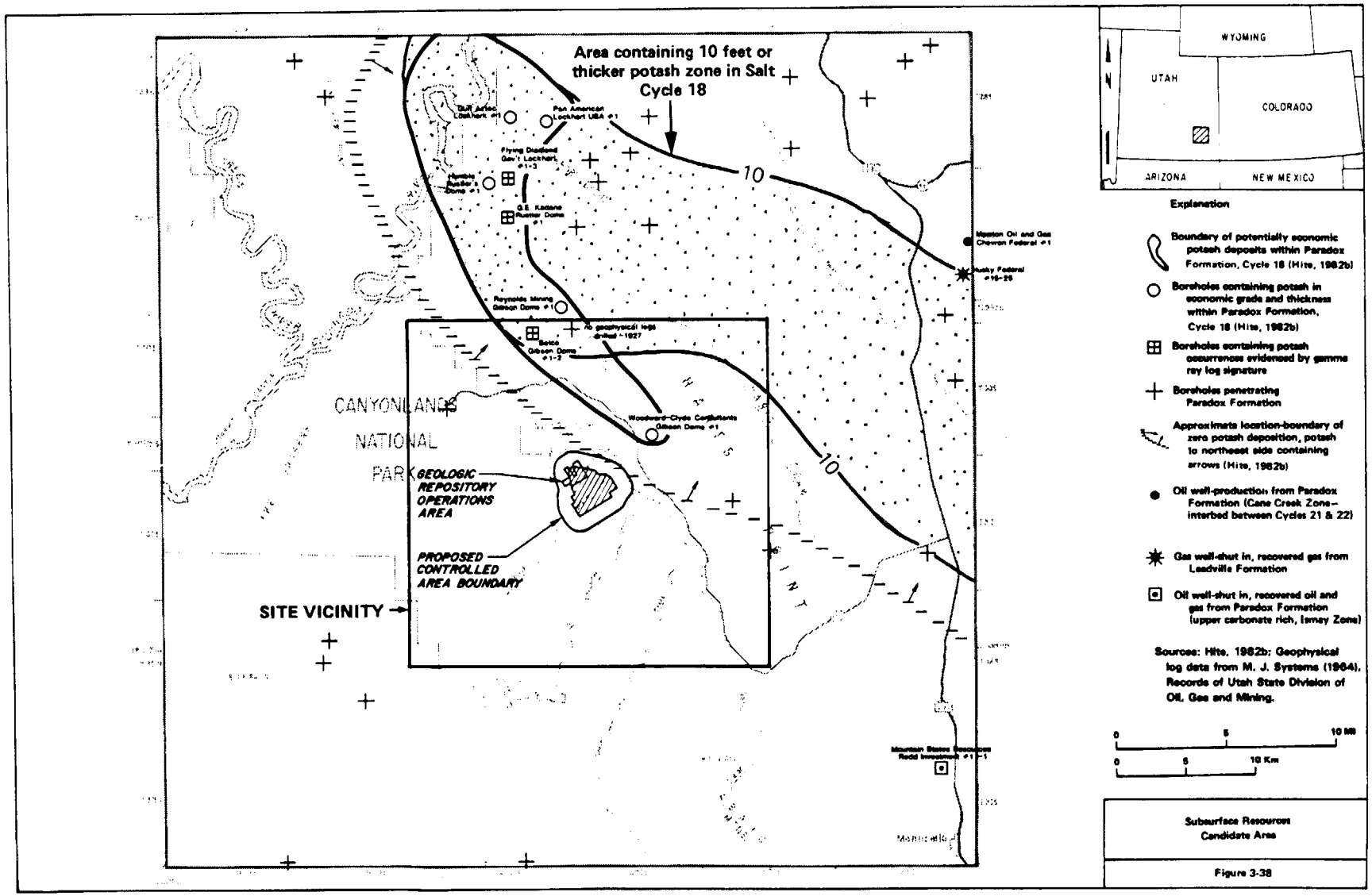
Known mineral resources within the Davis Canyon candidate area consist primarily of uranium and vanadium (184 of 196 known mineral localities within the candidate area) and deposits of potash (Figures 3-37 and 3-38). Minor surface deposits consist of copper, manganese, quartz, iron oxide, and sand and gravel (USGS, 1982; Merrell and Utah Geological and Mineral Survey, 1979, pp. 32-42; Hite, 1982b, p. 3). Dimension stone also occurs throughout the candidate area in the Moenkopi and Chinle formations and Wingate Sandstone, but no formal localities for this resource exist in the candidate area (Merrell and Utah Geological and Mineral Survey, 1979, p. 58). The Paradox Formation evaporite sequence includes extensive halite deposits.

Known and potential hydrocarbon resources within the candidate area consist of oil and gas in the following subsurface formations that have been productive elsewhere in the Paradox



Surface/Near Surface Mineral Resource Localities Candidate Area

Figure 3-37



Subsurface Resources Candidate Area

Figure 3-38

Basin: the Honaker Trail, Paradox, Leadville, Ouray, and Elbert Formations (Merrell and Utah Geological and Mineral Survey, 1979, pp. 24-27, 62). Coal-bearing units such as the Dakota Formation are not present within the candidate area.

The site vicinity contains no known hydrocarbon resources, and there has been no production, according to records at the Utah Division of Oil, Gas, and Mining. Potential hydrocarbon resources are judged to be classified as "undiscovered speculative resources," using the classification system in Bureau of Mines and USGS (1976, pp. A2-A4).

The Davis Canyon site vicinity contains mineral resources of uranium, vanadium, potash, iron oxide, sand, gravel, and dimension stone (Figure 3-37). Resource production has consisted of uranium, vanadium (the most recent in 1983), and a minor amount of sand and gravel (Merrell and Utah Geological and Mineral Survey, 1979, pp. 32-42; Merrell, 1983). These resources were classified, according to the system of the Bureau of Mines and USGS (1976, pp. A2-A4), as follows:

- Uranium and vanadium - "identified indicated reserves"
- Potash, iron oxide, sand, gravel, dimension stone - "identified submarginal resources."

Known production of uranium and vanadium resources in the site vicinity has been small to large, and potential resources remaining have been estimated to be none to medium (USGS, 1982). Known uranium localities are generally restricted to the Chinle Formation (Figure 3-37), whose lower contact is stratigraphically located 914 to 1,003 meters (3,000 to 3,290 feet) above Salt Cycle 6. The base of the Cutler Formation (containing uranium localities nearby to the north) is located stratigraphically 724 meters (2,375 feet) above Salt Cycle 6 (WCC, 1982, ONWI-290, Vol. II, Figures 5-15, 5-17).

The extensive halite beds of the Paradox Formation constitute a halite resource. However, its depth in the candidate area, its low value, and the abundance of recoverable halite elsewhere, virtually exclude any potential for development.

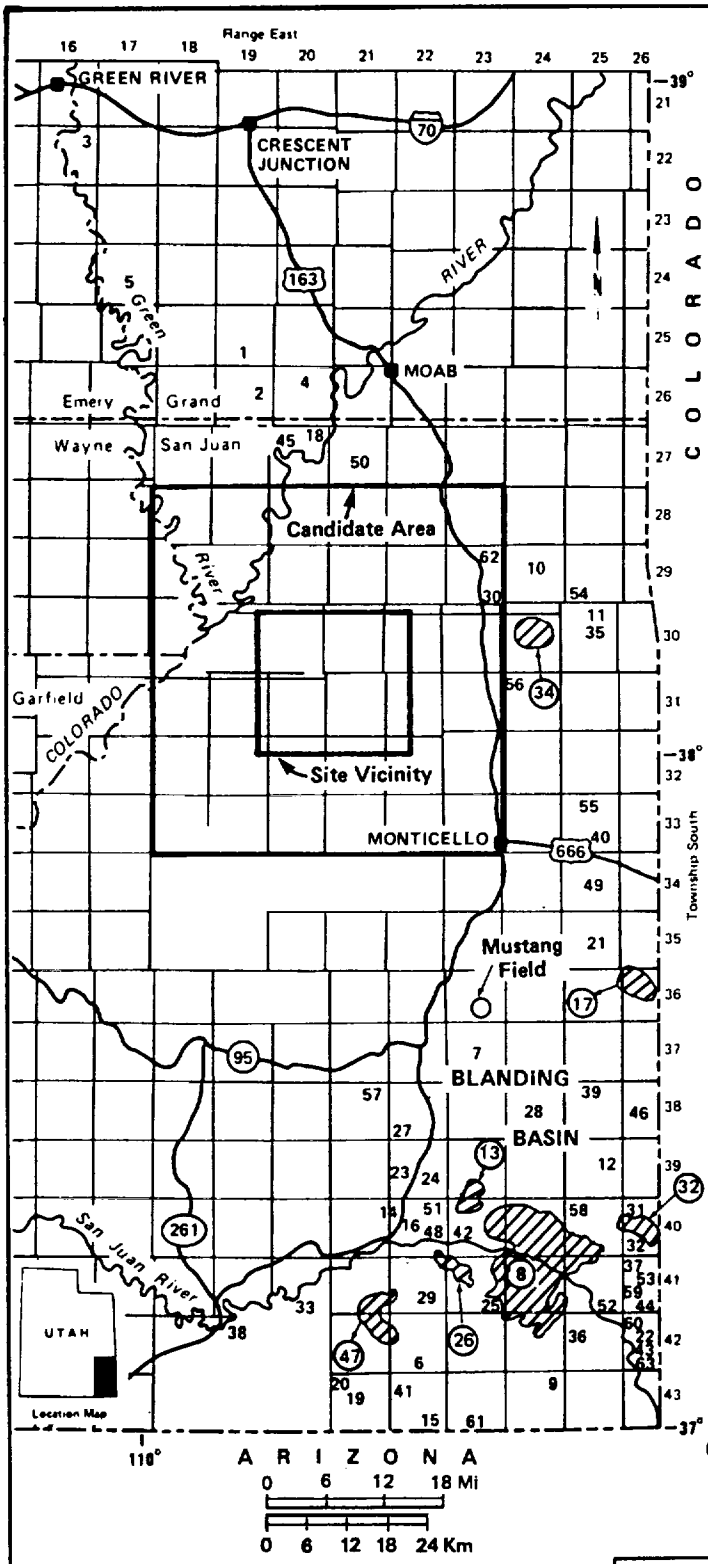
Any such potential hydrocarbon resources within the Honaker Trail, Paradox, or deeper formations could be located stratigraphically within a few hundred feet above or several thousand feet below the potential repository horizons.

3.2.8.1 Hydrocarbon Resources

The candidate area is located north and west of the major producing fields in the Paradox Basin. A map showing the candidate area in relation to these fields is shown in Figure 3-39. Only one producing field (the one-well Wilson Canyon Field) is located in the candidate area, on the extreme eastern margin of the area. The one-well Hook and Ladder Field, located 1.6 kilometers (1 mile) south of the Wilson Canyon Field, has never had any recorded production (Clem and Brown, 1984, pp. 66-67).

There are 52 boreholes deeper than 305 meters (1,000 feet) drilled for hydrocarbon or mineral exploration within the candidate area. Locations of these boreholes are shown in Figure 3-40. Those boreholes within the site vicinity are shown on Figure 3-41. Pertinent data for these boreholes are summarized in Table 3-8.

3.2.8.1.1 Oil and Gas Shows. Oil and gas shows within exploration boreholes drilled in the candidate area consist of (1) hydrocarbons recovered during drill stem tests (DSTs) or production tests, and (2) hydrocarbon shows observed in cores or samples. A summary of hydrocarbon occurrences in tests, cores, and samples is shown in Table 3-8; detailed data for DSTs are shown in Table 3-9, and for cores and samples in Table 3-10.



Map index.

Location on Map	Field	T,S	R,E
	GRAND COUNTY		
1	Bartlett Flat	25	19
2	Big Flat	26	19
3	Little Grand Wash	21	16
4	Long Canyon	26	20
5	Salt Wash	23	17
	SAN JUAN COUNTY		
6	Akah	42	22
7	Alkali Canyon	37	23
(8)	Aneth	41	24
9	Anido Creek	43	24
10	Big Indian Mississippian	29	24
11	Big Indian Pennsylvanian	30	25
12	Black Steer Canyon	39	25
(13)	Bluff	40	23
14	Bluff Bench	40	22
15	Boundary Butte	43	22
16	Broken Hills	40	22
(17)	Bug	36	26
18	Cane Creek	26	20
19	Chinle Wash	42	21
20	Cleft	43	21
21	Coal Bed Canyon	35	25
22	Cone Rock	42	26
23	Cottonwood Creek	39	22
24	Cowboy	39	22
25	Desert Creek	41	23
(26)	Gothic Mesa	41	22
27	Grayson	38	22
28	Hatch	38	24
29	Hogan	41	22
30	Hook and Ladder	29	23
31	Ismay	40	25
(32)	Ismay, South	40	26
33	Lime Ridge	40	20
(34)	Lisbon	30	24
35	Little Valley	30	25
36	Lone Mountain Creek	42	25
37	McElmo Mesa	41	26
38	Mexican Hat	42	19
39	Patterson	38	25
40	Piute Knoll	33	25
41	Rabbit Ears	43	22
42	Recapture Creek	40	23
43	River Bank	42	26
44	Rockwell Flat	41	26
45	Shafer Canyon	27	20
46	Squaw Canyon	38	26
(47)	Tohonadla	41	21
48	Turner Bluff	40	22
49	Unnamed (Boulder Knoll*)	34	25
50	Unnamed (Lion Mesa*)	27	21
51	Unnamed (Recapture Pocket*)	40	22
52	Unnamed (Rockwell Springs*)	41	25
53	Unnamed (Sentinel Peak*)	41	26
54	Unnamed (South Pine Ridge*)	30	25
55	Unnamed (White Canyon - Monticello*)	33	25
56	Unnamed	31	24
57	Unnamed	38	21
58	Unnamed	40	25
59	Unnamed	41	26
60	Unnamed	42	26
61	White Belly Wash	43	23
62	Wilson Canyon	29	23
63	Yellow Rock	42	26

*unofficial name

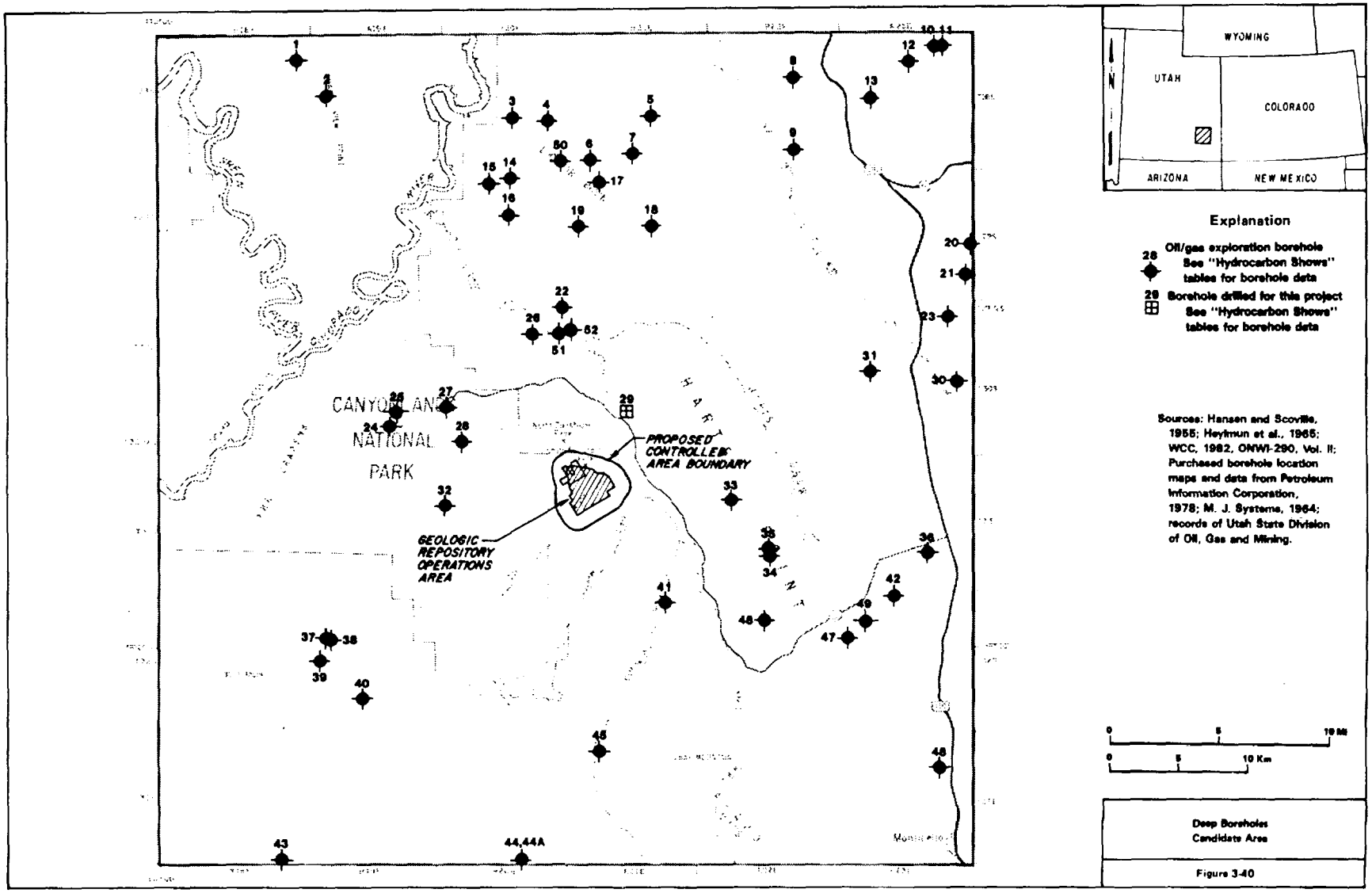
(8) = Major Field

SOURCE: Clem and Brown (1984)

Oil and Gas Fields in Utah Part of Paradox Basin

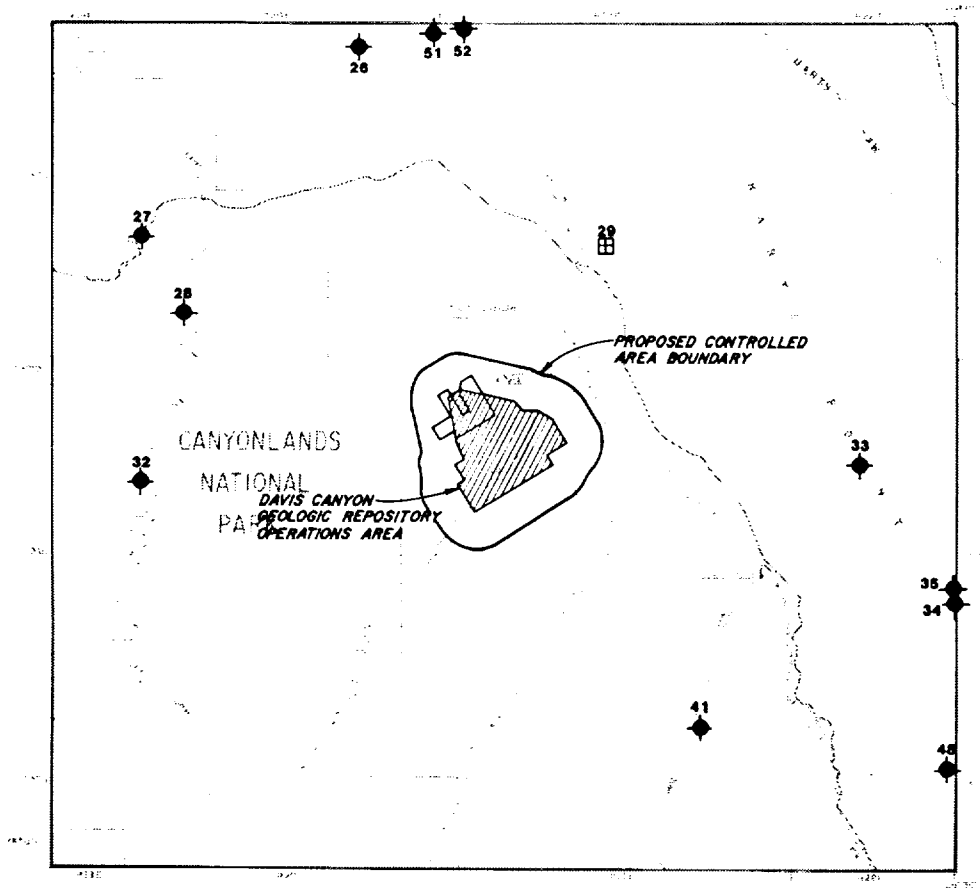
Source: Clem and Brown, 1984.

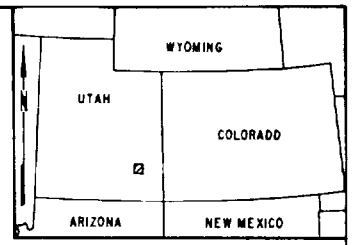
Figure 3-39



Deep Boreholes
Candidate Area

Figure 3-40





Explanation

28 Oil/gas exploration borehole
See "Hydrocarbon Shows" tables for borehole data

29 Borehole drilled for this project
See "Hydrocarbon Shows" tables for borehole data

Sources: Hansen and Scoville, 1955; Heylmun et al., 1965; WCC, 1982, ONWI-290, Vol. II; Purchased borehole location maps and data from Petroleum Information Corporation, 1978; M. J. Systems, 1964; records of Utah State Division of Oil, Gas and Mining.

0 1 2 2 4 Mi

0 1 2 3 4 5 Km

Deep Boreholes
Site and Vicinity

Figure 3-41

Table 3-8. Summary of Hydrocarbon Shows in Candidate Area Boreholes

A. Shows by Borehole

Borehole Name and Location	Borehole No. (Figure 3-40)	Total Depth (TD) (Feet)	Formation at TD	Status	Sample/Core Shows			DST Shows			Remarks
					Paradox	Leadville	Others	Paradox	Leadville	Others	
Pan American, Murphy Range #1 12-T28S-R18E	1	6,509	Cambrian	D & A						NO	
Shell Oil Co. Murphy Range #1 18-T28S-R19E	2	7,193	Elbert	D & A		X			X		
Gulf Oil Co. Lockhart Fed. #1 22-T28S-R20E	3	6,184	Elbert	D & A							No shows
Pan American Lockhart USA #1 23-T28S-R20E	4	5,630	Elbert	D & A	X						
Flying Diamond Lockhart State #1 36-T28S-R20E	50	3,936	Paradox(?)	D & A							
Pan American USA Charles #1 31-T28S-R21E	6	5,306	Cambrian	D & A			EL				
Kimbark Hatch Fed. #1 33-T28S-R21E	7	8,010	Ouray	D & A				X		NO	
Richfield Oil Co. Hatch Mesa #1 22-T28S-R21E	5	8,518	Elbert	D & A						NO	No shows
Pure Oil Co. Flat Iron #1 1D-T28S-R22E	8	7,850	Elbert	D & A							No shows
Gulf/Cities Service Hudson Wash Fed. #1 34-T28D-R22E	9	8,994	Elbert	D & A	X						
British American Lundell #1 17-T28S-R23E	13	8,450	Leadville	D & A					X		
West Coast 10-T28S-R23E	12	10,375	Elbert	D & A	X						
California Oil Co. Muleshoe #1 2-T28S-R23E	10	10,516	Leadville	D & A						NO	Flowed gas on DST (7994-8012); gas to surface in 7 minutes, 52.6 MCF rate at 7 minutes, decreased to 14.3 MCF at 45 minutes, holding steady to end of test[a]
Mineral Hill 2-T28S-R23E	11	1,495	Navajo	D & A							No shows
Humble Oil Rustler Dome #1 4-T29S-R2DE	15	5,076	Elbert(?)	D & A							No shows

Table 3-8. Summary of Hydrocarbon Shows in Candidate Area Boreholes
(Page 2 of 5)

A. Shows by Borehole

Borehole Name and Location	Borehole No. (Figure 3-40)	Total Depth (TD) (Feet)	Formation at TD	Status	Sample/Core Shows			DST Shows			Remarks
					Paradox	Leadville	Others	Paradox	Leadville	Others	
Flying Diamond Govt. Lockhart #1-3 3-T29S-R20E	14	5,010	Elbert	D & A							No shows
G.E. Kadane Rustler Dome #1 15-T29S-R20E	16	5,013	Leadville	D & A							No shows
Pure Oil Co. Horsehead #1 18-T29S-R21E	19	7,212	Elbert	D & A							No shows
Damson Oil Co. Rector Federal 5-T29S-R21E	17	4,220	Leadville	D & A							No shows
Husky Oil Co. Federal #6-15 15-T29S-R21E	18	8,420	Elbert	D & A							No shows
Merrion Oil & Gas Chevron Federal #1 24-T29S-R23E	20	9,916	Elbert	Oil Well				X production test			Only well in Wilson Canyon Field; produces from Lower Paradox salt section perforated Cane Creek zone (8,640-8,484), initial production was 147 bbls oil per day and gas per day[c]
Husky Oil Co. et al., Federal #15-25 25-T29S-R23E	21	9,578	Elbert	S.I. Gas	X				X		Shut in gas well; only well in Hook and Ladder Field; produced from Leadville; initial production (9,010-9,020) flowed 5,000 MCF gas per day and 5bbls condensate per day (low BTU gas)[a]
Reynolds Mining 36-T29 1/2S-R20E	22	6,036	Ouray	P & A				X production test			Production tested 47 bbls oil from Lower Paradox salt section; perforated 3,487-3,501, frac with 8,000 gal diesel and 10,000 lbs sand; recovered 47 bbls oil net[b]
Kimbark et al., Gulf State #1 36-T29 1/2S-R23E	23	9,540	Leadville	D & A					X		
Trident Co. Beef Basin #3 26-T30S-R19E	25	2,114	Paradox(?)	P & A							Swabbed 2-3 bbls oil per day from Upper Paradox (carbonate-rich) (1,873-1,911)[b]
Trident Co. Beef Basin #4 26-T30S-R19E	24	2,640	Honaker Trail(?)	D & A							No shows
Trident Co. Beef Basin #5 32-T30S-R20E	28	2,030	Paradox	D & A							No shows

Table 3-8. Summary of Hydrocarbon Shows in Candidate Area Boreholes
(Page 3 of 5)

A. Shows by Borehole

Borehole Name and Location	Borehole No. (Figure 3-40)	Total Depth (TD) (Feet)	Formation at TD	Status	Sample/Core Shows			DST Shows			Remarks
					Paradox	Leadville	Others	Paradox	Leadville	Others	
Pure Oil Co. Lost Canyon #1 19-T30S-R20E	27	5,215	Elbert	D & A							No shows
Belco Petroleum Gibson Dome #1-2 2-T30S-R20E	26	5,900	Leadville	D & A	X						
Utah Peroleum Gibson Dome #1-2 1-T30S-R20E	51	1,640(?)	Honaker Trail(?)	D & A							No shows
Empire 6-T30S-R21E	52	4,136	Paradox	D & A							No shows
Woodward Clyde Gibson Dome #1 21-T30S-R21E	29	6,384	Ouray		X	X					Left open for future hydrogeologic testing
Hanson Oil Corp. 17-T30S-R23E	31	4,258	Honaker Trail	O & A							No shows
Apache Drilling Apache-Lion #1 13-T30S-R23E	30	9,325	Elbert	D & A					X		
Stanolind Beef Basin #1 7-T31S-R20E	32	1,817(?)	Paradox	D & A							No shows
Gulf Oil Corp. Hart Point Fed. #1 8-T31S-R22E	33	7,810	Ouray	D & A	X				X		
Chorney Oil Co. et al. 22-T31S-R22E	35	8,000	Ebert	D & A							No shows
Champlin Dugout 14-22 #2 22-T31S-R22E	34	4,595	Paradox	D & A							No shows
Skelly Oil Co. Church Rock #1 26-T31S-R23E	36	8,434	Leadville	D & A							No shows
Occidental Cataract Canyon #2 7-T32S-R19E	37	2,947	Molas	D & A	X						
Occidental Cataract Canyon #1 8-T32S-R19E	38	1,658	Paradox	D & A							No shows
The Texas Co. Cataract Canyon #2 18-T32S-R19E	39	2,829	Leadville	D & A			PT				
The Texas Co. Cataract Canyon #1 28-T32S-R19E	40	4,946	Aneth(?)	D & A		X					

Table 3-8. Summary of Hydrocarbon Shows in Candidate Area Boreholes
(Page 4 of 5)

A. Shows by Borehole

Borehole Name and Location	Borehole No. (Figure 3-40)	Total Depth (TD) (Feet)	Formation at TD	Status	Sample/Core Shows			DST Shows			Remarks
					Paradox	Leadville	Others	Paradox	Leadville	Others	
Champlin Dugout 21-2 2-T32S-R21E	41	3,385	Paradox	D & A							No shows
Davis Oil Co. Abajo #4-1 4-T32S-R22E	48	4,731	Paradox	D & A							No shows
Davis Oil Co. Abajo #1 7-T32S-R23E	47	4,769	Paradox	D & A				X			Recovered free oil and gas on DST (4,508-4,592); gas to surface in 60 minutes, recovered 188 feet slightly gas cut mud, 60 feet heavily gas cut mud, 180 feet heavily gas cut mud and oil (25%) and 259 feet slightly mud cut oil (75-80%)[b]
Champlin Harts Draw 41-4 4-T32S-R23E	42	5,170	Paradox	D & A						HO	Tested oil from Honaker Trail (4,555-4,582), recovered 400 cc oil and 170 cc water from sample chamber[b]
Sinclair Oil & Gas Dark Canyon #1 36-T33S-R18E	43	3,877	Leadville	D & A	X						No shows
Natomas Redd Ranch #1-34 34-T33S-R20E	44	5,645	Elbert	D & A							No shows
Placid Oil Co. DU-2-USA 5-T33S-R21E	45	4,387	Leadville	D & A							Flowed sulfur water during DST in Ismay and Desert Creek zones
Mountain States Redd Investment 11-T33S-R23E	46	6,280	Paradox	P & A	X			X			Swabbed 5 bbls oil per day from Paradox (5,542-6,230)[b]
Davis Oil Co. Abajo Fed. #3 5-T32S-R23E	49	4,987	Paradox	D & A	X						
				Totals	11	3	2	6	6	6	

Table 3-8. Summary of Hydrocarbon Shows in Candidate Area Boreholes
(Page 5 of 5)

B. Shows by Formation Penetrated

Formation	Number of Penetrations		Number of Shows		Percent of Penetrations Having Shows	
	Candidate Area	Site Vicinity	Candidate Area	Site Vicinity	Candidate Area	Site Vicinity
Honaker Trail	52	12	4	0	8	0
Paradox	48	12	15	3	31	25
Pinkerton Trail	35	5	1	0	3	0
Leadville and Lower	34	5	10	2	29	40

Note: D & A - Dry and Abandoned.
P & A - Plugged and Abandoned.
S.I. Gas - Shut in gas well.
HO - Honaker Trail Formation.
PT - Pinkerton Trail Formation.
EL - Elbert Formation.

(a) Free gas recovered.
(b) Free oil recovered.
(c) Oil production.

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
Pan American Murphy Range Unit #1	1	3,245-3,365 (HO)			90 feet slightly gas-cut mud (HO)
		3,553-3,713 (HO)			80 feet slightly gas-cut mud (HO)
		4,940-5,037 (PA)	75 feet gas-cut mud		
		5,505-5,590 (LD)		None	
		5,652-5,8 (LD)		None	
		6,145-6,230 (OU)			None (O)
		6,289-6,371 (EL)			None (EL)
		6,392-6,509 (EL)			None (McCracken, Cambrian)
Shell Oil Co. Murphy Range Unit #1	2	6,237-6,325 (LD)		None	
		6,338-6,467 (LD)		None	
Gulf Oil Co. Gulf Aztec Lockhart Fed. #1	3	4,765-4,815 (PA)	None		
		5,120-5,220 (LD)		None	
		5,934-5,990 (EL)			None (EL)
Pan American Petroleum Co. Lockhart USA #1	4	2,312-2,370 (PA)	Slightly gas-cut mud		
		4,680-4,712 (LD)		None	
		5,450-5,613 (EL)			None (EL)
Richfield Oil Corp. Hatch Mesa #1	5	4,612-4,766 (PA)	None		
		7,329-7,385 (PT)			
		7,726-7,786 (LD)			None (PT)
		8,409-8,518 (EL)			None (EL)

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 2 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
Pan American Petroleum Co USA Charles #1	6	3,535-3,589 (LD)		None	
		3,589-3,714 (LD)		None	
		4,150-4,193 (EL)			None (EL)
		4,245-4,331 (EL)			None (EL)
		5,130-5,204 (CA)			None (CA)
Kimbark Operation Co. Hatch Fed #1	7	4,329-4,390 (PA)	None		
		6,298-6,490 (PA)	90 feet oil-cut mud, 246 feet gas-cut mud		
		7,180-7,406 (PT)			oil-cut mud, gas/water cut mud
		7,578-7,730 (LD)		None	
Pure Oil Co. Flat Iron #1	8	7,098-7,209 (LD)		None	
Gulf Oil Co. Hudson Wash Fed #1	9	4,108-4,186 (HO)			Slightly gas-cut mud (HO)
		4,116-4,166 (HO)			None (HO)
		4,111-4,186 (HO)			Gas-cut mud (HO)
		4,185-4,260 (HO)			None (HO)
		4,260-4,323 (HO)			Slightly gas-cut mud (HO)
		4,455-4,534 (HO)			Gas-cut water (HO)
		4,575-4,620 (HO)			Gas-cut water, gas-cut mud (HO)
		8,125-8,220 (LD)		None	
		8,877-8,900 (HO)			None (EL)

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 3 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
California Oil Co. Muleshoe Unit #1	10	7,994-8,012 (HO)			Gas and water-cut mud; flowed 52.6 MCF-first 5 minutes; flowed 43.5 MCF-next 15 minutes; flowed 14.3 MCF next 2.5 hours (HO)
West Coast Oil & Gas Co. Muleshoe Unit #1	12	9,210-9,370 (PA)	279 feet of slightly gas-cut mud		
		9,619-9,665 (LD)		None	
British American Oil Producing Co. Gov't. Lundell #1	13	8,246-8,385 (LD)		Slightly gas-cut mud	
		8,371-8,450 (LD)		Slighly gas-cut mud and Sulphur water	
Humble Oil & Refining Co. Carter Division Rustler Dome #1	15	4,193-4,240 (LD)		None	
		4,199-4,301 (LD)		None	
		4,334-4,344 (LD)		None	
		4,905-5,076 (EL)			None (EL)
G.E. Kadane & Sons Rustler Dome #1	16	4,968-5,013 (LD)		None	
Husky Oil Co. Federal #6-15	18	4,500-4,667 (PA)	None	Gas-cut water	
		7,775-7,868 (LD)		Gas-cut mud, gas-cut water	
		7,490-7,675 (LD)		Slightly gas-cut mud	
		7,667-7,765 (LD)			
		8,214-8,420 (EL)			Slightly gas-cut mud (EL)

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 4 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
Pure Oil Co. Horsehead Unit #1	19	6,359-6,420 (LD)		None	
		6,420-6,440 (LD)		None	
		7,131-7,256 (EL)			None (EL)
Merrion Oil Co. (Gulf Oil Co.) Chevron Federal #1	20	8,460-8,482 (PA)	Producing zone: single and only well in Wilson Canyon Field, cumulative production to May 1983 is 70,134 bbls oil, 116,032 MCF gas		
		5,094-5,170 (PA)	None		
		9,066-9,225 (PT-LD)		None	None (PT)
		9,810-9,955 (EL)			None (EL)
Husky Oil Co. et al. Federal #15-25	21	7,780-7,930 (PA)	None		
		8,170-8,305 (PA)	Gas-cut mud		
		8,850-8,955 (LD)		60 feet gas-cut mud	
		9,020-9,120 (LD)		100 feet of condensate and 380 feet water; flowed at 580 MCFD	
		9,412-9,571 (EL)			Slightly gas-cut mud (EL)
Reynold's Mining Corp. Gibson Dome #1	22	3,487-3,501 (PA)	Production test after sand and diesel frac treatment; produced 47 bbls oil, swabbed dry		
Kimbark et al. Gulf State #1	23	9,310-9,540 (LD)		Gas-cut water	

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 5 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests: Paradox Formation	Leadville Limestone	Other Formations
Belco Petroleum Corp. Gibson Dome #1-2	26	4,903-4,955 (PA)	Very slight trace of oil		
Pure Oil Co. Lost Canyon #1	27	3,742-3,807 (PA)	None		
		4,103-4,173 (PT)			None (PT)
		4,428-4,528 (LD)		None	
		5,070-5,215 (EL)			None (EL)
Woodward-Clyde Consultants Gibson Dome #1	29	3 tests (PE)			None (PE)
		6 tests (HO)			None (HO)
		22 tests (PA)	None		
		3 tests (LD)		None	
Apache Drilling Co. Appache Federal #1	30	8,545-8,650 (LD)		1,480 feet of gas, 270 feet of gas- and mud-cut salt water, 3,950 feet of heavily gas-cut salt water	
		9,201-9,325 (EL)			None (EL)
Hanson Oil Corp. Federal #1x	31	3,992-4,080 (HO)			None (HO)
		4,190-4,240 (HO)			None (HO)
Gulf Oil Co. Hart's Point Fed #1	33	4,409-4,503 (PA)	None		
		4,410-4,504 (PA)	None		
		4,585-4,666 (PA)	None		
		5,729-5,753 (PA)	Gas-cut mud		
		7,147-7,261 (PT)			None (PT)
		7,495-7,568 (LD)		Gas-cut mud	
		7,608-7,628 (LD)		None	

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 6 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
Champlin Petroleum Co. Dugout Ranch 14-22 #2	34	4,342-4,404 (PA)	None		
Chorney Oil Co. et al. Harts Point #1-22	35	4,270-4,375 (UPA)	310 feet very slightly gas-cut mud		
		7,458-7,542 (LD)		None	
Skelly Oil Co. Church Rock Unit #1	36	4,544-4,560 (HO)			None (HO)
		5,018-5,044 (PT)			None (PT)
		8,361-8,441 (LD)		None	
The Texas Co. Cataract Canyon #1	40	760-873 (PE)			
		3,205-3,103 (LD)		None	
Champlin Petroleum Co. Dugout #21-2	41	3,004-3,134 (PA)	None		
Champlin Petroleum Co. Harts Draw 41-4 #1	42	4,555-4,582 (HO)			Gas-cut oil, gas cut water; flowed gas 45.3 MCFPD (HO)
		4,890-4,980 (PA)	None		
Sinclair Oil & Gas Co. Dark Canyon Unit #1	43	2,473-2,523 (PA)	None		
		2,593-2,639 (PA)	None		
		3,776-3,825 (LD)		None	
Natomas North America, Inc. Redd Ranch #1-34-A	44	4,444-4,982 (PT-LD)		None	Includes some Pinkerton Trail, all Molas, and some Leadville

Table 3-9. Hydrocarbon Shows in Drill-Stem Tests
(Page 7 of 7)

Well Name	Well Number (Figure 3-40)	Drill-Stem Test Interval (feet) and Formation	Hydrocarbon Indications in Tests		
			Paradox Formation	Leadville Limestone	Other Formations
Placid Oil Co. #DU-2-USA	45	2,388-2,703 (PA)	None		
Mountain States Resources, Inc. Redd Investment #11-1	46	5,835-5,900 (UPA)	Heavily gas- and mud-cut oil (1.72 bbls); heavily oil- and gas-cut mud (0.44 bbls) (upper carbonate-rich part of Paradox Formation); no production or shut-in since 1981		
Davis Oil Co. Abajo Unit #1	47	4,508-4,592 (PA)	Slightly gas-cut mud; heavily gas-cut mud with trace oil; oil- and gas-cut mud (35% oil) mud-cut oil (80% oil)		
Davis Oil Co. Abajo Unit #4-1	48	4,468-4,530 (PA)	None		
Davis Oil Co. Abajo Federal #3	49	4,778-4,798 (UPA)	Ismay zone - none		

Note: PE = Permian Formations
HO = Honaker Trail Formation
UPA = Upper carbonate-rich part of Paradox Formation
PA = Lower evaporite-rich part of Paradox Formation
PT = Pinkerton Trail Formation
LD = Leadville Limestone
O = Ouray Formation
EL = Elbert Formation

Table 3-10. Hydrocarbon Shows in Cores and Samples

Well Name	Well No. (Fig. 3-40)	Formation	Depth	Lithology	Show Description
Shell Oil Co. Murphy Range #1 12-T28S-R19E	2	Leadville	6,277	dolomite	CORE: Bleeding dark brown oil
Richfield Oil Co. Hatch Mesa #1 22-T28S-R21E	5	Leadville	7,757	dolomite	CORE: Spotty brown oil stain and fluorescence
Pan American Charles USA #1 31-T28S-R21E	6	Elbert	4,289	dolomite/ sandstone	CORE: Bleeding oil on partings
Gulf (Cities Service) Hudson Wash Fed. #1 34-T28S-R22E	9	Paradox	4,143	dolomite	CORE: Fair oil cut, slight bleeding
	9	Paradox	4,298	dolomite	CORE: Fair oil cut, slight fluor-escence
Belco Petroleum Gibson Dome 1-2 2-T30S-R20E	28	Paradox	3,570	shale	SAMPLES: Trace-free oil and odor
	28	Paradox	4,930	siltstone	SAMPLES: Trace oil show cut fluorescence, scum of oil in pit
Woodward-Clyde Gibson Dome #1 21-T30S-R21E	29	Paradox			
		-salt 8-9 interbed	3,531-3,532	dolomitic mudstone	CORE: Hydrocarbon odor
		-salt 10-13 interbed	3,845-3,850	dolomitic carbon-aceous siltstone	CORE: Bleeding gas when extruded from core barrel
		-salt 19-20 interbed	4,995-4,996	calcareous siltstone	CORE: Strong gas odor
		-within salt 24	5,384-5,385	calcareous organic silty shale	CORE: Strong petro-liferous odor

Table 3-10. Hydrocarbon Shows in Cores and Samples
(Page 2 of 2)

Well Name	Well No. (Fig. 3-40)	Formation	Depth	Lithology	Show Description
	29	Leadvile	5,963-5,971	finely crystalline limestone	CORE: Oil and gas bleeding from core while being extruded from core barrel;
			5,983-6,002	finely crystalline limestone	Oil bled from pinpoint sources scattered along core; heavy gas odor during core extrusion
Gulf Oil Co. Harts Pt. Fed. #1 8-T31S-R22E	33	Paradox	4,488	limestone	CORE: Scattered fluorescence, stain, odor
Occidental Oil Co. Cataract Canyon #2 7-T32S-R19E	37	Paradox	1,905	limestone	CORE: Bleeding oil from small vugs
The Texas Co. Cataract Canyon #2 28-T32S-R19E	39	Honaker Tr.	1,736	limestone/ dolomite	CORE: Bleeding oil on fractures and oolitic limestone fragments
The Texas Co. Cataract Canyon #1 28-T32S-R19E	40	Leadville	3,205	dolomite	CORE: Vertical fractures and vugs contain oil
Sinclair Oil Co. Dark Canyon #1 36-T33S-R18E	43	Paradox	2,622	dolomite	CORE: Slight odor, fluorescence and cut; inter granular, vuggy porosity
Davis Oil Co. Abajo #3 5-T32S-R23E	49	Paradox	4,787	limestone	CORE: Fluorescence on fractures and in vugs

Oil and gas shows in DSTs and cores are most commonly found in the Paradox Formation and Leadville Limestone, as shown in Table 3-8. Shows are sometimes found in the Honaker Trail and Elbert Formations. Free oil and gas in DSTs and production tests were found in eight boreholes located in the candidate area (see Figure 3-40). These occurrences consist of one producing well (No. 20 in Table 3-8, the only producing well in the Wilson Canyon Field) and seven other boreholes (Nos. 10, 21, 22, 25, 42, 46, 47 in Table 3-8). In other boreholes, minor shows in fluids recovered during DSTs consist mostly of gas- or oil-cut mud or water (see Table 3-9). Hydrocarbon shows in cores were observed at 11 boreholes as described in Table 3-10.

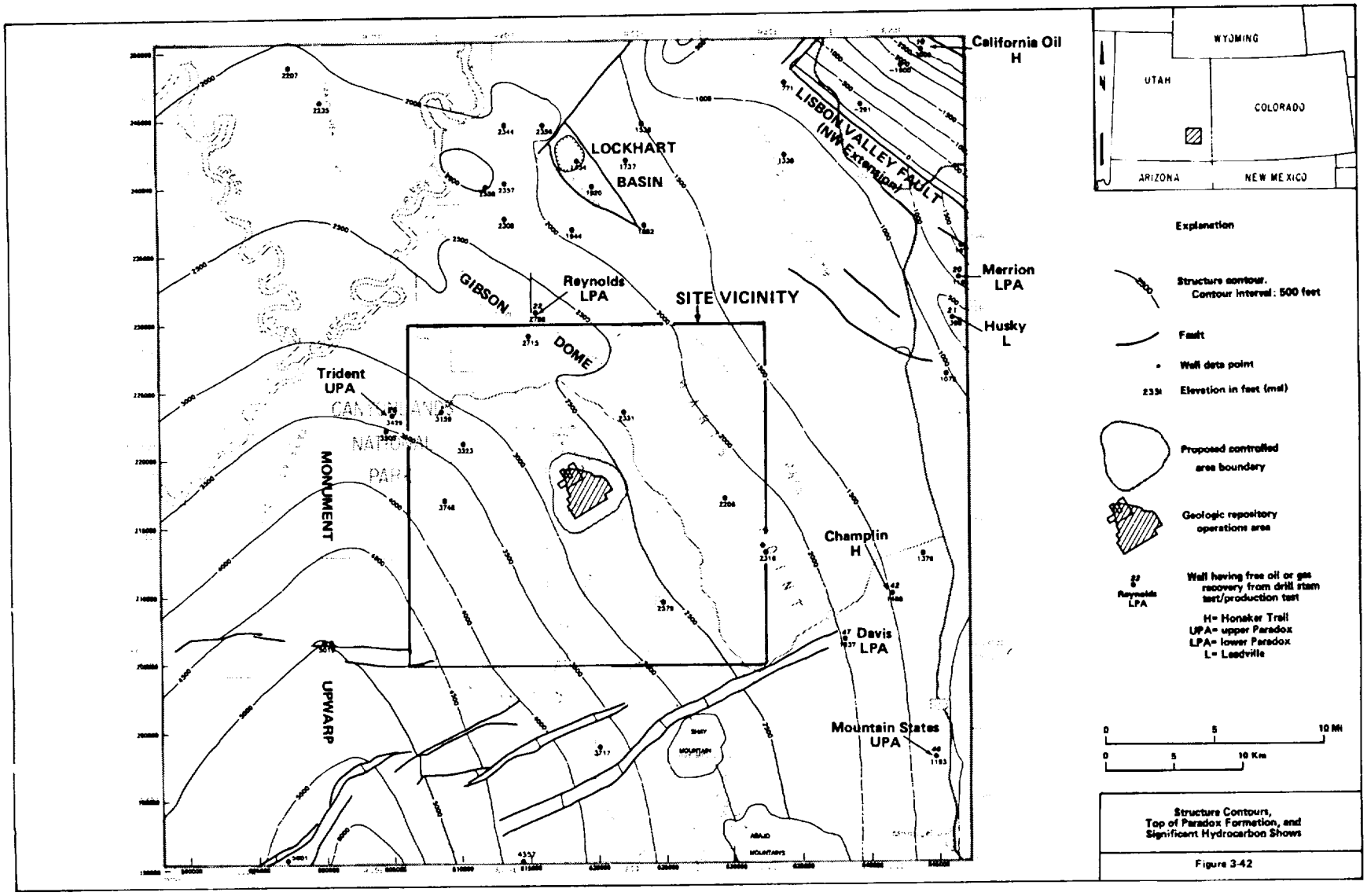
Within the site vicinity, there are no known free oil or gas shows in DSTs. Of the eight boreholes in this area having available DST information, seven had Paradox tests and four had Leadville tests; two of the seven Paradox tests and one of the four Leadville tests had minor shows. The borehole nearest the site (No. 29 - Woodward-Clyde Consultants GD-1) had no DST shows in any formation tested (Permian formations deeper than 305 meters [1,000 feet], Honaker Trail, Paradox, and Leadville Formations). The core from this borehole contained minor oil and gas shows in the Leadville Limestone and Paradox Formations as described in Table 3-9. Minor amounts of methane gas were observed during trips in and out of the hole while coring the Paradox Formation. Some hydrogen sulfide gas also was detected during coring of the Leadville Limestone.

The best hydrocarbon recovery near the site vicinity was in the Reynolds Mining borehole (No. 22) located less than 1.6 kilometers (1 mile) north of the site vicinity boundary (Figure 3-40). During a production test in the Paradox Formation, 7,472 liters (47 barrels) of oil were recovered from perforations at 1,063 to 1,067 meters (3,487 to 3,501 feet). The gravity of the oil was 36.6 (American Petroleum Institute [API]). The perforated interval dried up after treatment with 30,283 liters (8,000 gallons) of diesel oil and 4,536 kilograms (10,000 pounds) of sand. As no commercial production was found, the total production of oil (7,472 liters [47 barrels]) was pumped back into the perforated zone, and the well was plugged and abandoned.

The Trident Beef Basin #3 well (#25) is located 1.6 kilometers (1 mile) west of the site vicinity boundary. This well swabbed 159 to 477 liters (2 to 3 barrels) of oil per day from a zone in the upper (carbonate-rich) part of the Paradox Formation at a depth of 571 to 582 meters (1,873 to 1,911 feet). The water-to-oil ratio was about 12 to 1; the hole was plugged and abandoned as noncommercial.

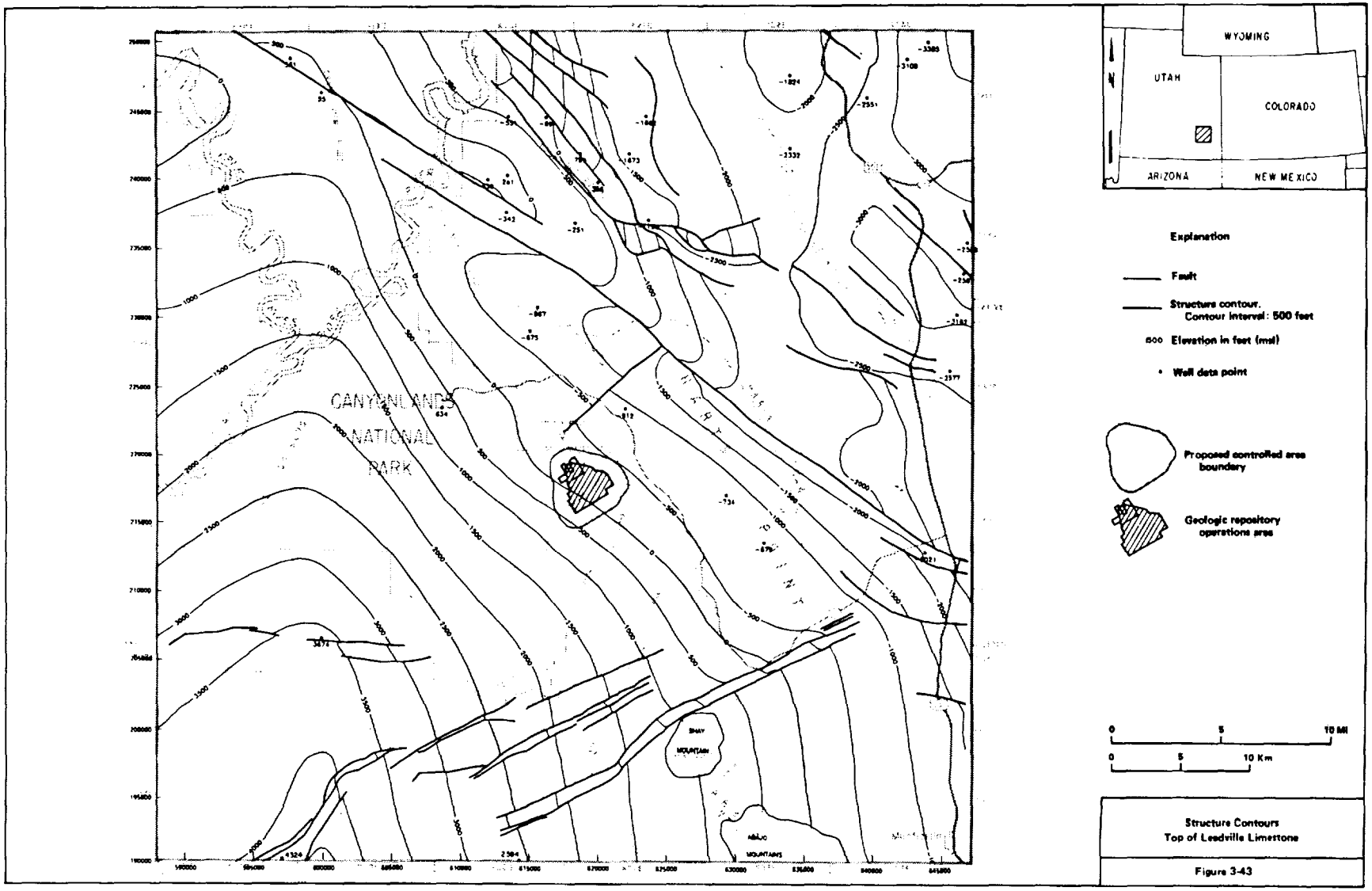
3.2.8.1.2 Oil and Gas Traps and Hydrocarbon Exploration. Three types of oil and gas traps provide accumulations in various target strata in the Paradox Basin: (1) stratigraphic traps (e.g., carbonate algal mounds), such as in the upper Paradox Formation at the Aneth Field, and stratigraphic pinchouts such as grading of carbonate beds into anhydrite beds; (2) anticlinal and fault structural traps, such as in the Leadville Limestone at the Lisbon field; and (3) structure and fracture porosity developed by faulting or folding of relatively impervious hydrocarbon-bearing strata, such as in the lower Paradox Formation in the Wilson Canyon field (Fassett and Thomaidis, 1978, Vol. II, p. 719). All of these strata are present in the subsurface within the candidate area. Therefore, this area has some potential for oil and gas in Pennsylvanian (Paradox) and Mississippian (Leadville) strata (Merrell and Utah Geological and Mineral Survey, 1979, pp. 24-27, 62-63).

Structure contour maps of the top of the Paradox Formation and on the top of the Leadville Limestone, as shown in Figures 3-42 and 3-43, were constructed to assist in identifying exploration guides to potentially favorable structures. The Paradox Formation structure map (Figure 3-42) shows the following major structures within the southern part of the area: Monument Upwarp, intrusive centers of the Abajo Mountains and Shay Mountain, and north-east- and east-west-trending grabens between these features. Gibson Dome, Lockhart Basin, and the northwest extension of the Lisbon Valley anticline are located in the northern part of the area. Most of these structures also appear on the Leadville Limestone structure contour map (Figure 3-43).



Structure Contours,
Top of Paradox Formation, and
Significant Hydrocarbon Shows

Figure 3-42



Structure Contours
Top of Leadville Limestone

Figure 3-43

Known hydrocarbon accumulations having carbonate mound stratigraphic traps (upper carbonate-rich part of the Paradox Formation, Ismay and Desert Creek zones) are located mostly to the southeast and east of the Abajo Mountains (Figure 3-39). These accumulations have only subtle, if any, associated surface or subsurface structure. Here, regional structures that were developing during Pennsylvanian time seem to have been controlling factors for the location of carbonate mounds or other stratigraphic traps. Recent discoveries in the upper Paradox (Ismay and Desert Creek zones) have been made east and south of the candidate area. One new field (Mustang Field, approximately 24 kilometers [15 miles] south of the candidate area, Figure 3-39) was discovered by the projection of a northwest-oriented break in slope of paleoshelf (Carroll, 1985). Northward, toward the central part of the candidate area, these carbonate-rich beds grade into and are progressively replaced by evaporitic lithologies of the lower Paradox Formation. Exploration for these carbonate-mound traps has continued recently in the southeast part of the candidate area (Mountain States borehole, 1981; Champlin boreholes, 1981; and Davis boreholes, 1983-84). These exploration efforts did not locate commercial quantities of hydrocarbons, and, at present, no further exploration drilling for such traps has been observed. The Honaker Trail Formation also contains oil and gas accumulations in either stratigraphic or stratigraphic and structural traps within the Paradox Basin (Clem and Brown, 1984 p. 2). Within the candidate area, locations of those boreholes having free oil or gas in DSTs or production tests within the Honaker Trail and upper part of the Paradox Formations are shown on Figure 3-42 (top of Paradox Formation structure contour map). These locations do not seem to be associated with any major faulting or structure shown on this map.

By contrast, the other two trap types, described above, are closely associated with fault and anticlinal structures. The anticline and fault trap type in the Leadville Formation is represented by the Lisbon Field, located approximately 8 kilometers (5 miles) east of the candidate area (Figure 3-39). In the candidate area, the only occurrence of free hydrocarbons in DSTs in the Leadville is at the Hook and Ladder Field (shut-in gas well; and Table 3-9). This one-well field (borehole 21, Husky) is located at the eastern edge of the candidate area near the Lisbon Field, and adjacent to a major fault shown on Figure 3-43 (top of Leadville structure contour map). Exploration for Leadville production in the Paradox Basin has been intense ever since discovery of the major Lisbon Field in 1960.

The other structure and fracture related trap type (fracture porosity developed in the relatively impervious lower Paradox Formation) is represented by the Wilson Canyon Field, a one-well field located at the eastern border of the candidate area (borehole 20, Figure 3-41). Hydrocarbon accumulations in the lower Paradox Formation occur within clastic interbeds between salt layers. These accumulations are often small and isolated and production usually declines rapidly from initial production levels. This condition is probably due to the fracture-controlled nature of the reservoir; the size of accumulation thus depends on the extent and intensity of fracturing. Other locations of free hydrocarbons in DSTs in the lower Paradox Formation are also shown on Figure 3-42 (boreholes 22 and 47). All of these boreholes are located on, or adjacent to, major faults or fold crests and faults (borehole 22). These structures have probably provided the fracture porosity necessary for these small, mostly subcommercial accumulations.

3.2.8.1.3 Comparison of Hydrocarbon Resource Potential in Site Vicinity with Surrounding Area. The hydrocarbon potential of a nonproducing area (site vicinity) can be judged by comparing it with nearby producing areas in terms of oil and gas shows, geologic conditions at known producing locations, and favored trap types in association with oil-bearing target formations. The distribution of shows, production, potentially favorable stratigraphy and structure has been described above, and is summarized in Table 3-11 for the site vicinity, candidate area, and Paradox Basin. Data in this table show that the type of structure and stratigraphic conditions associated with known producing locations outside the site vicinity are not found within the site vicinity.

Geologic structure within the site vicinity is dominated by a regional homoclinal northeast dip off of the Monument Upwarp, shown at both the top of Paradox and the top of the Leadville Formation horizon (Figures 3-42 and 3-43). The site is completely underlain by this northeast-dipping regional homocline. At the top of Paradox horizon within the site vicinity,

Table 3-11. Summary of Favorable Hydrocarbon Conditions

Condition	Site Vicinity	Davis Canyon Candidate Area	Paradox Basin
Cumulative Production	None	Wilson Canyon Field (one well - 20, Merrion) 70,000 bbls oil; 115,000 MCF gas, through May, 1983 (records of Utah State Division of Oil, Gas, and Mining)	476,648,000 bbls oil to Dec. 1980; 819,400 MMCF gas to Dec. 1980 (Clem and Brown, 1984, p. 130)
Stratigraphic Trends			
Upper Paradox (carbonate-rich): Ismay, Desert Creek zones	No free oil or gas shows No known trends	Free oil and gas show in two wells (29-Trident #3, 46-Mtn States) In SE part may contain projections of productive paleoshelf slope breaks or other trends to south and east (Carroll, 1985)	Major fields (Aneth Ismay, McElmo Creek) and many smaller fields located to south and east of candidate area in the Blanding Basin and Four Corners Platform
Structural Features			
Leadville (anticline-fault trap), also Ouray and Elbert	No free oil or gas shows No untested structures known	Free gas in one gas well (21-Husky) No untested structure known	Major field (Lisbon) and nearby smaller fields located east of candidate area

Table 3-11. Summary of Favorable Hydrocarbon Conditions
(Page 2 of 3)

Condition	Site Vicinity	Davis Canyon Candidate Area	Paradox Basin
Lower Paradox (evaporite and clastic interbeds; fractured impervious strata)	No free oil or gas shows No faults known cutting top of Paradox unit	Free oil shows in two boreholes (22-Reynolds, 47-Davis); both boreholes adjacent to faults cutting top of Paradox; borehole 22 also on crest of Gibson Dome structure Wilson Canyon Field - (on eastern margin of candidate area) - see production above	Small fields to north and east of candidate area, (e.g., Lion Mesa, T27S, R21E); most have small or no production; most are one-well or two-well fields; one well (Southern Natural Long Canyon #1, T26S, R20E) has produced more than 800,000 bbls oil from Cane Creek zone (Salt 21-22 interbed) since early 1960s
		Produces from Cane Creek zone (Salt 21-22 interbed) adjacent to fault cutting top of Paradox horizon	
Stratigraphic Trends			
Honaker Trail	No free oil or gas shows No known trends	Free oil shows in two boreholes (10-California Oil Co. and 42-Champlin) Controlling trends are not known, but may be similar to underlying Ismay	Small fields to east and south of candidate area Bug, McElmo Mesa) Controlling trends are not known but may be similar to underlying Ismay Big Indian (Honaker Trail) appears to be stratigraphically controlled by pinching out of thin sand units

Table 3-11. Summary of Favorable Hydrocarbon Conditions
(Page 3 of 3)

Condition	Site Vicinity	Davis Canyon Candidate Area	Paradox Basin
Statistical Data			
Total boreholes	12	57	NA
Oil or gas wells	0	2	
Swabbed or tested oil	0	4	
DST-free gas	0	1	
DST-free oil	0	1	
Slight shows	2	19	
Percent total boreholes having:			
production	0	3.5	NA
good shows	0	10.5	
slight shows	17	33	
slight shows, good shows, or production	17	47	
1984 Drilling Data			
Total boreholes drilled			131
Oil completions			61 (46.6%)
Gas completions			6 (4.6%)
Dry holes			64 (48.6%)

Note: NA = Not Applicable.

Source: Petroleum Information Corporation, 1985.

this homocline is modified by the Gibson Dome structure north of the site (Figure 3-42); this structure has been tested unsuccessfully by two recent boreholes and by two other boreholes drilled in the 1920s. At the top of the Leadville horizon, the homocline is interrupted by one northwest-trending fault and one north-east-trending fault. No untested known anticlinal structures are associated with these faults. By contrast, similar sized areas outside the site vicinity contain numerous faults and anticlinal structures (Figure 3-43).

Within the site vicinity, a potential for small hydrocarbon accumulations exists in the Honaker Trail Formation in both stratigraphic and structure traps. However, based on the data described above, the general hydrocarbon potential of the site vicinity is judged to be low relative to other surrounding areas in the Paradox Basin. This judgment is founded mainly on the following site vicinity characteristics:

- Absence of major oil and gas shows
- Apparent absence of favorable traps associated with oil-bearing formations
- Lack of known untested structures.

It should be noted that the very low density of wells drilled in both the candidate area and the site vicinity does not preclude the possibility of new hydrocarbon discoveries in future drilling; however, the potential for this is low.

3.2.8.2 Other Resources

Uranium and vanadium are the principal mineral resources identified within the candidate area. Resources of copper, manganese, iron oxide, potash, quartz, sand and gravel, and dimension stone are also present. Resource production in the candidate area has occurred only for uranium, vanadium, copper, manganese, and sand and gravel (USGS, 1982; Merrell and Utah Geological and Mineral Survey, 1979, pp. 32-42).

3.2.8.2.1 Uranium and Vanadium. The 184 uranium localities identified within the Davis Canyon candidate area consist of occurrences, prospects, and developed mines (Figure 3-37). Of those locations with descriptive data, there are 38 known producers, 20 known prospects, and 43 known occurrences (Table 3-12) (USGS, 1982). These localities occur primarily in the Cutler Formation, in the Moss Back Member of the Chinle Formation, and in the Salt Wash Member of the Morrison Formation. One locality occurs in the Elephant Canyon Formation near its upper contact with the Cutler Formation (S35, T29-1/2S, R20E); two other localities occur in the Kayenta, Wingate, and Navajo Formations (Campbell et al., 1982b, Appendix A, pp. A-81, A-95).

Mines in the site vicinity have been inactive since 1973, with the exception of the Lake Mine (former Moki Mine) which produced 1,089 metric tons (1,200 tons) of ore during 1983 (Merrell, 1983). Production in the candidate area in 1982 amounted to less than 272 metric tons (300 tons) of ore from the Yellow Circle Group and Junction Group properties, which are located at the extreme northeastern corner of the area (Figure 3-37, Nos. 43 and 59) (Chenoweth, 1983).

An independent evaluation of uranium resources for the Moab and Cortez 1 by 2 degree topographic sheets was prepared for the National Uranium Resource Evaluation (NURE) program by Campbell et al. (1982a, p. 86; 1982b, pp. 42-46). These reports indicate that areas favorable for uranium deposits occur in the candidate area in the Chinle Formation. Areas favorable for uranium deposits in the Cutler Formation occur north of a northwest-southeast line extending diagonally across the middle of the candidate area (Campbell et al., 1982a, pp. 47-49). Areas favorable for uranium deposits in the Morrison Formation occur only in the extreme northeastern corner and eastern side of the candidate area (Campbell et al., 1982b, pp. 13, 14, 38-41).

Identified uranium resources within the site vicinity are limited to the Moss Back member of the Chinle Formation. The site vicinity contains 19 uranium and vanadium localities, of which 14 have descriptive data (Figure 3-37, Table 3-12). Production has been recorded as

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES								
Rainbow Group	S24 T28S R18E	1	Raw prospect Inactive (1978) vanadium	Bedded, replacement, disseminated-lens, pods, irregular --	Small 4'T, 5'B	Surface 20x150'; rim stripping	None —	Chinle Fm, Moss Back Member-quartzite conglomerate, mudstone; —; —
Hot Rim and Soda Roll*	S24 T28S R18E	2	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown*	S30 T28S R19E	3	— — —	— —	—	—	— —	Chinle Fm; —; —
Sailor Group	S29 T28S R19E	4	Producer Inactive (1978) uranium, vanadium	Replacement, disseminated-lens, pods, tabular, irregular carnotite, uraninite	Small 20'T, 25'B, 1.5'M	Underground 25'D, 30'L	Small small at 0.1% U_3O_8	Chinle Fm, Moss Back Member-sandstone, gritstone, mudstone; carbon trash; sandstone paleochannel
Rainy Day Group	S29, T28S R19E	5	Producer Inactive (1978) uranium	Replacement, disseminated-lens, irregular, tabular uraninite	Small 20'T, 32'B 2'M	Underground 25'D, 160'L	Small —	Chinle Fm, Moss Back Member-sandstone, mudstone, pebble conglomerate; limonite; paleochannel
Unknown*	S33 T28S R19E	6	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown*	S17 T28S R19E	7	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown	S3 T28S R19E	8	Producer Inactive (1978) uranium	Replacement, disseminated-lens pods, tabular, irregular uraninite	Small 20'T, 25'B 1'M	Underground 25'D, 75'L	Small —	Chinle Fm, Moss Back Member-sandstone, mudstone, conglomerate; carbon trash, limonite; paleochannel
Unknown*	S3 T28S R19E	9	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown*	S3 T28S R19E	10	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown	S3 T28S R19E	11	Producer Inactive (1978) uranium, copper	Replacement, disseminated-lens, pods, tabular, irregular uraninite, azurite, malachite	Small 4'T, 20'B, 1'M	Underground 30'D, 170'L	Small; high grade from logs —	Chinle Fm, Moss Back Member-sandstone, mudstone, pebble conglomerate; organics, calcite, gypsum, limonite; paleochannel

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 2 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Unknown*	S3 T28S R19E	12	— — —	— —	—	—	— —	Chinle Fm; —; —
George #31	S12 T28S R19E	13	Raw prospect Inactive (1978) uranium, copper	Bedded, disseminated-lens, irregular uraninite, malachite	Small	Surface 50x500'	None small at 0.05% U_3O_8	Cutler Fm-sandstone; —; —
List, Nancy Anne	S4 T28S R20E	14	Raw prospect Inactive (1977) uranium, copper	— chalcocite, cuprite, brochanite, yellow uranium minerals (not seen)	—	Drilling prog. extent, results unknown	None —	Cutler Fm-arkosic sandstone, siltstone; secondary silica; white arkose lenses
Marie, Imogene claims (Jet Crash)	S3,10,11 T28S R20E	15	Raw prospect Inactive (1977) uranium, copper	Bedded, disseminated, replacement-discontinuous lenses, tabular chalcocite, cuprite, brochanite, yellow U minerals (not seen)	—	Drilling prog. extent, results unknown	None —	Cutler Fm-arkosic sandstone, mudstone, siltstone; secondary silica; white arkosic sandstone lenses
Lockhart Lulu	S13,14,23 T28S R20E	16	Raw prospect Inactive (1977) uranium, copper	Bedded, disseminated, replacement-discontinuous lenses, tabular, irregular; chalcocite, cuprite, brochanite, yellow U minerals (not seen)	Small at surface	Drilling prog. extent, results unknown	None small (?)	Cutler Fm-arkosic sandstone, mudstone; secondary silica; white arkose beds, precipitation in reducing environment from ground water
Unknown*	S35 T28S R20E	17	— — —	— —	—	—	— —	Chinle Fm-sandstone; —; —
Jet Crash*	S20 T28S R21E	18	— — —	— —	—	—	— —	Chinle Fm; —; —
Unknown*	S32 T28S R21E	19	— — —	— —	—	—	— —	Kayenta Fm, Wingate SS-sandstone; —; —
Camoose* Claims	S1 T28S R21E	20	— — —	— —	—	—	— —	Cutler Fm-sandstone; —; —
Lost* Treasure	S8 T28S R22E	21	— — —	— —	—	—	— —	Chinle Fm, Moss Back Member-sandstone; —; —

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 3 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Sauer	S2 T28S R22E	22	Developed producer Inactive (1977) uranium, vanadium	Disseminated, replacement-lens, pod, wedge out, rolls uraninite, corvusite	Small 20'T, 22'B, 2'M, 15x40'	Underground 22'D, 265'L 1 incline	Small (100-300 lbs. U_3O_8); small at 0.07% U_3O_8	Morrison Fm, Salt Wash Member-sandstone; limonite, carbon trash; paleochannel
Bridger Jack	S2 T28S R22E	23	Developed producer Inactive (1977) uranium, vanadium	Replacement, disseminated-lens, pod uraninite, montroseite, carnotite, tyuyamunite, corvusite	Medium 15'T, 4'M, 25x40'; 2-3 ore bodies	Underground 15'D, 430'L	Medium (up to 1,000 lbs U_3O_8); med. at 0.15% U_3O_8	Morrison Fm, Salt Wash Member-sandstone; limonite, gypsum; base of paleochannels, carbon trash, ground water
Unknown	S2 T28S R22E	24	Developed producer Active (1977) uranium, vanadium	Lens, pod carnotite, tyuyamunite, uraninite, corvusite	? 25'T, 30x40'	Underground 25'D, 510'L	Small (less than 100 lbs U_3O_8); small at 0.1% U_3O_8; 0.2% V_2O_5	Morrison Fm, Salt Wash Member-sandstone; limonite, logs, carbon trash, clay galls; paleochannel, carbon trash
Unknown	S2 T28S R22E	25	Developed producer Inactive (1977) uranium, vanadium	Replacement, disseminated-lens, pod carnotite, tyuyamunite, vanadium clay	Small 2'T, 25'B, 1.5'M	Underground 20'D, 285'L 2 inclines	Small small at 0.07% U_3O_8; 0.15% V_2O_5	Morrison Fm, Salt Wash Member-sandstone, mudstone; limonite, carbon trash, silicified logs; paleochannels
Old Powder Group	S2 T28S R22E	26	Developed producer Inactive (1977) uranium, vanadium	Replacement, disseminated-lens, pods tyuyamunite, vanadium mica	Small 10'T, 11'B, 1'M, 20x30'	Underground 11'D, 120'L	Small small at 0.07% U_3O_8	Morrison Fm, Salt Wash Member-sandstone, mudstone; limonite, carbon trash; paleochannel scours
Unknown	S2 T28S R22E	27	Raw prospect Inactive (1977) uranium	Bedded, replacement, disseminated-lens, pod carnotite	Small 4'T, 7'B, 1'M, 15x50'	Underground 7'D, 25'L 18x30'	None --	Morrison Fm, Salt Wash Member-sandstone; limonite, carbon trash, sulphates, clay galls; paleochannel scours and carbon trash, ground water
Pate Mine	S6 T28S R22E	29	Raw prospect Inactive (1977) uranium	Bedded, replacement-lens --	Small 15'T, 20'B, 2'M; 2x4'	Underground 25'D, 65'L	None none	Morrison Fm, Salt Wash Member-sandstone, mudstone; bleached mudstone; paleochannel
Lucky Strike (Peterino)*	S6 T28S R23E	30	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Lizard Mine	S17 T28S R23E	31	Raw prospect Inactive (1977) uranium, vanadium	Bedded, replacement-tabular --	10'T, 30'B, 2'M, 10x50'	Underground 300, 100'L	Small	Morrison Fm, Salt Wash Member-sandstone; --; --
Blue Bonnet (Top)	S6 T28S R23E	32	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement, disseminated-lenticular --	Small 0'T, 25'B, 2'M, 50x140'	Underground 25'D, 140'L	Small (118 lbs to 1973); small at 0.15 % U_3O_8 (1977)	Morrison Fm, Salt Wash Member-sandstone, conglomerate; --; paleochannel
Porcupine Prospect	S7 T28S R23E	33	Occurrence Inactive (1977) uranium, vanadium	Bedded-lenticular --	--	Surface 1 prosp. pit	None small at 0.10% U_3O_8	Morrison Fm, Salt Wash Member-sandstone; --; --

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 4 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Last Chance Mine (Shupe and Shamrock)	S18 T28S R23E	35	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement-tabular carnotite, vanadium mica	Medium 20'T, 150'B, 2'M, 50x100'	Underground 20'D, 800'L 1 incline, sev. stopes	Medium (2,000 tons ore to 1973) small	Morrison Fm, Salt Wash Member-sandstone; --; --
Mary Knoll Claim*	S17 T28S R23E	36	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Dip Prospect	S17 T28S R23E	37	Occurrence Inactive (1977) uranium, vanadium	Bedded, replacement carnotite, vanadium mica	20'T, 30'B, 1'M, 10x30'	Underground 30'D, 30'L	None small at 0.10% U_3O_8	Morrison Fm, Salt Wash Member-sandstone, mudstone; --; --
Top*	S6 T28S R23E	38	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Unknown	S16 T28S R23E	39	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement-tabular carnotite	10'T, 30'B, 6'M, 50x100'	Underground 6'D, 200'L large stope at base of paleochannel	Small --	Morrison Fm, Salt Wash Member-sandstone; limonite; --
Prince Albert Claim*	S16 T28S R23E	40	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Prospect on School Section	S16 T28S R23E	41	Raw prospect Inactive (1977) uranium, vanadium	Bedded, replacement-tabular --	Small 10'T, 12'B, 2'M, 10x30'	Underground 15'D, 15'L (one adit)	None --	Morrison Fm, Salt Wash Member-sandstone, mudstone; --; --
Protection (Little Devil)*	S3 T28S R23E	42	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Yellow Circle T28S (Primaro, Protection, Forked Canyon, etc.)	S2 R23E	43	Developed producer Active (1977) uranium, vanadium	Replacement, disseminated-tabular carnotite, vanoxite, vanadium mica	Medium 5'M, 50x200'	Underground 0'T, 1,000'B, 3,000'+ L several inclines, adits	Large (1956-70: 15-300'D, 71-72: 3.081 mill. lbs. uranium/vanadium); 500 tons at 0.20% U_3O_8 (1977)	Morrison Fm, Salt Wash Member-sandstone; Group --; --

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 5 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Grey Horse claims (Lostit claims)	S21 T28S R23E	44	Occurrence Inactive (1977) uranium, vanadium	Bedded, replacement-tabular —	—	Only a cat road	None none	Morrison Fm, Salt Wash Member-sandstone, mudstone; —; —
McGee Mine	S22 T28S R23E	45	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement-tabular carnotite, vanadium mica	Small 20'T, 100'B, 4'M, 100x100'	Underground 100'D, 200'+L flooded	Small very little	Morrison Fm, Salt Wash Member-sandstone; —; —
Blue Jay Mine (Joan, Pine Tree, Sunnyside)	S28 T28S R23E	46	Developed producer Inactive (1977) vanadium, uranium	Bedded, replacement-tabular gray vanadium hydromica, carnotite, vanoxite	Large 20'T, 300'B, 6'M, 300x1,500'	Underground 20'D, 1,500'+L	Large (24,000 lbs U_3O_8 to 1973) medium	Morrison Fm, Salt Wash Member-sandstone, mudstone; —; —
Pine Tree*	S34 T28S R27E	47	— — —	— —	—	—	— —	Morrison Fm, Salt Wash Member-sandstone; —; —
Gramlich Group*	S34 T28 R23E	48	— — —	— —	—	—	— —	Morrison Fm, Salt Wash Member-sandstone; —; —
Joan*	S34 T28S R23E	49	— — —	— —	—	—	— —	Morrison Fm, Salt Wash Member-sandstone; —; —
Sunnyside Mine (Joan, Blue Jay, Pine Tree)	S33 T28S R23E	50	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement-tabular carnotite, vanadium mica	Medium 10'T, 500'B, 4'M, 200'x 1,000'	Underground 300'D, 1,000'+L	Small small	Morrison Fm, Salt Wash Member-sandstone, mudstone; —; —
San Juan Mine	S33 T28S R23E	51	Developed producer Active (1977) uranium, vanadium	Bedded, replacement-tabular carnotite, vanadium mica	Medium 30'T, 500'B 4'M, 100x1,000'	Surface/ Underground 500'D, 1,000'+L 100x1,000'	Small small	Morrison Fm, Salt Wash Member-sandstone, mudstone; —; —
Unknown*	S4 T29S R19E	52	— — —	— —	—	—	— —	Chinle Fm; —; —

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 6 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Unknown	S1 T29S R19E	53	Developed prospect Inactive (1978) uranium, manganese	Replacement, disseminated-lens, pod, coating —	Small 10'B, 6'M	Surface 8,700' ft^2; 2 acres strip mined; 35 small pits	Small —	Cutler Fm-sandstone, shale; red jasper, white quartz; fracture filling in sandstone capped by shale
Lockhart* (Any on Claims)	S4 T29S R20E	54	— — —	— —	—	—	— —	Cutler Fm; —; disseminated in sediments
Cup No. 1	S22 T29S R20E	55	Occurrence — uranium	Bedded, replacement, disseminated-lens, irregular —	—	Drilling prog. 80x200' Extent, results unknown	None unknown	Cutler Fm-sandstone, mudstone; (?); white arkosic sandstone lenses
Rainbow Ledge	S22 T29S R20E	56	Developed producer Inactive (1977) uranium	Bedded, replacement, disseminated-lens, irregular —	10'T, 30'B, 2'M	Underground 30'D, 100'L	Small small at 0.10% U_3O_8	Cutler Fm-arkosic sandstone, siltstone; (?); white arkosic sandstone lens
Cutler	S27 T29S R20E	57	Developed producer Inactive (1977) uranium, copper	— —	—	Surface/ Underground 12'D, 18'L 140x150'	Small small at 0.1% U_3O_8	Cutler Fm-sandstone; (?); white bleached arkosic sandstone
Blue Bird (Junction Group)	S3 T29S R23E	59	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated-lens —	Small 10'T, 15'B, 4'M, 40x80'	Surface/ Underground 15'D, 80'L, 15x60'; 5 adits, longest 50'	Small small at 0.05-0.10% U_3O_8	Morrison Fm, Salt Wash Member-sandstone; (?); paleochannels
Unknown (Highway)	S2 T29S R23E	60	Occurrence Inactive (1977) uranium, vanadium	Bedded, replacement-tabular —	—	Surface bulldozer cuts	None —	Morrison Fm, Salt Wash Member-sandstone; —; —
Rattlesnake Mine	S12 T29S R23E	61	Developed producer Inactive (1977) uranium, vanadium	Bedded, replacement-tabular carnotite, tyuyamunite, uraninite	Large 200'T, 500'B, 10'M, 400x500'	Surface/ Underground 200'D, 2,000'+L, 1,000x1,000' open pit, then underground	Large (1.62 million lbs U_3O_8 up to 1973) —	Morrison Fm, Salt Wash Member-sandstone; —; —
Charlie Group*	S36 T29-1/2S R20E	62	— — —	— —	—	—	— —	Cutler Fm (?); —; —

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 7 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Queen of Harts	S4 T30S R21E	65	Occurrence Inactive (1977) uranium	Bedded-tabular, irregular —	—	Surface 20x40; extensive drilling prog., results unknown	Small none	Cutler Fm-sandstone; secondary silica; bleached sandstone, migrating ground water
Redskin II*	S9 T30S R21E	66	-- — —	— —	--	--	— —	Chinle Fm (?); --; --
Unknown (April Creek, Donnelly, Fat Chance)	S1 T30S R21E	67	Raw prospect Inactive (1977) no uranium, minerals encountered	— —	0'T, 12'B, 2'M	Underground 12'D, 20'L, 1 adit, few cuts and drillholes	None none	Chinle and Cutler Fms-gritstone, sandstone; —; —
Dip	S15 T30S R21E	68	Raw prospect Inactive (1977) uranium	— No mineralization encountered in bleached mudstone	—	Underground 80'D, 210'L, 1 adit	None none	Chinle Fm, Moss Back Member-sandstone, mudstone, conglomerate; limonite, carbon trash, gypsum; —
Top (Homestake)	S22 T31S R21E	69	Raw prospect Inactive (1977) uranium	-- --	--	Underground 50'D, 88'L, 1 adit	None none	Chinle Fm, Moss Back Member-sandstone, mudstone; carbon trash, calcite, limonite, silicified wood; —
Blue Hill Group	S35 T30S R21E	70	Raw prospect Inactive (1977) uranium, copper	—	--	Underground 60'D, 175'L	None nil	Chinle Fm, Moss Back Member-sandstone, mudstone, conglomerate; carbonized wood, carbon trash, limonite; paleochannels
Unknown*	S13 T30S R23E	72	-- — —	-- —	--	--	-- —	Navajo Sandstone (?)-sandstone; --; —
Conglomerate 2 & 7 (Lavender)*	S18 T31S R21E	73	-- -- --	-- --	—	--	— --	Chinle/Shinarump Fms; —; disseminated in sediments
Cup (Chuckar, Blue Goose)	S17 T31S R21E	74	Developed producer Inactive (1977) uranium	Replacement, irregular --	Small 1.5'T, 45'B, 1.8'M	Underground 45'D, 2,810'L	Small nil	Chinle Fm, Moss Back Member-sandstone, conglomerate, mudstone, gritstone; carbon trash, logs; paleochannel
Unknown*	S17 T31S R21E	75	-- -- --	-- --	--	--	-- --	Chinle/Shinarump Fms; --; --

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 8 of 12)

Name (a)	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit (b)	Workings (b)	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Unknown*	S17 T31S R21E	76	-- -- --	-- --	--	--	-- --	Chinle/Shinarump Fms; --; --
Lavendar Canyon*	S8 T31S R21E	77	-- -- --	-- --	--	--	-- --	Chinle/Shinarump Fms-sandstone; --; --
Unknown	S9 T31S R21E	78	Raw prospect Inactive (1977) uranium	Disseminated, bedded, replacement --	Small 30'T, 35'B, 1.5'M	Underground 35'D, 40'L, 1 adit	Small nil	Chinle Fm, Moss Back Member-sandstone, mudstone, conglomerate; limonite, gypsum; paleochannels
Paymaster (Bridger Jack)	S3 T31S R21E	79	Raw prospect Inactive (1977) uranium	--	6'T, 10'B	Underground 10'D, 45'L	None nil	Chinle Fm, Moss Back Member-sandstone, conglomerate, mudstone; limonite, silicified logs; paleochannel
Moki Mine (Nighthawk)	S13 T31S R21E	80	Developed producer Inactive (1977) uranium, copper	Replacement, bedded, disseminated-lens, tabular, irregular uraninite, carnotite, azurite	Large 0'T, 40'B, 3'M, 60x120'	Surface/ Underground 40'D, 2,000'+L, 40x80'; room & pillar mining	Large (115,830 lbs to 1973); medium at 0.1% U_3O_8	Chinle Fm, Moss Back Member-sandstone, mudstone, conglomerate; carbon trash, calcite, clay galls; scour paleochannels
Lake Mine (Moki Mine)	S13 T31S R21E	80	Produced 7/83-10/83 uranium		Small	Underground	Small (1,200 tons ore); 0.20% U_3O_8	Chinle Fm
Jean No. 1 Mine (Royal Mine)	S14 T31S R21E	81	Developed producer Inactive (1977) uranium, copper	Disseminated, replacement-lens, tabular, irregular --	Large 18'T, 60'B, 2'M	Surface/ Underground 60'D, 60x80', open pit, adit, incline, vertical shafts	Large (138,568 lbs U_3O_8 to 1973); medium at 0.1% U_3O_8	Chinle Fm, Moss Back Member-sandstone, conglomerate, mudstone; carbon trash, sulphates, limonite; paleochannels
Popeye*	S4 T32S R23E	84	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Lookout Mine (Slush #105)	S4 T32S R23E	85	Producer Inactive (1977) uranium, vanadium	Disseminated, bedded, replacement-tabular carnotite, corvusite, vanadium mica	Medium 80'T, 95'B, 3'M, 30x60'	Underground 95'D, 600'L	Large medium at 0.1% U_3O_8	Morrison Fm, Salt Wash Member-sandstone, mudstone, conglomerate; carbon material, clay galls, logs, gypsum; paleochannel
Little Joe	S9 T32S R23E	86	Raw prospect Inactive (1977) uranium, vanadium	Replacement carnotite, corvusite, vanadium, hydromica	Small 5'T, 12'B, 4"M	Underground 1 adit	None --	Morrison Fm, Salt Wash Member-sandstone, mudstone; clay galls; paleochannel

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 9 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Johnnie Mine Prospect	S2 T32S R23E	87	Raw prospect Inactive (1978) uranium, vanadium	Bedded replacement carnotite	Small	Surface rim stripping	Small --	Morrison Fm, Salt Wash Member-sandstone; --; --
Navajo 1 & 2	S12 T32S R23E	88	Producer Inactive (1978) uranium, vanadium	Bedded, disseminated-lens, irregular, pods carnotite, black vanadium mica	Small 4'T, 15'B, 3'M, 15x30'	Surface/ Underground 20'D, 60'L, 15x50'	Small --	Morrison Fm, Salt Wash Member-sandstone; carbon trash, silicified wood; paleo-channel
Rainy Weather*	S11 T32S R23E	89	-- -- --	-- --	--	--	-- --	Morrison Fm, Salt Wash Member-sandstone; --; --
Black Hawk 1 & 2 (Midnight)	S12 T32S R23E	90	Producer Inactive (1977) uranium, vanadium	Disseminated, bedded-lens, tabular, irregular carnotite, black vanadium mica	Small 6'T, 12'B, 1.2'M	Underground 15'D, 45'L, adit	Small --	Morrison Fm, Salt Wash Member-sandstone; limonite mottling; --
Unknown	S12 T32S R23E	91	Producer Inactive (1978) uranium, vanadium	Bedded, replacement carnotite, corvusite, black vanadium mica	Small 5'T, 2'M	Surface 20x60' small open pit	Small small at 0.1% U_3O_8 0.25% V_2O_5	Morrison Fm, Salt Wash Member-sandstone, mudstone; carbon trash; mineralized near apex of cross bedding
Happy Jack Mine (Peter No. 1-4)	S13 T32S F23E	92	Producer Inactive (1978) uranium, vanadium	Disseminated carnotite, corvusite	Small	Underground adits, incline (caved, flooded)	Medium (5,377 lbs U_3O_8 to 1973) small at 0.1% U_3O_8	Morrison Fm, Salt Wash Member-sandstone, mudstone, siltstone; (?); paleochannel
Horseshoe No. 1	S7 T33S R20E	93	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated, replacement-lens, pods --	Small 80'T, 100'B, 2'M, 120x300'	Underground 100'D, 300'L	Medium (4,771 lbs U_3O_8 to 1973 --	Chinle Fm, Moss Back Member-sandstone; (?); paleochannel
Horseshoe Mine	S8 T33S R20E	94	Raw prospect Inactive (1977) uranium	Disseminated-lens --	Small 15'T, 15'+B, 0.5'M, 1x3'	Underground 15'D, 45'L	None none	Chinle Fm, Moss Back Member-sandstone, mudstone; --; --
Unknown*	S10 T33S R20E	95	-- -- --	-- --	--	--	-- --	Chinle Fm-sandstone; --; --
Unknown	S3 T33S R20E	96	Raw prospect Inactive (1977) uranium	Bedded, disseminated-lens --	Small 60'T, 60'+B, 0.5'M, 1x3'	Underground 60'D, 30'L	None none	Chinle Fm-sandstone, mudstone; --; --
Unknown*	S2 T33S R20E	97	-- -- --	-- --	--	--	-- --	Chinle Fm-sandstone; --; --

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 10 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Unknown*	S22 T33S R20E	98	— — —	— —	—	—	— —	Chinle Fm-sandstone; —; —
Betty Mine	S28 T33S R20E	99	Developed producer Inactive (1977) uranium, vanadium, copper	— uraninite, chalcopyrite, pyrite, chalcocite, covelite	Large (caved)	Underground (caved)	Large (277,625 lbs U_3O_8 to 1973 unable to determine	Chinle Fm, Monitor Butte Member-sandstone; —; —
Abe Mine	S33 T33S R20E	100	Developed producer Inactive (1977) uranium, copper, vanadium	— uraninite, chalcopyrite, covelite, chalcocite	Large (flooded)	Underground (flooded)	Large (213,107 lbs U_3O_8 to 1973; 277,688 lbs Cu to 1973) unable to determine	Chinle Fm, Monitor Butte Member-sandstone; —; —
Glade Group*	S4 T33S R20E	101	— — —	— —	—	—	0-20,000 lbs U_3O_8 —	Chinle Fm, Moss Back Member-sandstone; —; —
Mormon Pasture*	S34 T33S R20E	102	— — —	— —	—	—	— —	Chinle Fm-sandstone; —; —
Hop Canyon*	S7,8 T33S R21E	103	— — —	— —	—	—	— —	Chinle/Shinarump Fms-sandstone; —; —
Shay Mtn. Mines (Blue Claims)	S11,14 T33S R21E	104	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated, replacement-lens, pods uraninite, vanadium mica, metatyuyamunite	Medium 10'T, 100'B, 2'M, 20x40'	Underground 100'D, 500'L 6 adits	Medium (4,270 lbs U_3O_8 to 1973 small at 0.1% U_3O_8	Morrison Fm, Salt Wash Member-sandstone; (?); paleochannel
Robertson Pasture Deposit	S20 T33S R22E	106	Developed producer Inactive (1977) uranium	Disseminated, bedded-tabular, pod uraninite	Small 10'T, 10'+B, 3'M, 6x40'	Surface 15x100'	Small small at 0.05% U_3O_8 maximum	Morrison Fm, Salt Wash Member-sandstone, mudstone; (?); paleochannel
Shay Road Deposit	S17 T33S R22E	107	Developed producer Inactive (1977) uranium	— —	Small 10'T, 10'+B, 3'M, 3x10'	Underground 20'D, 60'L	Small none	Morrison Fm, Salt Wash Member-sandstone; —; —
Lake Claim	S10 T33S R22E	108	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated-pod —	Small 5'T, 40'B, 2'M, 20x40'	Surface/Underground 40'D, 50'L, 40x60'	Small none	Morrison Fm, Salt Wash Member-sandstone, mudstone; (?); paleochannel

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 11 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
URANIUM/VANADIUM RESOURCES (continued)								
Indian Creek No. 2 Mine (Hart Point)	S10 T33S R22E	109	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated, replacement-tabular, pod metatyuyamunite	Medium 30'T, 70'B, 4'M, 25x40'	Underground 70'D, 735'L 4 adits	Medium (1,795 lbs U_3O_8, 1,437 lbs V_2O_5 to 1973); medium	Morrison Fm, Salt Wash Member-sandstone; --; --
Harts Draw Deposits (Pay Off)	S2 T33S R22E	110	Developed producer Inactive (1977) uranium, vanadium	Bedded, disseminated-irregular tabular, pods uraninite, metatyuyamunite	Small 15'T	Underground 2 adits	Small (539 lbs U_3O_8 to 1973) --	Morrison Fm, Salt Wash Member-sandstone, mudstone; --; --
COPPER RESOURCES								
Tuffy Copper Deposit	S5 T33S R22E	105	Developed producer Inactive (1977) copper, uranium	Disseminated replacement-tabular blanket azurite, malachite, carnotite	Small 20'T, 30'B, 2'M, 50x100'	Underground 25'D, 80'L	Small --	Entrada SS-sandstone, siltstone; chert; joints and cross bedding planes in sandstone
Copper Queen Mine	S35 T33S R22E	111	Developed producer Inactive (1977) copper	Fissure vein, replacement-tabular malachite, azurite, chalcopyrite bornite, chalcocite	Small 30'T, 60'B, 0.5'M, 100'ML	Underground 50'D, 100'L,	Small small	Mancos Shale, Dakota SS, diorite - metamorphosed sandstones, shales, associated diorite; pyrite, limonite; fissure veins
MANGANESE RESOURES								
Muleshoe Wash Mang. Deposit	S19 T28S R23E	34	Developed producer Inactive (1977) manganese	Vein, bedded-linear, tabular pyrolusite	Small 0'T, 30'B, 2'M 1/4x1/2 mile (sev. veins & zones)	Surface/ Underground 5'0, 10'L, 20x600'	Small small	Navajo SS-sandstone; (?); veins and bedding planes
QUARTZ RESOURCES								
Chert Collecting Locality	S3 T29S R23E	58	Raw prospect Inactive (1977) quartz	Bedded-blanket chalcedony	Large 0'T, 5'M horizon extends for sev. miles	Surface no workings; a collecting locality	None --	Summerville Fm-limestone, siltstone; --; --
Spanish Bottoms Chalcedony	S34 T30S R18E	63	Occurrence Inactive (1977) within Canyonlands National Park	Bedded-tabular, lens, nodules chalcedony, chert, jasper	Medium 0'T, 1'M	No workings	None medium	Hermosa and Elephant Canyon Fms-limestone; --; --
IRON OXIDE RESOURCES								
Unknown	S13 T30S R20E	64	Occurrence Inactive (1977) iron oxide	-- --	0'T, 2"M	Surface 60x100' open pit	None --	Cutler Fm-sandstone, mudstone; (?); white bleached lens in sandstone, coating on bedding planes

Table 3-12. Mineral Resources in the Davis Canyon Candidate Area (Page 12 of 12)

Name[a]	Loc.	No	Explor. Status; Commod. Present	Type of Deposit; Ore Materials	Size of Deposit[b]	Workings[b]	Production; Pot. Resources	Geology; Mineralogy; Ore Control
SAND AND GRAVEL RESOURCES								
Utah Dept of Highways Pit No. 19005	S1 T28S R22E	28	Developed producer Inactive (1977) —	Unconsolidated sediments-lenticular igneous and sedimentary rock clasts	Large 0'T, 10'B, 10'M, 150x1,000'	Surface 25x75'	Small 230,000 s. tons	River terrace gravels-unconsolidated Quaternary sediments; --; —
Utah Dept of Highways Pit No. 19013	S10 T30S R23E	71	Producer Inactive (1977) —	Unconsolidated sediments-lenticular sedimentary rocks, chert	Medium 0'T, 6'B, 6'M, 300x1,000' cap on a bench	Surface 100x200'	Medium 60,000 cubic yards	River terrace deposits-unconsolidated Quaternary sediments; --; —
Utah Dept of Highways Pit No. 19015	S24 T31S R23E	82	Producer Inactive (1977) —	Unconsolidated sediments-lenticular igneous and sedimentary rocks	Small 2'T, 5'B, 18'M, 150x500'	Surface 150x150'	Small 40,000 cubic yards	River terrace deposits-unconsolidated Quaternary sediments; --; —
Utah Dept of Highways Pit No. 19017	S36 T31S R23E	83	Producer Inactive (1977) —	Unconsolicated sediments-lenticular igneous and sedimentary rocks	Small 0'T, 5'B, 5'M, 150x600'	Surface 105x450'	Small 7,000 cubic yards	River terrace deposits-unconsolidated Quaternary sediments; --; —
Utah Dept of Highways Pit No. 19020	S24 T33S R23E	112	Developed producer Inactive (1977) —	Unconsolidated sediments-lenticular igneous rocks	Small 0'T, 5'B, 6'M, 200x3,000'	Surface 150x300' 2 pits	Small 20,000 s. tons	River terrace deposits-unconsolidated Quaternary sediments; --; —
Utah Dept of Highways Pit No. 19021	S25 T33S R23E	113	Developed producer Inactive (1977) —	Unconsolidated sediments igneous and sedimentary rocks	Large 0'T, 20'B, 20'M, 1,000x2,000'	Surface 450x450'	Medium 400,000 s. tons	River terrace deposits-unconsolidated Quaternary sediments; --; —

(a) All data are from USGS (1982) except those marked * which are from Campbell et al., (1982a, b).

(b) Abbreviations:
T = To top
B = To bottom
M = Maximum thickness
ML = Maximum length
D = Depth
L = Length

"small" for two localities and "large" for the Moki Mine and Jean No. 1 mine, located 5.3 kilometers (3.3 miles) from the geologic repository operations area (GROA). The small production mines are located within 2 kilometers (1.2 miles) of the GROA; the nearest uranium deposit in the Cutler Formation is 11.2 kilometers (7 miles) north of this area (USGS, 1982).

The site vicinity contains only four documented uranium and vanadium production localities, fewer than most other areas of similar size and geologic conditions within the candidate area (Figure 3-37, Table 3-12). Discussions with several persons knowledgeable of uranium and vanadium resources in this region (Doelling, 1983; Merrell, 1983; Chenoweth, 1983) indicate that uranium and vanadium potential within the site vicinity is low relative to the candidate area and region. Compared with areas of similar size and geology outside the candidate area in southeastern Utah, uranium and vanadium resources of the site vicinity are judged to be low to very low.

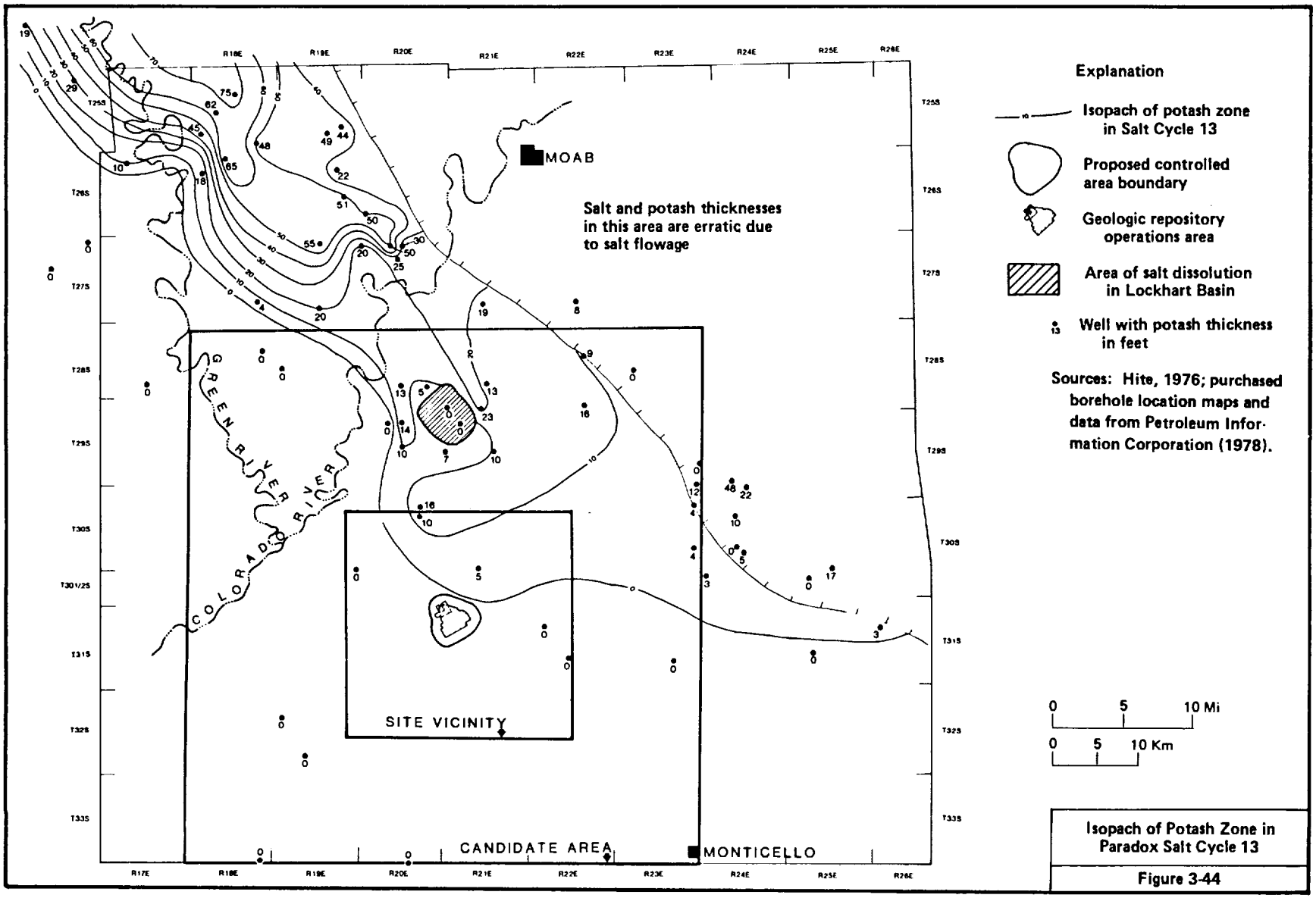
3.2.8.2.2 Potash. Subsurface occurrences of potash are located in the Paradox Formation within many of the 29 evaporite cycles identified by Hite (1960, p. 86, Figure 2). These occurrences are generally located near the top of an individual salt cycle. The principal potash minerals are sylvite and carnallite.

In the Davis Canyon candidate area, the most extensive potash occurrences are located within three salt cycles (Cycles 6, 13, and 18). Elsewhere in the Paradox Basin (to the north and east towards the basin depocenter), other cycles contain significant potash occurrences. For example, to the north, Cycles 2 and 5 contain significant occurrences; Cycle 5 is currently being mined (by solution methods) by Texas Gulf Inc., at Potash. Also to the east in the Lisbon Valley area, Cycles 19, 20, and 24 contain significant potash occurrences. Within the candidate area however, only Cycles 6, 13, and 18 have been observed to contain such potash occurrences.

Based on testing of core and analysis of geophysical log data, potash occurrences in Salt Cycles 13 and 18 constitute deposits that are potentially economic in various areas within the Paradox Basin (Hite, 1976, p. 4; 1978, pp. 1, 2; 1982b, pp. 4, 7). The variations in thickness of potash zones within these salt cycles are shown on isopach maps in Figures 3-44 and 3-45 (see also Section 3.2.3, Figures 3-21 and 3-23). In each case, the potash zone thickness increases to the north, east, and (for Cycle 18) southeast, while zone thickness (and in Salt Cycle 6, potash content) decreases toward the site. For Salt Cycle 18, the western limit of these zones near the site is poorly defined; it is likely that any deposits within these zones do not underlie Davis Canyon and the site (Hite 1982b, p. 7). Hite's (1982b) estimate of boundaries of zero potash deposition and potentially economic deposits in Salt Cycle 18 are shown in Figure 3-38. Potash content and the extent of the carnallite marker horizon in Salt Cycle 6 are discussed in Section 3.2.3.3.

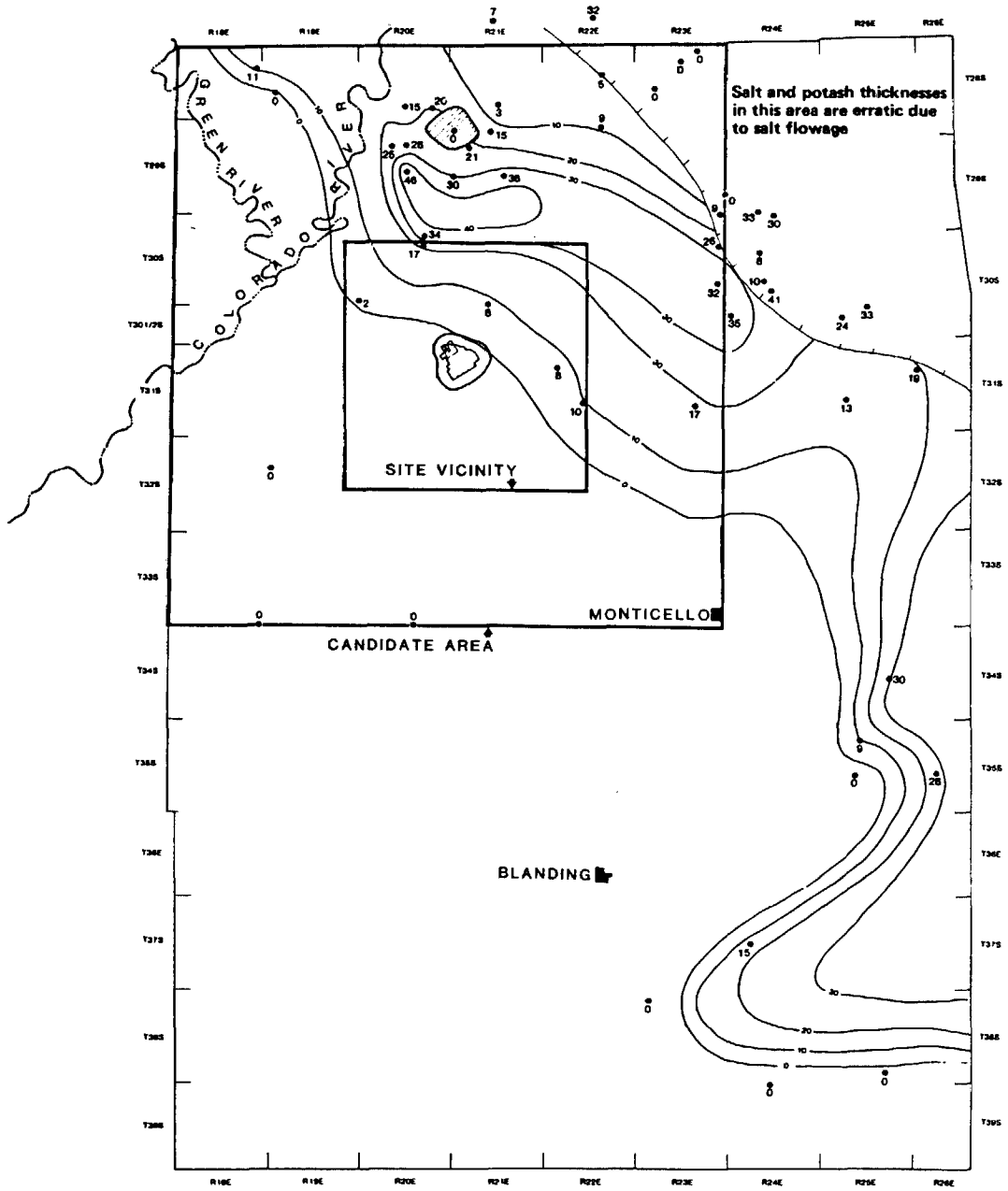
Potash occurrences in Salt Cycle 6 are found in a zone commonly referred to as the "carnallite marker" (Section 3.2.3.3). This subunit is composed primarily of halite that contains abundant carnallite and anhydrite stringers with minor amounts of sylvite occurring near the top. Within the basin, this carnallite marker zone is more than 30 meters (100 feet) thick. In the GD-1 borehole, the carnallite marker is approximately 40 meters (130 feet) thick (Hite, 1982b, p. 1) but contains an average of only one percent K_2O. Two thin (0.6 to 1.2 meters [2 to 4 feet]) zones near the base of the zone average 2.4 and 4.1 percent K_2O. Despite the very thick 40-meter (130-foot) section, the low potassium content, anhydrite stringers, and magnesium content of the carnallite make this potash zone uneconomical even for solution mining.

Since potash occurrences in Salt Cycles 13 and 18 are considered to be potentially economic, a preliminary estimate was made of the volumes of potential mineable potash resources in each cycle for the site vicinity, candidate area, and surrounding parts of the Paradox Basin. For this estimate a minimum mineable thickness cutoff of 3 meters (10 feet), and a grade-times-thickness cutoff value of 150 was assumed and used. The 3-meter (10-foot) mineable thickness cutoff was adopted because 3 meters (10 feet) is the minimum thickness normally recoverable in underground mining operations, thus, mining of potash beds thinner than 3 meters (10 feet) would be diluted by nonpotash material within the overbreak on either



Isopach of Potash Zone in Paradox Salt Cycle 13

Figure 3-44



Explanation

Isopach of potash zone in Salt Cycle 18

Proposed controlled area boundary

Geologic repository operations area

Area of salt dissolution in Lockhart Basin

Well with potash thickness in feet

Sources: Hite, 1978; purchased borehole location maps and data from Petroleum Information Corporation (1978).

0 5 10 20 Mi

0 5 10 20 Km

Isopach of Potash Zone in Paradox Salt Cycle 18

Figure 3-45

side of the potash bed. This concept would apply either to standard underground mining techniques or to solution mining. The grade-times-thickness measure is an exploration guide and normalizing technique used to compare potash beds of varying grade and thickness. The 150 value for grade times thickness cutoff was used by Dames and Moore (1978) during an inventory of potash resources in part of the Paradox Basin.

Potash in Salt Cycle 13 occurs over a large part of the Paradox Basin, but is best developed (thicker, higher grade) 48 to 64 kilometers (30 to 40 miles) north and northwest of the GD-1 borehole in an area known as the Seven Mile area. Here, potash zones in Salt Cycle 13 contain the high-grade potash mineral sylvite, which makes this zone a very good solution mining target, given sufficient thickness. In the GD-1 borehole the potash zone was 1.9 meters (6.2 feet) thick, and the average grade was 16.5 percent K_2O (Hite, 1982b, p. 4); this results in a grade-thickness value of 102.3, lower than the 150 value used for cutoff for potash resources. An estimated 20.9 billion metric tons (25.5 billion tons) of potash resources was calculated for the Salt Cycle 13 potash in the Seven Mile area, based on the isopach map of Salt Cycle 13 potash (Figure 3-44) and the two cutoff values. There is some potential for potash production from this bed in the northern part of the candidate area, but generally very little potential within the site vicinity where the potash bed is very thin (less than the 3-meter [10-foot] cutoff thickness in most of the site vicinity) (Figure 3-45). A comparison of the site vicinity, candidate area, and the Seven Mile area in terms of potential total resources in Salt Cycle 13 is shown in Table 3-13. The site vicinity covers 0.7 percent of the total area involved, but only 0.17 percent of the potential total resources in terms of area times average thickness. In terms of calculated tonnage, the site vicinity constitutes only 1.3 percent of the total tonnage in the candidate area.

Potash in Salt Cycle 18 occurs in one or more beds that extend over a large area of the Paradox Basin; these beds have sufficient grade and thickness to make them a potential solution mining target. These beds are best developed southeast of the candidate area, towards Monticello and Hatch Trading Post, Utah, and Dove Creek, Colorado. This roughly rectangular 32 by 56-kilometer (20 by 35-mile) area contains potash in Salt Cycle 18 at depths of 1,768 to 2,133 meters (5,800 to 7,000 feet); total potash bed thickness is 3 to 12 meters (10 to 40 feet). Using the isopach map in Figure 3-45 and cutoff values, an estimated 48.0 billion metric tons (58.6 billion tons) of potash resource was calculated for Salt Cycle 18 potash within both the Davis Canyon, Monticello and Dove Creek areas. In the northern part of the Davis Canyon candidate area, the Cycle 18 beds are also up to 12 meters (40 feet) in total thickness, but thin rapidly toward the south and within the site vicinity (Figures 3-38 and 3-45). There are usually two sylvite beds present that are separated by a bed of halite. In the GD-1 borehole, only the upper sylvite bed was present. The thickness of this sylvite bed is 2.5 meters (8.2 feet) and the grade is 22.1 percent K_2O, resulting in a grade-thickness value of 181. At this point, the grade and thickness are favorable, although the depth of 1,350 meters (4,430 feet) is too deep for solution mining at the present time. This same potash horizon occurs at shallower depths to the north along the crests of some structures; at Rustler Dome, Gibson Dome, and Lockhart anticline, depths are from 1,036 to 1,250 meters (3,400 to 4,100 feet). As indicated on Figure 3-45, potash bed thickness is also greater here than within the site vicinity. Similar to Salt Cycle 13, there is potential for production from this cycle in the northern point of the candidate area, but generally very little potential within the site vicinity. Potash beds are thinner than the 3-meter (10-foot) cutoff in most of the site vicinity (Figure 3-38). A comparison of the site vicinity, candidate area, and the Monticello and Dove Creek area in terms of potential potash resource in Salt Cycle 18 is shown in Table 3-13. The site vicinity covers 3 percent of the total area involved, and contains 1.6 percent of the potential potash resources. In terms of tonnage, the site vicinity contains only 8.2 percent of the total tonnage in the candidate area.

A summary of the Paradox Basin potash resources (consisting of the above described potash potential of Cycles 13 and 18) is also shown in Table 3-13. A comparison of the site vicinity, candidate area, and total basin resource inventory in this table shows that the site vicinity contains only 0.4 percent and the candidate area only 7.0 percent of the total potash inventory within the Paradox Basin.

Table 3-13. Potash Resource Data, Paradox Basin

Salt Cycle 13:

	Area of Potash Bed Above Cutoff Values (sq. miles)	Percent of Total Area[a]	Average Thickness (TH) of Potash Beds	Average TH x Area	Percent of Tonnage	Tonnage Calculated[b] (1,000 tons)
Site Vicinity	3	0.7	10 (minimum)	30	0.17	51,000[c]
Candidate Area	140	32	20	2,800	16	4,760,000
"Seven Mile" Area (NW of candidate area)	300	68	50	15,000	84	25,500,000

(a) Total Area (140 + 300) = 440 square miles.
(b) Tonnage calculations for this study were made as follows:
square miles x conversion factor x average thickness = tons potash
conversion factor = 1.7×10^6 = tons of potash/square mile/one-foot thickness (using 16 cubic-feet-per-ton).
(c) 1.3% of candidate area.

Salt Cycle 18:

	Area of Potash Bed Above Cutoff Values (sq. miles)	Percent of Total Area[d]	Average Thickness (TH) of Potash Beds	Average TH x Area	Percent of Tonnage	Tonnage Calculated[e] (1,000 tons)
Site Vicinity	38	3	15	570	2	969,000[f]
Candidate Area	330	24	25	8,250	24	14,025,000
Monticello/Dove Creek Area (SE of candidate area)	1,050	76	25	26,250	76	44,625,000

(d) Total Area (330 + 1,050) = 1,380 square miles.
(e) Tonnage calculations for this study were made as follows:
square miles x conversion factors x average thickness = tons potash
conversion factor = 1.7×10^6 = tons of potash/square mile/one-foot thickness (using 16 cubic-feet-per-ton).
(f) 8.2% of candidate area.

Table 3-13. Potash Resource Data, Paradox Basin
(Page 2 of 2)

	Total Area (sq. miles)	Percent of Total Area	Estimated Potash Inventory (million tons)	Percent of Total Potash Inventory
Site Vicinity	256	2.6	1,020[g]	0.4
Candidate Area	1,444	14	18,785	7
Paradox Basin	10,000	100	270,000(average)[g]	100

(g) Tonnage calculations for this study were made as follows:
square miles x conversion factor x average thickness = tons potash
conversion factor = 1.7×10^6 = tons of potash/square mile/one-foot thickness (using 16 cubic-feet-per-ton).

In order to gain an understanding of the relative importance of Paradox Basin potash resources to United States and world potash resources, a survey of various statistical commodity studies reported in the literature was made. There are widely divergent published estimates for Paradox Basin potash resources (from 1.6 billion metric tons [2 billion tons] [Bureau of Mines, 1984, p. 119] to 16.4 billion metric tons [200 billion tons] [Searls, 1985, p. 16]). These differences are in part due to the use of different areas, and probably different techniques. However, the relative proportion of resources reported by the Bureau of Mines (1984, p. 119) between worldwide, Canada, United States, and Utah is believed to be reasonable; this proportion is as follows:

- Worldwide - 100.0 percent
- Canada - 67.0 percent
- U.S. - 2.4 percent
- Utah - 0.8 percent.

Canadian deposits are generally shallower, higher grade, and significantly larger than Paradox Basin resources. Thus it is very difficult at the present time for the United States or Paradox Basin to compete in the potash industry except where railroad or other transportation rates provide the equalizing factor. It is predicted that, in future years, United States consumers will become increasingly dependent on imported potash from the huge Canadian deposits (as much as 90 percent of projected demand by the year 2000) (Searls, 1983).

In summary, the thickness and grade of potash in Paradox Salt Cycle 18 (constituting large resources), will probably be one of the principal targets to be exploited within the next few centuries as economic conditions change and need and supply of potash dictates prices that allow for deeper solution mining operations. Based on potash potential and the geologic conditions of the site vicinity as compared to the surrounding areas (described above), it is judged very unlikely that the site vicinity potash potential will ever be exploited either now or in the future. This judgment is based on two factors: (1) the very thin (grading to zero) potash thicknesses present in the sylvite beds of Salt Cycles 13 and 18, and (2) the very low potassium content in the thick but very low grade of the "carnallite marker" zone in Salt Cycle 6.

3.2.8.2.3 Miscellaneous Minerals.* Copper, manganese, quartz, iron oxide, sand, gravel, and dimension stone resources are present within the candidate area. Copper is known to occur at two localities in the southeastern part of the candidate area in mineralized veins within the Mancos Shale, Dakota Sandstone, and Entrada Sandstone. Copper is also a common secondary mineral commodity in uranium ores; at one mine, more copper than uranium was produced.

Manganese production is known to occur at one locality in the northeastern part of the candidate area. Manganese is also reported as a minor constituent at one uranium deposit in the Cutler Formation west of the Colorado River.

Quartz in the form of chalcedony, chert, and jasper occurs at two localities on the eastern and western margins of the candidate area; no production of this material has been recorded.

One iron oxide occurrence is located near the center of the candidate area (Figure 3-37). The deposit consists of hematite within sandstone lenses in the Cutler Formation. It extends over an 18-by-30-meter (60-by-100-foot) area, and is judged not to contain adequate volume for mining (Merrell and Utah Geological and Mineral Survey, 1979, p. 58).

Quaternary-age gravel and terrace deposits have been developed by the Utah Department of Highways at six localities along U.S. 191 on the eastern margin of the candidate area (Figure 3-37). These open pits were classified as inactive in 1977. Within the site, gravel

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*The data presented in this section are taken from USGS (1982) unless otherwise noted.

deposits of up to 3 meters (10 feet) thick occur on isolated stream terrace remnants above and bordering Indian Creek; abundant sand occurs in the alluvium of modern stream channels (WCC, 1982, ONWI-290, Vol. II, pp. 4-6 to 4-9). Minor sand and gravel production for local use is evident at a site along Utah 211, approximately 4 kilometers (2.4 miles) northeast of the geologic repository operations area.

Dimension stone for local use has been produced from sandstone in various formations, including the Chinle and Moenkopi (Merrell and Utah Geological and Mineral Survey, 1979, pp. 58-59). However, production has occurred only outside the candidate area. The massive Wingate Sandstone may be an additional source of dimension stone. Dimension stone is rarely used in modern construction, and would be mined as close as possible to any site where it is used.

3.2.8.3 Leasing Activity

A survey of oil, gas, and mineral leasing status and of mining claim status was made in May, 1985, based on records at the Bureau of Land Management (BLM), Utah State Lands and Forestry Division, and the San Juan County Recorder's Office. Within the candidate area, most of the Federal and State lands available for leasing (e.g., outside of Canyonlands National Park) are leased for oil and gas exploration. Within the site vicinity, 65 percent of such lands are leased; most of the controlled area is outside of these leased lands. The only current oil and gas lease on private lands in the site vicinity is located southeast of the controlled area.

Mineral leases are present only on State lands, and only in the northern and eastern parts of the candidate area; none of these are within the controlled area. No mineral leases on private lands are present in the controlled area or elsewhere in the site vicinity.

Mining claims cover much of the candidate area except for the southwestern part. Most of the candidate area contains less than ten claims per section. The eastern part of the site vicinity and an area at the proposed site are covered by more than 20 claims per section.

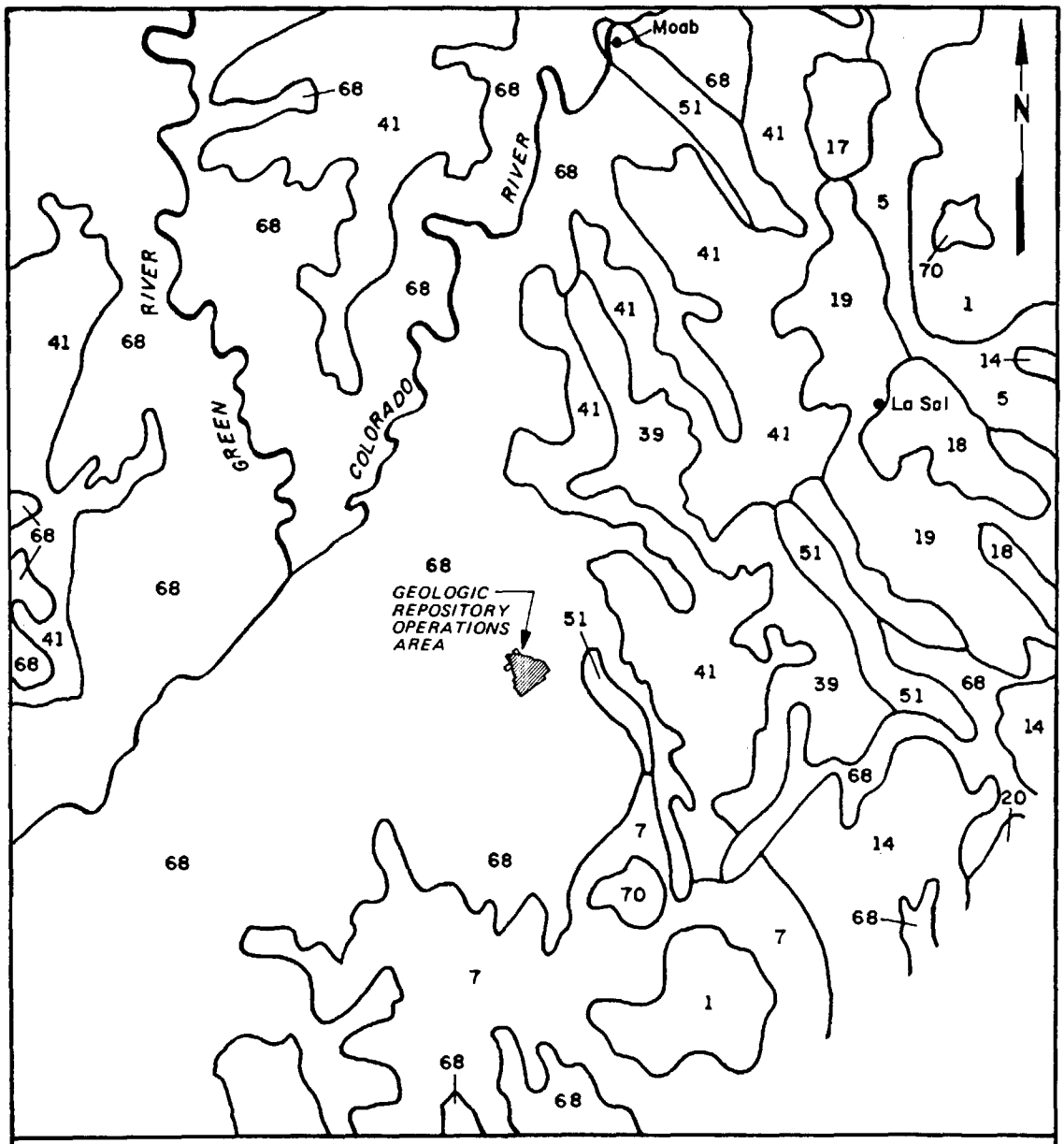
A similar survey of leasing and claim status was made in 1982 for the area at and near the proposed site (drainage basins of streams in Davis and Lavender Canyons). The 1985 survey found that most of the 1982 oil and gas leases and all the 1982 mineral leases in this area had expired, and the lands had not been re-leased. There were also fewer active mining claims in 1985 than in 1982.

It should be noted that there is no particular correlation between lease or claim activity and actual mineral occurrences. Changes in activity are more likely a function of general economic and marketing conditions (such as the decrease in lease activity in the currently declining uranium exploration industry). The decline in oil and gas leasing near the site follows general trends of declining oil exploration activity in the United States and worldwide, due to recent declines in world oil prices. By contrast, increased drilling activity in 1984 was reported for the State of Utah (912,614 meters versus 779,837 meters [2,994,142 feet versus 2,558,520 feet] for 1983) (Petroleum Information Corp., 1985, p. 39). This increased drilling footage was accounted for mostly by development drilling within existing fields, some of which have been discovered since 1980. The new discoveries and increased drilling southeast of the candidate area probably reflect a perceived greater oil and gas potential there, as discussed above in Section 3.2.8.1.

3.2.9 Soils

The Davis Canyon geologic repository operations area (GROA) lies in a soil-mapping unit identified as Rock Land on the Utah State soil map (Wilson et al., 1975) (Figure 3-46). The following soil mapping units have been preliminarily identified within the Davis Canyon GROA (Figure 3-47) (SCS, 1978):

- Begay sandy loam, 2- to 6-percent slopes
- Ignacio-Leanto fine sandy loam, 2- to 6-percent slopes



Explanation

1. ARGIC CRYOBOROLLS–PACHIC CRYOBOROLLS–CRYIC PALEBOROLLS
5. TYPIC AGRIBOROLLS-LITHIC ARGIBOROLLS–TYPIC HAPLOBOROLLS
7. LITHIC ARGIBOROLLS
14. UDIC ARGIBOROLLS–TYPIC ARGIUSTOLLS
17. PETROCALCIC CALCIBOROLLS–ARIDIC CALCIBOROLLS
18. ARIDIC ARGIUSTOLLS–TYPIC ARGIUSTOLLS
19. LITHIC ARGIUSTOLLS– ARIDIC ARGIUSTOLLS LITHIC CALCIUSTOLLS
20. USTOLLIC HAPLARGIDS–USTOLLIC CALCIORTHIDS
39. TYPIC USTORTHENTS–TYPIC CALCIUSTOLLS
41. LITHIC USTOLLIC CALCIORTHIDS–LITHIC USTIC TORRIORTHENTS
51. AQUIC XEROFLUVENTS–AQUIC USTIFLUVENTS–TYPIC TORRIFLUVENTS
68. ROCK LAND
70. ROCK LAND OF THE HIGH MOUNTAINS

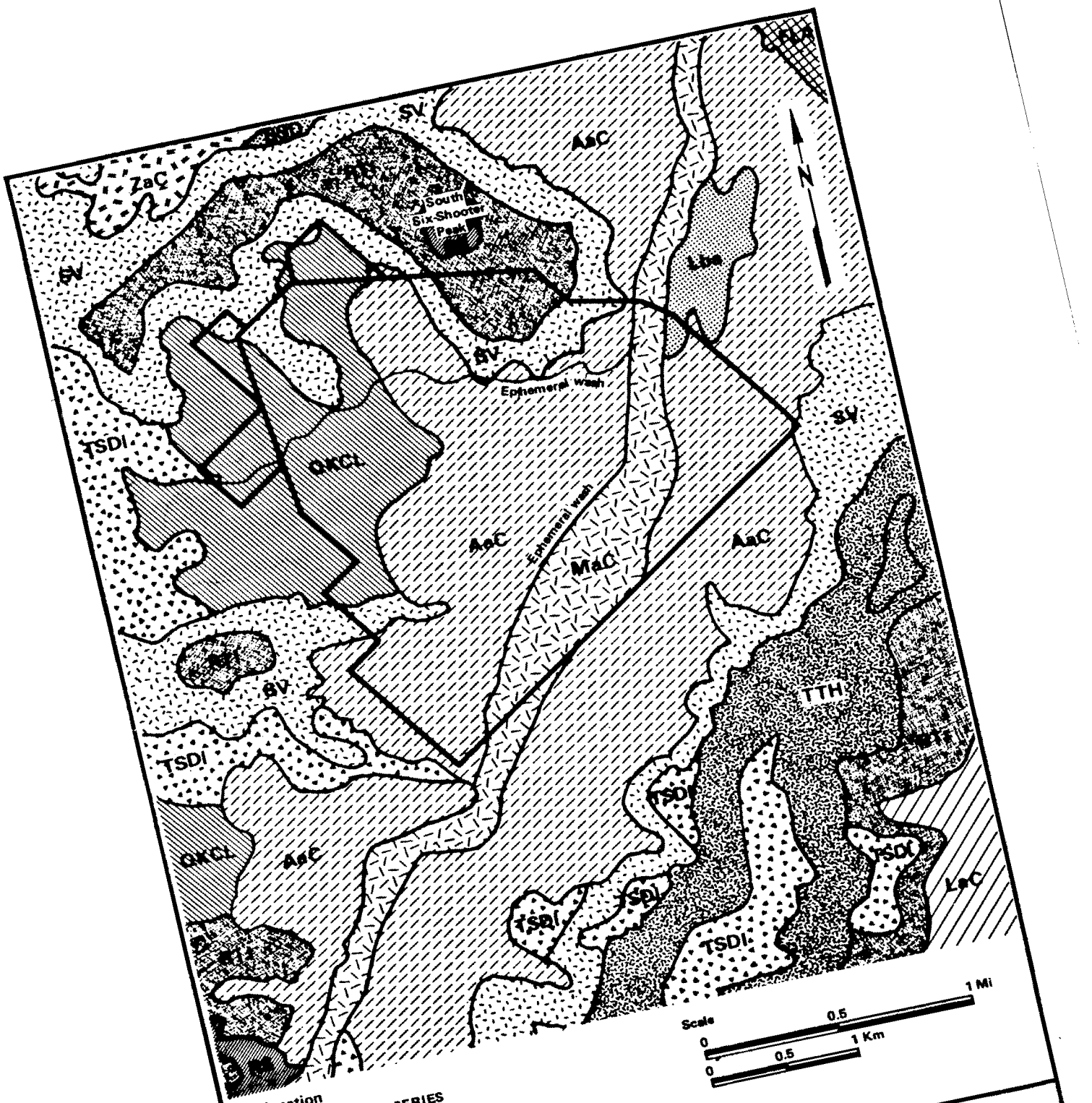
0 10 20 Mi

0 10 20 Km

Source: Wilson et al., 1975.

Soils
Davis Canyon Site and Vicinity

Figure 3-46



Explanation

MAPPING UNITS	SERIES
AsC	Begay
QKCL	Ingacio-Leanto
SV, RS, RTI	Rock Outcrop
MaC	Mido Series
TSDI	Rizno Series

GEOLOGIC REPOSITORY OPERATIONS AREA

Source: BNI, 1985c.

Davis Canyon
Geologic Repository Operations Area Soils

Figure 3-47

- Redbank very fine sandy loam, alkali, 0- to 3-percent slopes
- Redbank fine sandy loam, dry, 0- to 3-percent slopes.

The upper part of Davis Canyon (outside the GROA) is characterized by soils of the Mido series. Soils of this series are very deep, well drained, highly permeable, and were formed on windblown deposits derived primarily from sandstone.

The Davis Canyon site is characterized by soils of the Ignacio and Begay soil series. The Ignacio series consists of moderately deep, well-drained, moderately permeable soils that formed in eolian deposits derived primarily from sandstone. Soil thickness is approximately 51 to 102 centimeters (20 to 40 inches) and ranges from mildly alkaline (pH 7.6) near the surface to strongly alkaline (pH 8.8) in the deepest sections. The Begay series consists of very deep, well-drained, moderately permeable soils that formed in eolian deposits derived primarily from sandstone. Soil depth is in excess of 152 centimeters (60 inches); alkalinity is moderate (pH 8.2) at shallow depths and strongly alkaline (pH 9.0) in the lower part of the soil.

The high pH values may suggest that existing sodium concentrations are high; however, detailed soil chemistry studies have not been conducted to determine the specific chemical characteristics.

The vegetation at the site provides some protection against the water and wind erosion. This stabilizing vegetation includes not only shrubs and grasses, but also plants responsible for the formation of the thin cryptogamic soil crust, which is particularly important to easily eroded soils such as the Begay series. The location of the Begay soils at the site is shown in Figure 3-47. The existing mean erosion rate established from measurements from a number of locations in the candidate area is 2.5 metric tons per hectare (1.11 tons per acre) per year, with a range of 0.4 to 6.4 metric tons per hectare (0.18 to 2.85 tons per acre) per year (BNI, 1984a). The erosion rates are lower than the regional average sediment yields, because the sampling locations were nearly level with moderate plant cover.

3.3 HYDROLOGIC CONDITIONS

This section discusses the hydrologic conditions at the site. It includes a description of the surface-water conditions in the area, the geohydrologic conditions and ground-water flow system, and the water use in the vicinity of the site.

3.3.1 Surface Water

Surface waters are a vital component of both intrastate and interstate water supplies, serving the needs of municipalities, industries, agriculture, recreation, public utilities, and wildlife. The hydrologic character of the region is established through a complex interaction of climate, geology, topography, vegetation, and human activities.

3.3.1.1 Hydrologic Setting

The Davis Canyon candidate area is located in the Upper Colorado River Basin, which is part of the Upper Colorado Water Resource Region (UCWRR) (Figure 3-48). The UCWRR covers an area of approximately 294,000 square kilometers (113,500 square miles) within western Colorado, eastern Utah, southwestern Wyoming, northwestern New Mexico, and northeastern Arizona. Approximately 283,600 square kilometers (109,500 square miles) of the UCWRR are in the Upper Colorado River drainage basin; 10,300 square kilometers (3,960 square miles) drain into the Great Divide Closed Basin in Wyoming.

The Colorado River originates in north-central Colorado and flows 1,030 kilometers (640 miles) southwest through the UCWRR (Figure 3-49). Its major tributary, the Green River, originates in western Wyoming and travels 1,180 kilometers (730 miles) to meet the Colorado River in southeastern Utah. The Gunnison, Dolores, and San Juan Rivers flow west into the

Explanation

PARADOX BEDDED SALT REGION

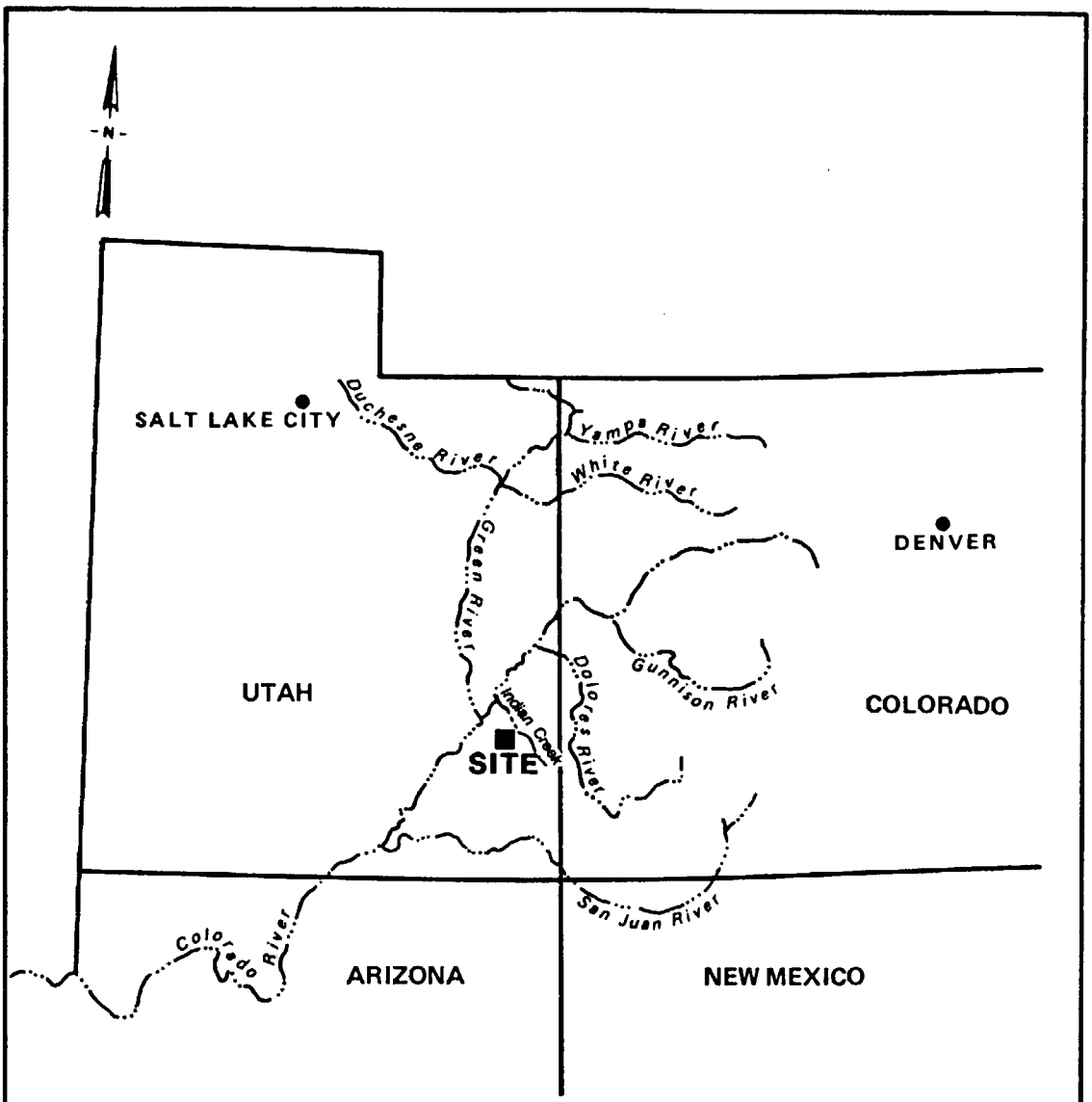
0 200 400 600 800 1000 Mi

0 200 400 600 800 1000 Km

Source: BNI, 1982, ONWI-68.

Water Resource Regions of the United States

Figure 3-48



Regional Drainage Pattern

Figure 3-49

Colorado River; the Yampa and White Rivers from the east and the Duchesne River from the west empty into the Green River. Colorado River water-quality problems include high levels of suspended and dissolved solids.

The Davis Canyon geologic repository operations area (GROA) is located in southeastern Utah at an elevation of approximately 1,585 meters (5,200 feet) above mean sea level (MSL). The proposed surface facilities are situated in a small unnamed desert ephemeral wash near the mouth of Davis Canyon (Figure 3-47). At its confluence with the main wash for Davis Canyon, this unnamed wash drains an area of approximately 9.3 square kilometers (3.6 square miles), while the drainage area of Davis Canyon at this point is estimated to be 49 square kilometers (19 square miles). Davis Canyon is a tributary of Indian Creek, which joins the Colorado River 23 kilometers (14 miles) northwest of the GROA.

The climate in southeastern Utah is characterized by warm summers and cold winters. It is classified as a predominantly cool, semiarid, midlatitude steppe, with isolated areas classified as midlatitude desert (BLM, 1982a). Climatic data for the site are sparse. The nearest U.S. National Weather Service meteorological stations are at Moab and Monticello, 53 and 39 kilometers (33 and 24 miles) north-northeast and southeast of the site, respectively. The mean annual total precipitation is 203 millimeters (8.0 inches) at Moab, elevation 1,209 meters (3,965 feet), and 366 millimeters (14.4 inches) at Monticello, elevation 2,128 meters (6,980 feet) (NOAA, 1984a, b). For the period of record, 1951 to 1980, the observed mean monthly total precipitation at Moab ranges from a low of 9.4 millimeters (0.37 inch) in June to a high of 23.9 millimeters (0.94 inch) in October. The greatest daily amount was 53.3 millimeters (2.10 inches) which occurred on April 9, 1978. For the same period, the observed precipitation at Monticello ranges from a mean monthly low of 12.2 millimeters (0.48 inch) in June to a high of 48.0 millimeters (1.89 inches) in August. The greatest daily amount was 85.9 millimeters (3.38 inches) on August 1, 1968. As indicated in the record, a high variability in precipitation exists depending on season, and about 25 percent of the mean annual precipitation can sometimes occur in a single day. Because differences in elevation and rugged terrain can cause local differences in weather conditions, the data observed at Moab and Monticello only approximate that for the GROA. The annual lake evaporation value for the GROA was estimated to be approximately 127 centimeters (50 inches) (Farnsworth et al., 1982, Map 3).

The headwaters of Indian Creek and its two major tributaries, Cottonwood Creek and Harts Draw, drain the igneous intrusive rocks of the highest part of the Abajo Mountains. The upper reaches of these streams are perennial (WCC, 1982, ONWI-290, Vol. II, p. 4-3). The upland surfaces are drained by an integrated network of tributaries that transport water and sediment to Indian Creek, which flows northwest to meet the Colorado River. Most of the tributaries are ephemeral, flowing only during and immediately after intense summer storms. Current data indicate one small stock-watering pond on Indian Creek near Dugout Ranch, which is used for irrigation.

Annual runoff in and around the site is less than 2.5 centimeters (1 inch) per year except at the highest elevation, where up to 10 centimeters (4 inches) of runoff is produced each year (Bureau of Reclamation, 1969, p. 46). Runoff is derived principally from spring snowmelt at higher elevations and from late summer thunderstorms at lower elevations. Little snowfall accumulates below an altitude of approximately 1,830 meters (6,000 feet). Thus, snowpack is not an important factor in local spring runoff, because the Davis Canyon watersheds are between 1,220 and 1,980 meters (4,000 and 6,500 feet) in elevation.

The Davis Canyon site is characterized by nearly vertical canyon walls rising from a relatively broad valley floor. In the unnamed wash, the valley floor is approximately 1.6 kilometers (1 mile) wide with a slope of approximately 1- to 2-percent parallel to and approximately 1- to 4-percent perpendicular to the canyon axis. The soils in the valley floor are well-drained, loamy, fine sand derived from the weathering of the canyon walls, which are composed primarily of shale and sandstone. The local watersheds are small; therefore, summer thunderstorms may cause local flooding. The runoff can be fast, heavy, and destructive. Extreme flood events are generally caused by local thunderstorms occurring in August and September. These storms are associated with the passage of warm, moist, air masses that originate in the Gulf of California and the southeastern Pacific.

3.3.1.2 Streamflow Characteristics

No streamflow data are available for the Davis Canyon GROA. Streamflow data are available for several gaging locations (now discontinued) that were previously maintained by the U.S. Geological Survey in the Indian Creek basin. The locations of these stations are shown on Figure 3-50; the data are summarized in Table 3-14.

Table 3-15 presents the mean monthly streamflow values of Indian Creek above Cottonwood Creek, the stream-gaging station with the longest record in this area. These data indicate that the flows in these streams are seasonal, and that the majority of the flows occur in the snowmelt period from April to June. Substantial daily variations occur, particularly in the summer months, as a result of thunderstorms.

3.3.1.3 Water Quality

Water-quality data for the Colorado River are the most complete in the region. Table 3-16 presents water-quality data for the Colorado River at the Cisco gaging station, approximately 80 kilometers (50 miles) northeast of the confluence with Indian Creek. Data are for the highest (1982 through 1983) and lowest (1976 through 1977) annual flows recorded at this station since 1971. The Colorado River had a mean annual flow of 195 cubic meters per second (6,895 cubic feet per second) during the period of 1971 to 1983. It also had a high suspended sediment content, averaging 7.16 million metric tons (7.89 million tons) per year for the same period (USGS, 1971-1983). An average salt load in the Colorado River of 3.46 million metric tons (3.82 million tons) per year was reported by the Bureau of Land Management (BLM) (1982b, p. 57) for the period 1966 through 1975. Salinity is identified as the most significant surface water-quality problem of the region (BGI, 1982, ONWI-144, p. 58).

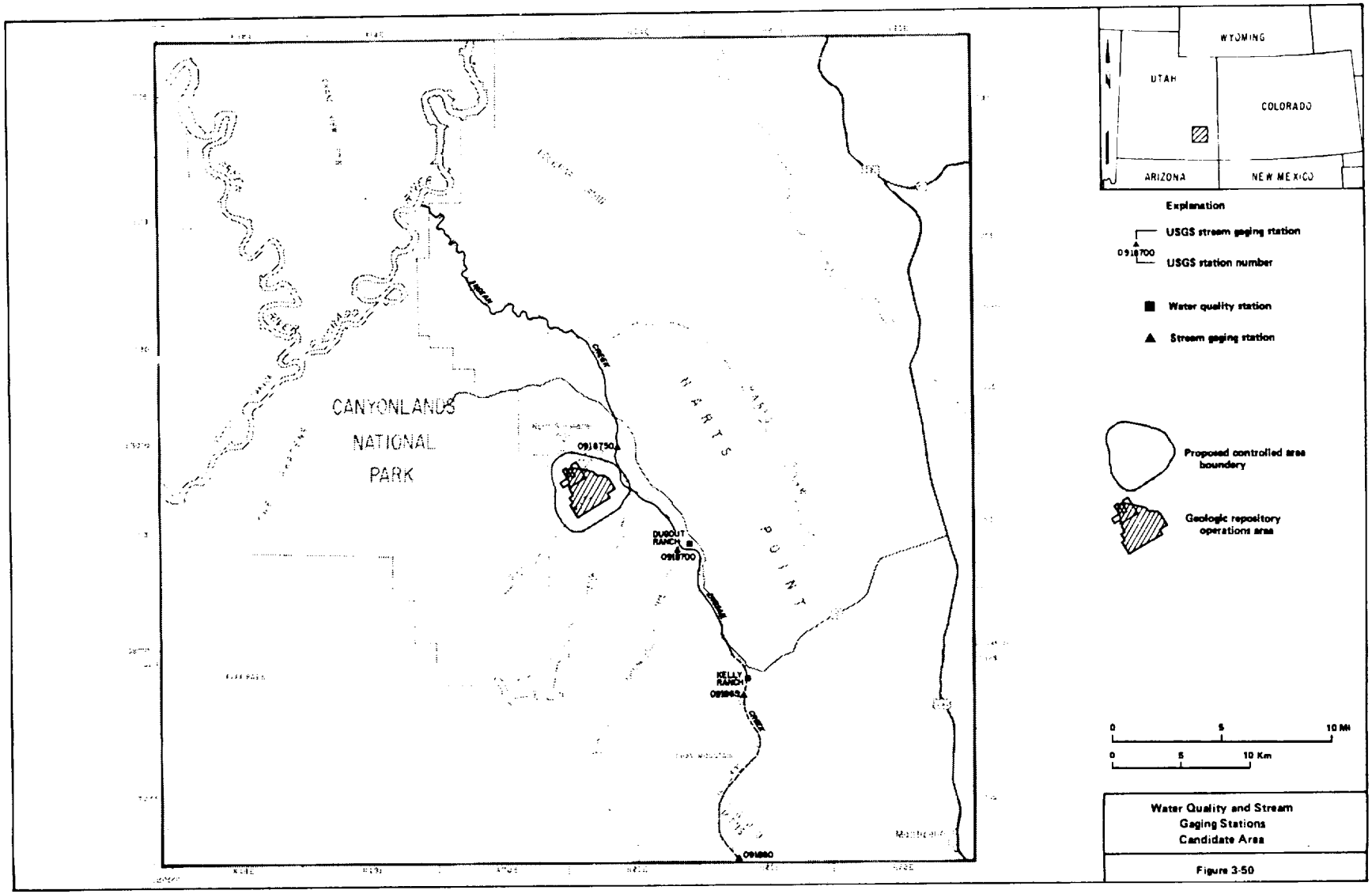
No water-quality data exist for the Davis Canyon GROA. However, water-quality data exist for various locations along Indian Creek; these data are available from a cooperative program between the BLM and the Utah Department of Health. The sampling locations at Dugout and Kelly Ranches are shown on Figure 3-50; water-quality data are summarized in Tables 3-17 through 3-19. These data indicate that the quality of water in Indian Creek deteriorates rapidly over the 19 kilometers (12 miles) from Kelly Ranch to the National Park Service extension of Utah 211 (Table 3-19).

Windblown sediments were observed to accumulate in wash bottoms and contribute to sediment load during runoff periods. Salt deposits from evaporation of stream water were found intermittently along the banks of Indian and Cottonwood Creeks and more extensively along Lavender Canyon.

3.3.1.4 Flooding

Flood data are scarce for small watersheds in the GROA because stream-gaging stations do not exist there. Extreme flood events are generally caused by local thunderstorms (cloudbursts) occurring in August and September. One of the most intense cloudbursts ever experienced in Utah occurred on August 1, 1968 in the Monticello-Blanding area. Several precipitation-intensity records were set when 16.5 centimeters (6.5 inches) of rain fell within a 24-hour period. The peak discharge at Cottonwood Wash near Bluff was estimated to be 1,190 cubic meters (42,100 cubic feet) per second. The unit rate of runoff from this drainage area of 880 square kilometers (340 square miles) was 1.35 cubic meters per second per square kilometer (124 cubic feet per second per square mile) (Butler and Marsell, 1972, p. 46).

A flood study was performed to delineate the probable maximum and 100-year floodplains in the vicinity of the surface facilities at the Davis Canyon site. Figure 3-51 shows the area that would be inundated by the probable maximum and 100-year flood events (BGI, 1984, p. 15). These floodplains were primarily developed for the unnamed ephemeral wash in the Davis Canyon where a field survey of channel cross-sections was conducted. They were derived by computing the water surface profiles of the water courses in the vicinity, using the corresponding



Water Quality and Stream Gaging Stations Candidate Area

Figure 3-50

Table 3-14. Streamflow Data, Gibson Dome

Stream	Station Number	Drainage Area (sq mi)	Means Annual Discharge (cfs)	Instantaneous Flow (cfs) Max	Min	Period of Record
Indian Creek near Monticello	091860	4.7	2.88	122	0	1947-1957
Indian Creek above Cottonwood Creek	091865	31.2	4.4	2,330	0	1948-1971
Cottonwood Creek near Monticello	0918700	115	3.10	2,140	0	1949-1957
Indian Creek	0918750	258	5.99	3,120	0	1949-1957

Sources: USGS, 1964, pp. 187-190; 1972, pp. 23, 25.

Table 3-15. Mean Monthly Streamflows, Indian Creek[a]

Month	Streamflow	Month	Streamflow
January	0.85	July	2.62
February	0.82	August	2.30
March	1.26	September	1.34
April	7.06	October	1.49
May	19.10	November	1.40
June	13.40	December	1.05
	Mean = 4.40		

(a) Above Cottonwood Creek, near Monticello, Utah, Station 091865. Drainage Area = 80.8 square kilometers (31.2 square miles). Values are in cubic feet per second. Period of record is from October 1949 to September 1971. Indian Creek Tunnel diverts water above the station to the San Juan River basin for irrigation and municipal supply.

Source: USGS, 1954; 1964; 1970; 1972; 1973.

Table 3-16. Colorado River Flow and Water Quality at Cisco, Utah - Water Years 1977 and 1983

Date	Instantaneous Discharge, cfs	Specific Conductance μ mhos	pH	Hardness (mg/l as $CaCO_2$)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SO_4 mg/l	Cl mg/l	TDS mg/l
Water Year 1977											
10/19, 1976	3,100	1560	8.5	510	130	46	150	5.7	470	150	1070
11/16, 1976	3,980	1300	8.3	380	92	36	140	5.5	310	150	836
12/16, 1976	4,040	1320	8.4	380	94	35	130	5.4	290	150	813
01/19, 1977	3,400	1360	8.2	360	93	31	150	6.1	260	190	856
02/17, 1977	2,430	1600	8.9	390	94	38	190	7.4	330	240	1010
03/24, 1977	1,740	1890	8.4	490	120	47	230	8.8	440	260	1220
04/28, 1977	1,450	1970	8.5	610	140	62	210	8.3	600	210	1330
05/19, 1977	2,500	1550	8.2	510	130	44	150	5.5	460	130	1040
06/28, 1977	1,520	1920	8.3	690	170	65	180	6.1	750	170	1420
07/19, 1977	1,250	2100	8.3	800	200	73	190	6.5	760	160	1530
08/30, 1977	1,900	1760	8.0	650	170	55	160	6.6	550	170	1230
09/29, 1977	1,940	1780	8.2	670	170	59	170	5.5	560	160	1270
Water Year 1983											
10/21, 1982	6,080	1030	8.3	319	81	28	97	4.1	260	110	674
11/22, 1982	5,460	1140	8.2	342	86	31	120	4.5	250	130	720
12/27, 1982	4,120	1010	8.0	310	78	28	110	4.4	230	120	669
01/24, 1983	4,220	1100	8.2	289	73	26	100	3.9	210	120	628
02/24, 1983	4,350	980	8.3	287	70	27	110	4.4	210	120	638
03/25, 1983	4,880	1100	8.2	328	82	30	110	4.1	230	110	671
04/27, 1983	18,200	390	7.9	161	46	11	23	1.7	90	16	247
05/26, 1983	40,700	340	8.2	143	39	11	18	2.2	69	11	218
06/21, 1983	45,700	290	8.0	125	35	9.1	18	1.0	65	11	200
07/22, 1983	18,800	620	8.2	185	51	14	44	2.6	120	47	348
08/26, 1983	8,810	880	8.1	303	78	26	76	3.2	230	73	581
09/06, 1983	6,080	1090	8.4	361	95	30	98	4.3	270	110	706

Source: Water Resources Data for Colorado River (USGS, 1971-1983).

Table 3-17. Indian Creek Water Quality at Kelly Ranch[a]

Date Sampled	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Carbonate as CO_3	Bicarbonate as HCO_3	Sulfate as SO_4	Chloride as Cl	Nitrate as NO_3-N	Silica as SiO_2	Iron as Fe	Manganese as Mn	Zinc as Zn	Fluoride as F	pH	Conductivity C5 micromhos /cm	Turbidity NTU	TDS
9/25/76	43	19	12	2.5	0	213	28	5.3	0.000	10	ND[c]	ND	ND	0.3	8.9	380	ND	226
8/02/77	70	16	12	2	0	276	37	4	0.05	15	0.04	0.88	0.005	0.16	8.5	460	6.5	280
3/21/78	67	18	10	1	0	268	50	4	0.30	13	0.25	0.37	0.010	0.22	8.2	470	0.9	286
3/27/79	67	14	7	1	0	238	41	3	<0.05	11	0.12	<0.025	0.005	0.22	8.2	430	0.7	256
8/01/79	56	8	6	1	6	182	32	4	0.15	13	0.14	0.045	0.010	0.14	8.7	340	5.0	219
3/27/80*[b]	58	18	13	1	0	224	53	5	0.05	12	0.04	0.036	0.007	0.13	8.2	465	0.7	253
3/02/81**	58	17	13	1	0	228	55	4	<0.05	12	0.05	ND	ND	0.15	ND	450	1.7	272
9/16/81***	42	22	22	3	0	212	60	10	0.03	11	0.165	0.010	0.006	0.17	8.1	410	ND	269

(a) Sample Location Lat. 109° 31' - Long. 38° 58', T32S, R22E, Sec 28. All values in mg/L unless noted otherwise.
(b) Total coliform 430*, 40**, and 13000*** MPN/100 ml on these samples typical seasonal variation.
(c) ND = No data.

Source: Backus, 1984 (data From USDI, BLM).

Table 3-18. Indian Creek Water Quality at Selected Locations Downstream From Kelly Ranch[a]

Sample Location[b]; Date Sampled	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Carbonate as CO_3	Bicarbonate as HCO_3	Sulfate as SO_4	Chloride as Cl	Nitrate as NO_3-N	Silica as SiO_2	Iron as Fe	Manganese as Mn	Zinc as Zn	Fluoride as F	pH	Conductivity C5 micromhos /cm	Turbidity NTU	TDS
1. 3/21/78	40	41	124	4	0	318	140	96	0.15	13	0.80	0.28	0.025	0.4	8.3	990	290	582
2. 3/27/79	53	33	70	4	4	306	104	56	0.15	11	<0.01	ND	0.01	0.4	8.3	830	<1,000	494
8/01/79	56	39	160	4	10	396	197	120	0.20	15	<0.01	ND[c]	0.005	0.64	8.3	1,250	4	812
3/27/80	52	31	90	5	0	302	116	65	0.10	11	0.85	0.14	0.013	0.30	8.3	915	140	498
7/29/81	48	23	60	7	6	274	93	39	0.30	13	3.45	1.0	ND	0.36	8.4	750	215	430
3/25/81 (d)	44	56	235	5	0	416	260	210	0.05	12	<0.03	ND	ND	0.52	8.2	1676	6	906
9/15/81 (d)	41	29	95	5	0	283	141	42	0.12	10	0.20	0.02	0.028	0.28	8.1	ND	ND	490
3/10/82 (d)	48	35	87	3	0	310	106	71	ND[c]	ND	0.48	0.14	0.05	ND	8.2	940	125	490
3. 8/02/77	64	19	15	3	0	264	42	5	0.15	18	0.80	0.10	0.015	0.16	8.3	460	37	290
3/21/78	64	25	13	2	0	280	65	8	0.02	13	0.010	0.01	0.01	0.24	8.1	520	1.5	316

(a) All analytic values in mg/L unless noted otherwise.
(b) 1. At Lockhart Basin Road crossing, Latitude 109° 40', Longitude 38° 13', T30S, R20E, Sec. 1.
2. At CNP Road crossing, Latitude 109° 37', Longitude 38° 09', T30S, R21E, Sec. 28.
3. At Shay Canyon, Latitude 109° 32', Longitude 38° 00', T32S, R22E, Sec. 28.
(c) ND = No data.
(d) Total coliform varied from 90 to 1100 MPN/100ml on these samples - typical.

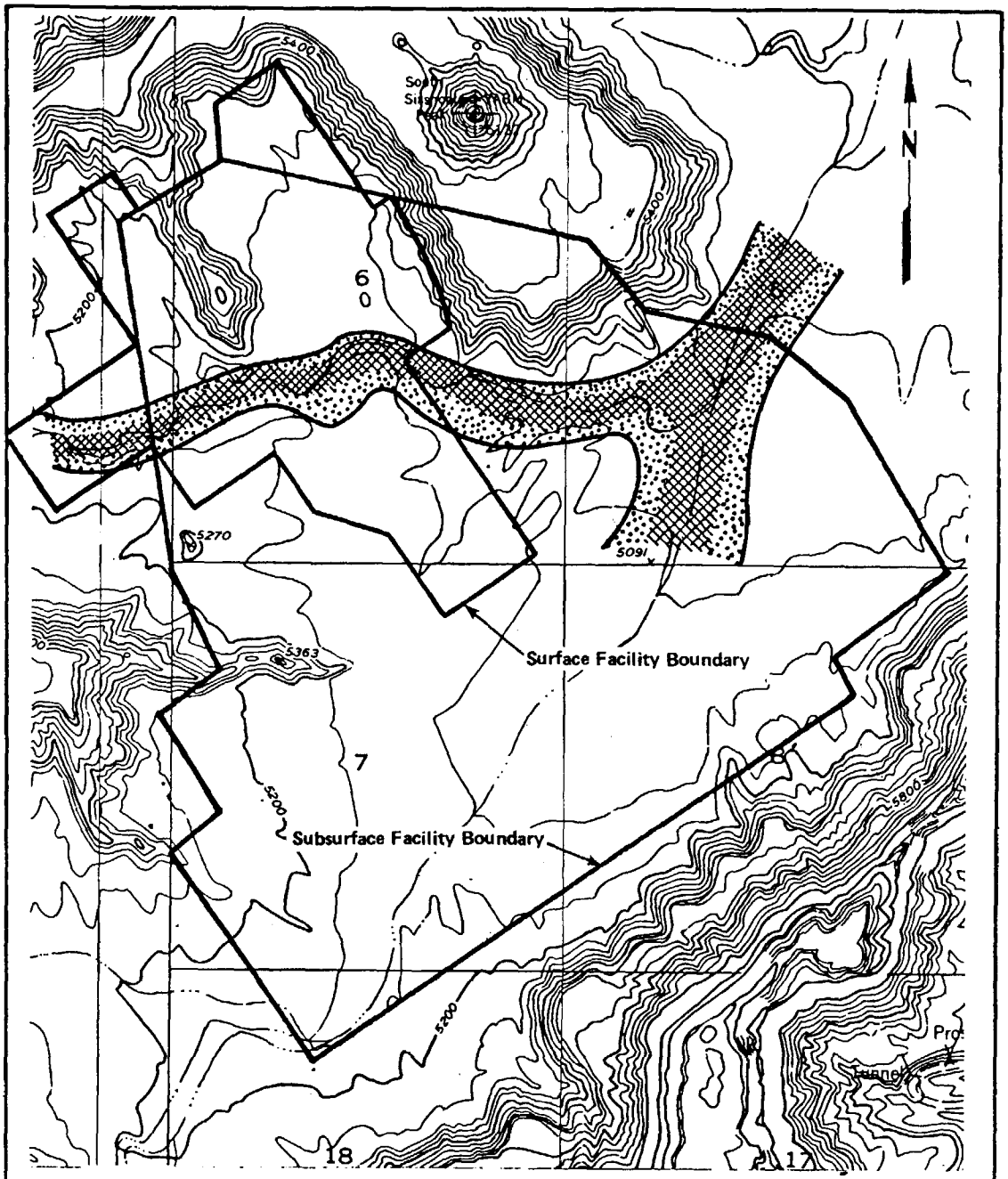
Source: Backus, 1984 (Data from USDI, BLM).

Table 3-19. Comparison of Kelly Ranch Sample Water Quality with Downstream Locations for Like Sample Dates[a]

Date	Sample Location	Ca	Mg	Na	HCO_3	SO_4	Cl	Fe	Mn	Zn	F	pH	Conductivity Micromhos/cm	Turbidity NTU	TDS
3/21/78	Kelly Ranch	67	18	10	268	50	4	0.25	0.37	0.01	0.22	8.2	470	0.9	286
3/21/78	Shay Canyon	64	25	13	280	65	8	0.01	<0.01	<0.01	0.24	8.1	520	1.5	316
3/21/78	Lockhart Basin Road Crossing	40	41	124	318	140	96	0.80	0.28	0.025	0.40	8.3	990	290	582
3/27/80	Kelly Ranch	58	18	13	224	53	5	0.04	0.036	0.007	0.13	8.2	465	0.7	253
3/27/80	At CNP Road	52	31	90	302	116	65	0.85	0.14	0.013	0.30	8.3	915	140	498
9/16/81	Kelly Ranch	42	22	22	212	60	10	0.165	0.010	0.006	0.17	8.1	410	ND[b]	268
9/15/81	At CNP Rd	41	29	95	283	141	42	0.02	0.02	0.028	0.28	8.1	ND[c]	125	490

(a) All values in mg/L unless otherwise noted.
(b) High suspended solids (640 mg/L) noted by Ford Lab - might mean high turbidity.
(c) Estimated conductance 900 micromhos/cm - from cond./diss. solids ratio of 3/27/80 sample.

Source: Backus, 1984 (Data from Tables 3-17 and 3-18).



Explanation

100–YEAR FLOODPLAIN

PROBABLE MAXIMUM FLOODPLAIN

GEOLOGIC REPOSITORY OPERATIONS AREA

0 .5 1 Mi

0 .5 1 Km

Davis Canyon
Probable Maximum and
100-Year Floodplains

Source: BGI, 1983, ONWI-476.

Figure 3-51

probable maximum flood (PMF), the 100-year flood peak discharges, and surveyed channel cross-sectional data. At its confluence with Davis Canyon, this unnamed tributary drains an area of about 9.3 square kilometers (3.6 square miles). The PMF and 100-year flood peak discharges were estimated to be 600 cubic meters per second (21,200 cubic feet per second) and 42 cubic meters per second (1,470 cubic feet per second), respectively. They were derived by applying the basic rainfall excess developed from the probable maximum precipitation (PMP) and the 100-year storm events to the synthetic unit hydrograph for the unnamed tributary. Estimates of the PMF and the 100-year rainfall were obtained from publications of the NOAA (1984a, b). The computer programs, HEC-1 (flood hydrograph package) and HEC-2 (water surface profiles) developed by the U.S. Army Corps of Engineers, were used to aid the development of the flood hydrographs and water surface profiles. A detailed description of the methodology of this flood study can be found in BGI (1984).

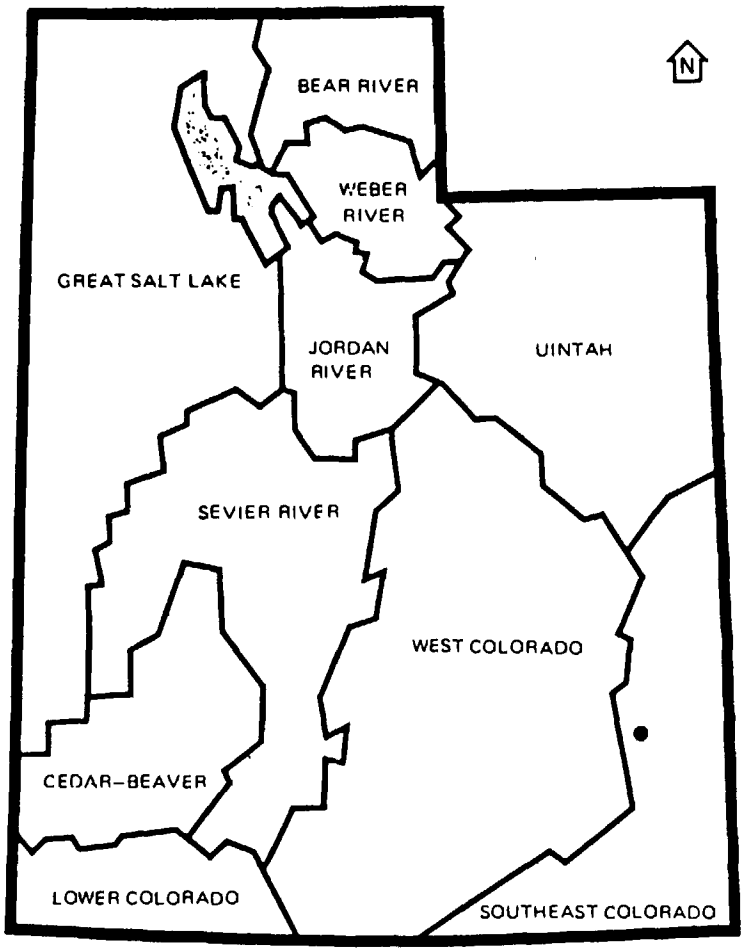
3.3.1.5 Water Availability and Demand

The total annual influx of precipitation into the UCWRR is estimated at 117 billion cubic meters (95 million acre-feet). After subtracting natural consumptive losses and ground-water recharge, the average annual (1914 to 1965) virgin water supply available to the UCWRR at Lees Ferry was computed to be 18.3 billion cubic meters (14.8 million acre-feet), with a low of 6.9 billion cubic meters (5.6 million acre-feet) in 1934 to a high of 30 billion cubic meters (24.0 million acre-feet) in 1917. Because of various laws and compacts governing the use the Colorado River, States in the UCWRR are obligated to provide the Lower Colorado Water Resources Region with a minimum 10-year average of 9.2 billion cubic meters (7.5 million acre-feet) of water per annum (UCRSFIG, 1971, pp. 16-18).

Utah's share of Colorado River water is computed to be 1.77 billion cubic meters (1.438 million acre-feet) annually. Of this amount, approximately 0.055 billion cubic meters (45,000 acre-feet) are available for appropriation for future development in this region.

The Davis Canyon site is located in the Southeast Colorado Hydrologic area of Utah, one of the 10 hydrologic areas defined by the Utah Department of Natural Resources (Figure 3-52). The principal use of surface water in this hydrologic area is irrigated agriculture. According to a report by the Utah Department of Natural Resources (1972), this hydrologic area, despite its relatively large size, has the smallest annual requirement of any other hydrologic area in Utah - approximately 0.08 billion cubic meters (65,000 acre-feet). However, future needs are expected to increase from this level to 0.376 billion cubic meters (305,000 acre-feet) by 2020. This approximately 400-percent increase in water requirement represents by far the largest increase of any hydrologic area in Utah. The principal reason for this large increase is associated with the projected development of new agricultural lands around the San Juan River (Utah Department of Natural Resources, 1972) and does not include water requirements for the repository construction and operations.

In addition, the U.S. Water Resources Council (1978) reported the water requirements (both withdrawals and consumptions) in 1975 and their projections for the years 1985 and 2000. These data, for two of the three subregions in the UCWRR near the Davis Canyon site (Colorado-Gunnison and Colorado-San Juan) are given in Tables 3-20 and 3-21 (U.S. Water Resources Council, 1978, Vol. 3, App. II, p. 86). These two subregions include the areas served by Grand County and San Juan County Water Conservancy Districts. Although the reported and projected water requirements do not distinguish between surface and ground-water resources, they clearly indicate that agricultural use constitutes more than 90 percent of the total water requirement in these two subregions. In 1975, water consumption was only about 40 to 50 percent of the water withdrawals. For the Colorado-Gunnison subregion, while the projected withdrawal amounts indicate a decrease of 1 percent and 3 percent over the 1975 value, for the years 1985 and 2000, respectively, the projected consumption shows an increase of 5 and 10 percent over the 1975 values. For the Colorado-San Juan subregion, a substantial increase in both withdrawal and consumption is predicted. While the projected withdrawal amounts indicate an increase of 78 percent and 62 percent over the 1975 values for the years 1985 and 2000, respectively, the projected consumption shows an increase of 96 and 121 percent over the 1975 value for these 2 years, respectively.



● APPROXIMATE LOCATION OF SITE (± 3 MILES).

0 25 50 75 100 Mi
0 40 80 120 Km

Utah's Ten Hydrologic Areas

Figure 3-52

Table 3-20. Water Requirements for Offstream Uses
Colorado-Gunnison Subregion[a]
(million gallons per day)

Use Category	Total Withdrawals			Total Consumption		
	Reported	Projected		Reported	Projected	
	1975	1985	2000	1975	1985	2000
Agriculture	2,418	2,406	2,258	945	989	986
Steam Elec. Generat.	30	10	52	1	0	34
Manufacturing	4	1	1	2	0	1
Domestic	25	27	29	6	6	7
Commercial	2	2	3	1	1	1
Minerals	19	35	75	4	11	26
Public Lands	28	27	27	28	27	27
Fish Hatcheries	6	8	9	0	0	0
Total Fresh Water	2,532	2,516	2,454	987	1,034	1,082
Total Saline	0	0	0	0	0	0
Total Water Requirements	2,532	2,516	2,454	987	1,034	1,082

(a) Includes surface and subsurface uses; instream flow requirements to maintain aquatic habitats are not included.

Source: U.S. Water Resources Council, 1978, Vol. 3, Appendix II, p. 86.

Table 3-21. Water Requirements for Offstream Uses
Colorado-San Juan Subregion[a]
(million gallons per day)

Use Category	Total Withdrawals			Total Consumption		
	Reported	Projected		Reported	Projected	
	1975	1985	2000	1975	1985	2000
Agriculture	1,032	1,861	1,653	378	709	786
Steam Elec. Generat.	44	81	72	16	58	61
Manufacturing	0	1	1	0	1	1
Domestic	25	28	31	10	12	13
Commercial	4	4	4	1	2	2
Minerals	33	50	80	16	25	48
Public Lands	13	22	23	13	22	23
Fish Hatcheries	0	0	0	0	0	0
Total Fresh Water	1,151	2,047	1,864	423	829	934
Total Saline	0	0	0	0	0	0
Total Water Requirements	1,151	2,047	1,864	423	829	934

(a) Includes surface and subsurface uses; instream flow requirements to maintain aquatic habitats are not included.

Source: U.S. Water Resources Council, 1978, Vol. 3, Appendix II, p. 86.

3.3.2 Ground Water

This section discusses the hydrology, modeling, and general ground-water quality for the area around the Davis Canyon site.

3.3.2.1 Hydrology and Modeling

Regional ground-water flow in the Paradox Basin is influenced by several hydrologic and geologic factors. The Paradox Basin is defined by the presence of a thick sequence of Pennsylvanian-age evaporitic sediments, generally overlain and underlain by carbonate rocks. The following major structural features surround the basin: the Uncompahgre Uplift to the northeast, the San Rafael Swell to the northwest, the Monument Upwarp to the west, and the San Juan Mountain Uplift to the east. The La Sal laccolithic complex within the Paradox fold and fault belt creates the highest mountains in the basin, up to approximately 3,962 meters (13,000 feet) mean sea level (MSL). The Abajo laccoliths pierce bedded salt approximately 22 kilometers (14 miles) south of the Davis Canyon geologic repository operations area (GROA).

These structural features and the drainage basin morphology control precipitation patterns and recharge and discharge relationships. Faults, folds, fractures, and lithologic facies patterns also influence the fluid-transmitting character of the rocks (WCC, 1982, ONWI-290, Vol. I, pp. 9-1 to 9-20; WCC, 1983, ONWI-92, pp. 243-264).

At this stage of the investigation, the upper Paleozoic section of the bedded salt area of the western Paradox Basin is tentatively subdivided into three hydrostratigraphic units to facilitate discussion (Table 3-22). These units consist of stratigraphic intervals that possess similar hydrogeologic characteristics (WCC, 1982, ONWI-290, Vol. I, pp. 9-1 to 9-3). This subdivision is preliminary and not well defined because of limited data. Additional hydrostratigraphic units probably exist in the Mesozoic strata above the upper hydrostratigraphic unit. However, because the Jurassic aquifers are separated from the Permian aquifers by thick aquitards (the Chinle and Moenkopi Formations), and because the Jurassic aquifers are not present, or occur as isolated bedrock ridges in the GROA, these aquifers do not warrant detailed discussion in this section. Further subdivision of the units in the Paleozoic section may be indicated as more data become available from drilling and hydrogeologic testing.

As presently defined, the upper hydrostratigraphic unit includes Permian strata and extends downward to approximately the lower third of the Pennsylvanian Honaker Trail Formation. The middle hydrostratigraphic unit includes the lower third of the Honaker Trail Formation and the Paradox Formation, while the lower hydrostratigraphic unit consists of the carbonate rocks below the Paradox Formation (Section 3.2.2.1).

Ground water that flows through the upper hydrostratigraphic unit in the Davis Canyon site probably enters the system in areas adjacent to the Abajo or La Sal Mountains, where increased precipitation encourages recharge. The ultimate discharge boundary of the flow system is the Colorado River, although minor amounts of ground water discharge from the upper unit at springs scattered throughout the candidate area.

Large elevation differences between the highlands and the canyon floors throughout the region influence the flow systems in the upper hydrostratigraphic unit. Local ground-water flow systems develop in areas having pronounced local relief, especially at relatively shallow depths in the upper hydrostratigraphic unit. With increasing depth in the upper unit, intermediate flow systems are developed. Beyond the effect of pronounced local variations in ground-level elevation, a regional flow system develops in the deeper portions of the upper hydrostratigraphic unit, and flow-path length increases with depth (WCC, 1982, ONWI-290, Vol. I, pp. 9-2 to 9-16).

Table 3-22. Davis Canyon Hydrostratigraphic Column

ERATHEM	SYSTEM	FORMATION	THICKNESS	LITHOLOGY	HYDROSTRATIGRAPHIC UNIT	HYDROLOGICAL CHARACTERISTICS
PALEOZOIC	PERMIAN	White Rim Sandstone (Cutler Group)	10m	White fine grained calcareous cross-bedded sandstone	Upper Hydrostratigraphic Unit	Generally an aquifer but does contain low permeability aquitards
		Upper Cutler Formation (Organ Rock equivalent) (Cutler Group)	50m	Red arkosic poorly sorted sandstones and siltstones		Generally an aquifer but does contain low permeability aquitards
		Cedar Mesa Formation (Cutler Group)	275m	White fine grained calcareous cross-bedded sandstone interbedded with red siltstones		Generally an aquifer but does contain low permeability aquitards
		Elephant Canyon Formation (Cutler Group)	170m	Interbedded limestone, sandstone, and siltstone; fossiliferous		Generally an aquifer but does contain low permeability aquitards
	PENNSYLVANIAN	Hermosa Group: Honaker Trail Formation	420m	Predominantly limestone interbedded with sandstone, silty sandy limestone, calcareous siltstone, claystone, politic limestone, dolomite, cherty limestone	(Boundary uncertain) — ? — ? — ? —	aquitard — aquifer
		Hermosa Group: Paradox Formation	880m	Cyclic evaporites including salt, anhydrite, dolomite, limestone and shale	Middle Hydrostratigraphic Unit	aquifuge — aquitard
		Hermosa Group: Pinkerton Trail Formation	65m	Gray to black interbedded limestone, siltstone, shale, limestone, dolomite and anhydrite	Lower Hydrostratigraphic Unit	aquifer — aquitard
		Molas Formation	45m	Red clayey mudstone with limestone clasts at the base; interbedded limestone, shale, calcareous siltstone and sandstone in the upper portion		aquitard
	MISSISSIPPIAN	Leadville Limestone	145m	Light gray limestone with karst features, some interbedded dolomite and chert		aquifer
		Ouray Limestone	30m	Brown to gray limestone with thin, green waxy shale beds	— ? — ? — ? — (Lowest extent uncertain)	aquifer
	DEVONIAN	Elbert Formation: Upper Elbert Member	60-75m	Thinly bedded dolomite with interbeds of gray-green to red shales		aquifer
		Elbert Formation: McCracken Sandstone Member		Light-gray to red fine to medium grained sandstone with some interbedded dolomite		aquifer
		Aneth Formation	0-30m	Dark-gray argillaceous dolomite with scattered lenses of black shale and dark siltstone		unknown

Figure 3-53 shows the ranges of permeability* values for the upper and lower hydrostratigraphic units calculated from approximately 230 drill-stem test (DST) records available from petroleum test boreholes throughout the western Paradox Basin region (WCC, 1982, ONWI-290, Vol. V, Appendix A). These petroleum DST results may be biased toward the higher permeability zones, because they are often the target test zones within a given area.

DST data from the GD-1 borehole, 5 kilometers (3 miles) from the Davis Canyon geologic repository operations area, provide the most definitive values available for formation permeabilities at the Davis Canyon site. These tests were performed on intervals that appeared to have the highest relative transmissivity based on inspection of core and geophysical logs. Hydraulic test data obtained from the GD-1 borehole are presented in Table 3-23, and Thackston et al. (1984, ONWI-491, Table 4-2).

The Cedar Mesa Sandstone is reported to be the most useful Permian aquifer in southeastern Utah (Ritzma and Doelling, 1969, p. 103); however, it is not a highly productive aquifer in the site. Springs and water wells generally yield small amounts of water from the Cedar Mesa Sandstone (Table 3-24 and Figure 3-54) (Thackston et al., 1984, ONWI-491, Table 3-3; Ritzma and Doelling, 1969, Table IV; Feltis, 1966, p. 31, Table 4; Irwin et al., 1971, p. 24). At the GD-1 borehole, only a few gallons per minute (gpm) were produced from the entire thickness of this formation. There are no test data on permeabilities in the Cedar Mesa sandstone; but it is estimated that the range of permeabilities is similar to those of the permeable sandstone beds in the underlying Elephant Canyon Formation (approximately 0.001 to 10 millidarcies [9.87×10^{-19} to 9.87×10^{-15} square meters], and hydraulic conductivity of 9.6×10^{-10} to 9.6×10^{-6} centimeters per second). Effective porosities probably range from 6 to 19 percent. Total dissolved solids (TDS) in the Cedar Mesa Sandstone are generally low. Figure 3-55 shows the distribution of TDS values from shallow wells and springs near the site. TDS values from the candidate area for both the Cedar Mesa Sandstone and the Cutler Formation are also shown on Figure 3-55. The higher values are from the Cutler Formation to the north of the site and may come from springs that are issuing from the lateral equivalent of either the Cedar Mesa or Elephant Canyon Formations.

The Elephant Canyon Formation, which underlies the Cedar Mesa Sandstone, contains the largest producing aquifer encountered in the upper hydrostratigraphic unit at GD-1. At this location, the aquifer is estimated to have a transmissivity of approximately 0.2 square meter (2.2 square feet) per day and may be capable of producing up to approximately 1.9 liters per second (30 gallons per minute) from a properly designed well. This aquifer is a sandstone bed that was encountered at a depth of approximately 300 meters (1,000 feet) in the GD-1 borehole and is 6 meters (20 feet) thick. Deposits of this type are interpreted as channel deposits and do not occur as continuous sheets (McCleary and Romie, 1985, p. 55). These channels probably follow a meandering course to the southwest and may pinch out. Sandstones of this type make up less than 10 percent of the total thickness of the formation. Test results for the Elephant Canyon Formation in the GD-1 borehole are shown on Figure 3-56 and Table 3-23. The productive sandstone aquifers in the formation have permeabilities as high as 25 to 87 millidarcies (2.4×10^{-14} to 8.5×10^{-14} square meter, hydraulic conductivity of 2.4×10^{-5} centimeter per second to 8.3×10^{-5} centimeter per second) and effective porosities estimated to range from 12 to 20 percent. Permeabilities for the limestones and mudstones that comprise the remaining bulk of the formation are probably in the range of the other DSTs in the formation (0.0073 to 0.00078 millidarcies [7.2×10^{-18} to 7.7×10^{-19} square meter], hydraulic conductivity of 7.0×10^{-9} to 7.5×10^{-10} centimeter per second) (Table 3-23) with effective porosities expected to range from 5 to 13 percent. These ranges of values compare favorably with the regional range of values for the upper hydrostratigraphic unit shown on

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*The term permeability as used here refers to specific or intrinsic permeability, as is standard practice in petroleum engineering. Transmissibility is defined as permeability times formation thickness divided by fluid viscosity. Conversions to the units of hydraulic conductivity and transmissivity assume that the pore fluid is fresh water at a temperature of 20 C (86 F).

Table 3-23. Gibson Dome No. 1 Hydraulic Test Results Summary
(Page 2 of 3)

Formation Sample Rock Type	Laboratory Results			Field Results							
				Short-Term Tests				Long-Term Tests			
	Sample No. (Depth in ft KB[a])	Effect. Porosity (percent)	Hydraulic Conductivity (cm/sec)[b]	Total Porosity, Density Log (percent)	DST No. (Depth in ft KB)	Hydraulic Conductivity (cm/sec)	P* (H)[c]	LT Test # (Depth in feet BKB)	Test Type[d]	Hydraulic Conductivity (cm/sec)	P* (H)
										Salt squeeze dominated hydraulic response	
Mudstone	43 (3043)	11.4	V 3.6×10^{-8} H 2.2×10^{-9}	5.3-26.4							
Halite	49 (3129)	0.3	V $<1.0 \times 10^{-10}$ H $<1.0 \times 10^{-10}$	6.9-12.9							
Halite	52 (3344)	0.2	V $<1.0 \times 10^{-10}$ H $<1.0 \times 10^{-10}$	5.9-9.9							
Mudstone/ Anhydrite	59 (3367)	10.2	V 4.2×10^{-10} H 2.4×10^{-10}	4.0-29.8	16 (3354-3554)	1.4×10^{-6} (ET)	129 (1908)	5 (3344-3554) 74[f]	SIT (LT) SIT (LT)[g]	1.2×10^{-10} 2.6×10^{-8}	2446 (7268) 526 (2833)
Halite	61 (3380)	0.5	V $<1.0 \times 10^{-10}$ H 2.6×10^{-10}	0-17.8							
Anhydrite	66 (3445)	0.6	V 4.3×10^{-10} H 4.1×10^{-10}	11.6-21.5							
Anhydrite	68 (3526)	2.5	V 1.4×10^{-10} H 2.1×10^{-8}	7.7-35.9							
Mudstone	71 (3541)	12.6	V 4.0×10^{-8} H 1.5×10^{-8}	0-12.0							
Siltstone	76 (3842)	8.8	V 3.1×10^{-10} H 1.1×10^{-9}	1.3-39.3	12 (3810-3950)	1.8×10^{-6} (ET) 9.2×10^{-8} (LT)	511 (2334)				
Halite	79 (4206)	0.6	V $<1.0 \times 10^{-10}$ H 1.9×10^{-10}	0-10.9	15 (4035-4235)	1.1×10^{-6} (ET) 9.2×10^{-8} (LT)	511 (2571)				
Siltstone/ Anhydrite	83 (4214)	0.8	V 2.0×10^{-10} H 4.4×10^{-10}	0-29.3							

Table 3-23. Gibson Dome No. 1 Hydraulic Test Results Summary
(Page 3 of 3)

Formation Sample Rock Type	Laboratory Results: Sample No. (Depth in ft KB[a])	Laboratory Results: Effect. Porosity (percent)	Laboratory Results: Hydraulic Conductivity (cm/sec)[b]	Field Results: Total Porosity, Density Log (percent)	Field Results: Short-Term Tests: DST No. (Depth in ft KB)	Field Results: Short-Term Tests: Hydraulic Conductivity (cm/sec)	Field Results: Short-Term Tests: P* (H)[c]	Field Results: Long-Term Tests: LT Test # (Depth in feet BKB)	Field Results: Long-Term Tests: Test Type[d]	Field Results: Long-Term Tests: Hydraulic Conductivity (cm/sec)	Field Results: Long-Term Tests: P* (H)
Silty Limestone	94 (5265)	6.5	V 6.6×10^{-10} H 3.2×10^{-10}	5.3-13.5	10 (5220-5360)	4.6×10^{-6} (ET) 1.1×10^{-7} (LT)	368 (594)				
Pinkerton Trail Formation											
Calcareous Siltstone	100 (5579)	4.50	V $<1.0 \times 10^{-10}$ H $<1.0 \times 10^{-10}$	0-3.0							
Calcareous Silstone	106 (5596)	2.93	V $<1.0 \times 10^{-10}$ H $<1.0 \times 10^{-10}$	0-14.5							
MOLAS FORMATION											
Calcareous Sandstone	104 (5806)	2.4	V $<1.0 \times 10^{-10}$ H 1.8×10^{-10}	0-9.6							
Leadville Limestone Formation											
Limestone	119 (2978)	15.0	V 8.7×10^{-8} H 3.0×10^{-7}	0.6-8.5	25 (5917-6093)	2.4×10^{-5}	2389 (4536)				
Limestone	133 (6118)	11.2	V 1.4×10^{-7} H 1.5×10^{-6}	2.4-8.4	24 (6093-6225)	2.1×10^{-5}	2353 (4331)				
Limestone/ Dolomite	139 (6218)	14.5	V 5.1×10^{-9} H 2.4×10^{-8}	0-14.3	23 (6194-6385)	1.2×10^{-6}	2400 (4338)				

(a) KB = Below kelly bushing datum.
(b) Highest value reported in series of lab tests on a given sample, from Table 3.
(c) P* = Estimated static reservoir pressure.
H = Potentiometric level, equivalent feet of fresh water above sea level.
(d) Test Types:
IFT = Injection and fall-off test
PST = Pressurized slug test
DST = Short-term drill stem test
SIT = Long-term shut-in test.
(e) (ET) = Early time data utilized.
(LT) = Late time data utilized.
(f) Effective thickness of zone, less halite, estimated from geophysical logs.
(g) This analysis corrected for salt squeeze.

Table 3-24. Available Data On Water Wells and Springs, Davis Canyon Area

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
101w	unknown	30/22-18 cab	6,181	373	NS	--	15	--	--	--	--
102w	Bureau of Land Management (BLM)	30/22-13 bda	6,001	370	NS	campground	10	--	06/06/79	--	--
103w	BLM	30/21-25 bcc	6,421	200	WS	supply	3	6,382	--	--	--
104w	Dugout Ranch	30/23-8 dad	5,880	300	NS	stockwater	3	--	06/09/79	--	--
105w	Dugout Ranch	30/23-17 cab	5,801	375	NS	stockwater	7	--	06/09/79	--	--
106w	Dugout Ranch	30/23-22 bcc	5,830	300	NS	--	8	5,679	06/09/79	--	--
107w	unknown	31/23-9 ddd	6,181	360	NS	--	10	6,021	--	--	--
108w	Halliday	31/23-28 cab	6,421	60	ES	stockwater domestic	7 --	-- --	06/21/79 --	-- --	-- --
109w	unknown	31/23-29 cca	6,139	1,545	J	--	--	5,732	--	--	--
110w	unknown	32/23-1 acd	6,119	280	ES	--	40	5,958	--	--	--
111w	Canyonlands National Park #2 (GW-022-01)[g]	30/20-20 dad	5,010	65	CMS	campground supply	33 -- --	4,989 -- --	06/18/79 05/02/68 11/13/79	-- -- 321	-- 305 523
112w	Canyonlands National Park #3A (GW-023-01)	30/20-30 cbd	5,020	52	CMS	campground supply	4 -- --	5,003 -- --	06/08/79 05/02/68 11/13/79	-- -- 322	-- 867 1,120
113w	Canyonlands National Park #3B	30/20-30 cbd	5,020	50	CMS	campground supply	--	5,007	--	--	--
114w	Canyonlands National Park #4	30/19-25 dac	5,040	77	CMS	not currently used	--	5,013	10/09/68	--	926
115w	Canyonlands National Park #5	30/20-20 aaa	4,882	77	CMS	not currently used	--	4,859	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 2 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
116w	BLM	28/21-16 bba	5,860	700	NS	Hatch Campground	10	--	06/06/79	--	--
117w	unknown	28/22-1 cda	5,039	100	NS	--	40	5,015	--	--	--
118w	unknown	28/23-4 bcb	5,820	430	KF	--	90	5,541	--	--	--
119w	unknown	28/23-19 dcc	5,683	450	KF	--	10	5,383	--	--	--
120w	unknown	28/23-25 cba	6,359	142	BCF	--	5	6,278	--	--	--
121w	unknown	28/23-31 bbc	6,001	850	WS	--	7	5,511	--	--	--
122w	unknown	29-1/2/23-33 aca	5,561	133	NS	--	14	5,521	--	--	--
123w	Dugout Ranch	30/23-20 bbb	6,099	310	NS	--	7	--	06/09/79	--	--
124w	unknown	31/23-1 dbb	6,001	276	NS	--	9	5,866	--	--	--
125w	unknown	31/23-27 acd	6,181	325	NS	--	3	5,916	06/09/79	--	--
126w	BLM Windmill	29/22-35 dd	--	330	NS	--	15	--	--	--	--
127w	unknown	32/23-26 aaa	6,700	70	DS	--	2	6,685	--	--	--
128w	Monticello Airport	33/23-1 cad	6,920	--	DS	--	30	--	09/20/78	--	--
129s	Horse Canyon Spring	29/18-20 ccd	--	--	CMS	--	(h)	4,022	07/25/78	--	814
130s	Pictograph Spring	30/18-6 dbc	--	--	CMS	--	2	--	07/26/78	--	406
131s	Jasper Canyon Spring	30/18-9 bbd	--	--	CMS	--	(h)	--	07/27/78	--	360
132s	Water Canyon Spring	30/18-15 cca	--	--	CMS	--	2	--	08/02/78	--	322
133s	BLM Three Mile	29/22-19 ad	--	297	NS	--	12	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 3 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
134s	Kane Springs	28/22-1 ca	—	—	ES	—	20 20	— —	09/19/78 10/28/33	— 154	— 379
135s	Yellow Circle Mine	28/23-3 aa	—	—	BCF	—	(h)	—	09/20/78	—	—
136s	Brown Hole #1	28/23-23 dcc	—	—	BCF	—	11	—	09/19/78	—	—
137s	Brown Hole #2	28/23-23 ddb	—	—	BCF	—	2	—	09/19/78	—	—
138s	Cottonwood Canyon	28/23-23 acc	—	—	BCF	—	3	—	09/19/78	—	—
139s	Buck Hollow	28/23-25 bbd	—	—	BCF	—	20	—	09/19/78	—	—
140s	West Coyote Creek (Trough Spring)	28/23-36 dba	—	—	BCF	—	5 —	— —	09/19/78 10/25/33	— 157	— 504
141s	Joe Wilson Canyon	29/23-31 dbc	—	—	NS	—	1	—	06/06/79	—	—
142s	Harts Draw Springs	29-1/2/22-31 cbd	—	—	WS	—	— —	— —	06/07/79 —	— —	— 198
143s	Squaw Spring	30/19-25 cdc	—	—	CMS	—	— —	— —	— 06/08/79	— —	279 —
144s	Soda Spring	30/19-27 cdc	—	—	CMS	—	— —	— —	— 06/08/79	— —	334 —
145s	Elephant Canyon	30/19-28 acd	—	—	CMS	—	—	—	06/08/79	—	—
146s	Cyclone Canyon	30/19-30 aca	—	—	CMS	—	—	—	06/08/79	—	—
147s	Cave Spring	30/20-20 cdd	—	—	CMS	—	—	—	06/08/79	—	—

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 4 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
148s	GS-003-01	30-1/2/27-22 abd	3,870	--	HTF	--	2	3,870	09/79	302	1,235
	GS-003-02						4		10/80	337	1,200
149s	GS-004-01	30-1/2/18-27 dab	3,870	--	HTF	--	1	3,870	09/79	303	13,558
	GS-004-02						1		10/80	338	17,500
	GS-004-03						--		12/04/83	--	--
150s	GS-006-01	31/18-5 cca	3,830	--	HTF	--	3	3,830	09/79	305	1,330
	GS-006-02						2		10/80	339	1,600
	GS-006-03						--		12/07/83	--	--
151s	GS-005-01	31/18-5 ddb	3,830	--	HTF	--	1	3,830	09/79	304	4,556
152s	GS-007-01	31/18-6 dcd	3,830	--	HTF	--	3	3,830	09/79	306	3,331
153s	GS-008-01	31/18-7 cbb	3,830	--	HTF	--	2	3,830	09/79	307	3,868
	GS-008-02						2		10/80	340	4,100
	GS-008-03						--		12/09/83	--	--
154s	Salt Creek GS-025-01	30/19-2 bcc	4,160	--	ECF	--	1	4,160	12/79	324	3,800
155s	GS-024-01	30/19-26 bbc	4,160	--	ECF	--	1	4,160	12/79	323	760
156s	GS-090-01	31/18-7 cbb	3,830	--	HTF	--	4	--	12/09/83	--	--
157s	GS-020-01	31/20-24 bbd	5,280	--	A	--	1	5,280	11/79	319	570
158s	Rustler Spring GS-014-01	29/19-12 dad	4,200	--	CUF	--	1	4,200	11/79	313	5,435
159s	Horsethief Spring GS-026-01	28/20-28 bbb	4,160	--	CUF	--	2	4,160	12/79	325	1,050
160s	Lockhart Spring GS-016-01	28/20-26 aca	4,240	--	CUF	--	4	4,200	11/79	315	4,230
161s	GS-015-01	32/18-29 cdd	6,100	--	ECF	--	2	6,100	11/79	314	660

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 5 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
162s	Peekaboo Spring GS-021-01	31/20-6 ada	5,020	--	CMS	--	1 1	5,020 5,020	06/08/79 11/12/79	-- 320	-- 668
163s	Harts Spring Draw	31/22-1 dad	--	--	NS	--	(h)	--	06/07/79	--	--
164s	The Seeps	31/23-31 aaa	--	--	NS	--	--	--	06/07/79	--	--
165s	Homewater Spring	32/18-32 da	--	--	CMS	--	1	--	08/07/79	--	--
166s	Stanley Spring	32/18-36 aaa	--	--	CMS	--	1 --	-- 5,005	-- 08/07/79	-- --	-- 386
167s	Calf Wash Spring	32/18-36 cd	--	--	CMS	--	11	--	08/07/79	--	--
168s	Peter's Spring	32/23-24 ccc	--	--	BCF	--	-- --	-- --	-- 10/28/33	-- 180	-- 324
169s	Sweet Alice Spring	33/18-24 acc	--	--	CMS	--	3	--	08/08/79	--	--
170s	Crystal Spring	33/18-27 abd	--	--	CHF	--	3	--	08/08/79	--	--
171s	North Cottonwood	33/21-17 bbb	--	--	CHF	--	2	--	09/22/79	--	--
172s	North Cottonwood	33/21-17 bcd	--	--	CHF	--	(h)	--	09/22/79	--	--
173s	Jackson Spring	33/22-2 dab	--	--	DS	--	2	--	09/21/78	--	--
174s	Upper Jackson Spring	33/22-11 abb	--	--	DS	--	2	--	09/21/78	--	--
175s	Indian Creek	33/22-20 bba	--	--	DS	--	2		09/21/78	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 6 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
176s	Harts Draw Reservoir Spring	33/22-22 baa	--	--	DS	--	1	--	09/21/78	--	--
177s	Spring Creek Lake	33/22-23 dac	--	--	DS	--	3	--	09/20/78	--	--
178s	Taylor Spring Point	33/22-25 add	--	--	CHF	--	5 --	-- --	-- 09/20/78	-- --	-- 120
179s	Lower Taylor Spring	33/22-15 cca	--	--	CHF	--	5 --	-- --	-- 09/20/78	-- --	-- 120
180s	Dalton Spring	33/23-30 dca	--	--	DS	--	5 --	-- --	-- 09/20/78	-- --	-- 137
181s	Dalton Spring	33/23-30 dda	--	--	DS	--	5 --	-- --	-- 09/20/78	-- --	-- 120
182s	BLM	29/23-33 dbb	5,670	133	NS	watertable well	--	5,639	09/08/83	--	--
183w	Summers	31/23-24 dbd	5,980	164	NS	watertable well	--	5,915	09/08/83	--	--
184s	Willow Seep	28/18-1 abc	--	--	NS	--	--	--	11/13/69	--	500
185s	White Rim #1 Spring	28/19-11 aac	--	--	WRS	--	--	--	08/21/77	--	270
186s	White Rim #2 Spring	28/19-11 bbb	--	--	WRS	--	--	--	08/21/77	--	308
187s	Lathrop Spring	28/19-1 ccd	--	--	CUF	--	--	4,160	08/21/77	--	2,410
188s	Titus Canyon Spring #1	32/21/-23 adb	6,320	--	KF	--	(h)	6,320	--	--	--
189s	Titus Canyon Spring #2	32/21-24 bac	6,320	--	KF	--	(h)	6,320	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 7 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
190s	Trout Canyon Spring	28/22-17 ccc	4,800	--	WS	--	(h)	4,800	--	--	--
191s	unnamed spring #1	29/21-9 dbc	5,400	--	WS	--	(h)	5,400	--	--	--
192s	unnamed spring #2	30/22-5 dab	5,600	--	WS	--	(h)	5,600	--	--	--
193s	unnamed spring #3	30/22-23 cda	5,600	--	WS	--	(h)	5,600	--	--	--
194s	Hop Spring	33/21-16 aab	6,800	--	WS	--	150	6,800	--	--	--
195s	My Spring	28/20-16 dbd	4,080	--	CUF	--	(h)	4,080	--	--	--
196s	Eric Spring	28/20-21 ccd	4,160	--	CUF	--	1	4,160	--	--	--
197s	Indian Creek Seep	29/20-18 acd	4,160	--	CUF	--	--	4,160	--	--	--
198s	unnamed spring	29/19-26 bbb	4,300	--	EC-HF	--	1	4,300	--	--	--
199s	Loop Trail Spring	29-1/2/19-36 bbb	4,320	--	EC-HF	--	1	4,320	04/07/70	--	583
200s	Lower Big Spring	30/19-10 dbd	4,720	--	EC-HF	--	5	4,720	04/08/70	--	236
201s	Lower Jump Spring	30/19-12 acc	4,720	--	EC-HF	--	13	4,720	05/20/69	--	2,180
202s	Big Springs	30/19-26 abc	5,060	--	EC-HF	--	4	5,060	07/02/78	--	271
203s	Upper Jump Spring	31/20-31 acc	5,540	--	EC-HF	--	2	5,540	--	--	--
204s	North Home Spring	32/18-28 bdb	6,000	--	EC-HF	--	3	6,000	06/15/78	--	458
205s	Big Spring	30/18-29 dbd	6,000	--	EC-HF	--	125	6,000	06/17/78	--	464

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 8 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
206s	Upper Big Seeps	30/19-15 adb	5,020	--	CMS	--	--	5,020	--	--	--
207s	Lower Little Spring	30/19-14 adb	4,800	--	CMS	--	13	4,800	04/07/70	--	337
208s	Hangover Spring	30-1/2/19-34 cac	5,200	--	CMS	--	(h)	5,200	10/09/68	--	54
209s	Little Spring	30/19-23 dad	4,950	--	CMS	--	1	4,950	03/05/68	--	237
210s	Dorius Spring	31/19-4 adc	5,360	--	CMS	--	(h)	5,360	05/20/69	--	228
211s	Echo Spring	31/19-3 bad	5,270	--	CMS	--	3	5,270	08/05/78	--	248
212s	Paul Bunyon Spring	31/20-4 abb	5,480	--	CMS	--	(h)	5,480	06/15/78	--	164
213s	unnamed seep #1	31/21-32 cbb	6,000	--	CMS	--	--	6,000	06/18/78	--	3,620
214s	Beef Basin washspring	32/18-36 cdb	6,400	--	CMS	--	(h)	6,400	--	--	--
215s	Little Home-water Spring	32/18-27 bca	6,400	--	CMS	--	1	6,400	06/15/78/	--	320
216s	South Spring	32/18-33 ccc	6,220	--	CMS	--	1	6,220	06/16/78	--	340
217s	Iron Spring	32/19-32 dbc	6,460	--	CMS	--	(h)	6,460	--	--	--
218w	Case Broderick	33/23-36 ddd	--	335	--	--	20	--	11/22/55	--	--
219w	Galigher Co. Mill No. 3	33/23-36 dda	--	235	--	--	15	--	11/29/50	---	--
220w	Galigher Co.	33/23-36 ddb	--	175	--	--	25	--	10/09/50	--	--
221w	City of Monticello	33/23-26 cbd	--	540	--	--	3	--	12/03/56	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 9 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
222w	U.S. Atomic Energy Commission	33/23-36 ddd	--	262	--	--	55	--	06/01/56	--	--
223w	Young's Machine Co.	33/23-25 aba	--	190	--	--	30	--	12/10/54	--	--
224w	Palmer	33/23-24 baa	--	380.5	--	--	3	--	03/31/42	--	--
225w	Hansen	33/23-24 acc	--	135	--	--	--	--	spring/38	--	--
226w	Redd	33/23-11 abb	--	220	--	--	40	--	11/15/54	--	--
227w	Bailey	33/23-10 aad	--	80	--	--	(h)	--	02/36	--	--
228w	Adams	32/23-36 cda	--	165	--	--	10	--	04/20/50	--	--
229w	Neilson	31/23-36 dad	--	402	--	--	16	--	05/22/53	--	--
230w	Ogden	31/23-26 abd	--	225	--	--	10	--	08/22/46	--	--
231w	Abbot	31/23-23 add	--	256	--	--	12	--	02/16/34	--	--
232w	Christensen and Sons	31/23-11 ddd	--	230	--	--	10	--	10/26/34	--	--
233w	Taylor Grazing	31/23-16 aac	--	360	--	--	10	--	01/05/35	--	--
234w	Wood-Fowler	30/23-11 cbd	--	972	--	--	70	--	09/19/53	--	--
235w	Jones	30/23-17 acd	--	276	--	--	5	--	07/26/46	--	--
236w	Department of the Interior	28/23-31 acc	--	510	--	--	7	--	03/19/37	--	--
237w	Pacific NW Pipeline Co.	28/23-31 acb	--	925	--	--	17	--	11/25/55	--	--
238w	Riggs	30/23-11 ddd	--	130	--	--	15	--	11/01/34	--	--
239w	Ott	30/23-11 caa	--	--	--	--	15	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 10 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
240w	Utah State Road Commission	28/22-1 caa	--	114	--	--	30	--	10/16/41	--	--
241w	City of Monticello	33/23-26 dcb	--	275	--	domestic	33	--	06/23/77	--	--
242w	City of Monticello	33/23-36 dcc	--	335	--	domestic	50	--	11/15/77	--	--
243w	Wetherington	33/23-36 dda	--	100	--	domestic	1	--	--	--	--
244w	City of Monticello	33/23-36 bbb	--	290	--	domestic	20	--	07/15/77	--	--
245w	Laws	33/23-36 caa	--	210	--	irrigation	--	--	--	--	--
246w	Nielson	33/23-36 dbd	--	320	--	domestic	15	--	08/26/77	--	--
247w	Cooper-James	33/23-36 acc	--	380	--	irrigation	12	--	10/13/77	--	--
248w	Sunderegger	33/23-25 daa	--	375	--	irrigation	--	--	--	--	--
249w	Perkins	33/23-25 ddd	--	50	--	stockwater	50	--	05/30/79	--	--
250w	Fellmeth	33/23-25 acc	--	370	--	stockwater	--	--	--	--	--
251w	Dalton	33/23-24 dba	--	440	--	irrigation/ stockwater	15	--	11/23/79	--	--
252w	Scorup	33/23-22 add	--	480	--	stockwater	10	--	06/30/61	--	--
253w	Evans	33/23-14 aad	--	330	--	stockwater	15	--	10/10/77	--	--
254w	Palmer	33/23-14 aba	--	300	--	stockwater	40	--	07/05/67	--	--
255w	Palmer	33/23-13 dcb	--	320	--	stockwater	7	--	04/11/62	--	--
256w	Summers	33/23-9 ddc	--	200	--	stockwater	--	--	04/30/71	--	--
257w	San Juan City	33/23-1 cad	--	81	--	municipal	30	--	11/07/66	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 11 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
258w	Energy Fuels Nuclear Co.	33/20-28 dca	--	350	--	domestic	20	--	04/29/80	--	--
259w	Howe	32/23-26 aaa	--	70	--	irrigation	2	--	03/36	--	--
260w	Muselman	32/23-24 cbc	--	300	--	domestic	7	--	--	--	--
261w	Palmer	32/23-1 acd	--	280	--	stockwater	40	--	07/01/67	--	--
262w	Dalton	31/23-34 aad	--	340	--	irrigation	8	--	12/17/71	--	--
263w	DeBruine	31/23-27 acc	--	325	--	domestic	3	--	06/11/70	--	--
264w	Lewis	31/23-25 bba	--	110	--	stockwater	7	--	07/12/65	--	--
265w	Utah State Land Board	31/23-2 ccc	--	275	--	stockwater	15	--	02/01/65	--	--
266w	Redd	30/23-16 ddd	--	217	--	stockwater	25	--	06/14/67	--	--
267w	BLM	30/21-25 aac	--	200	--	stockwater	3	--	08/30/66	--	--
268w	El Paso Natural Gas Co.	28/23-31 bbc	--	827	--	industrial	7	-	09/21/68	--	--
269w	Graves Oil Company	29/23-4 cba	--	828	NS	commercial --	-- 12	-- --	01/15/64 --	164 --	505 --
270w	Bailey	31/23-7 b	--	--	WS	--	--	--	10/25/33	176	--
271w	U.S. Atomic Energy Commission	33/23-36 daa	--	--	DS/ BCF	--	31	--	05/11/55	187	390
272w	Redd	33/22 bbd	--	185	--	stockwater	7	--	--	--	--
273w	Halliday	33/23-25 ddd	--	300	--	domestic	7	--	--	--	--
274w	City of Monticello	33/23-25 dbb	--	--	--	municipal	898	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 12 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
275w	Dunow	33/23-34 abb	--	96	--	stockwater/ domestic	14	--	--	--	--
276w	Bronson	33/23-36 bbb	--	445	--	irrigation	9	--	--	--	--
277w	Bronson	33/23-36 bcc	--	315	--	domestic	7	--	--	--	--
278w	Halliday	33/23-36 ddd	--	300	--	irrigation/ domestic	7	--	--	--	--
279w	Hansen	33/23-36 acc	--	100	--	irrigation	4	--	--	--	--
280w	Hansen	33/23-25 ddd	--	100	--	irrigation	7	--	--	--	--
281w	Roring	33/23-36 acc	--	300	--	irrigation/ domestic	7	--	--	--	--
282w	Redd	33/23-36 bcc	--	360	--	stockwater/ domestic	7	--	--	--	--
283w	Neilson	33/23-36 bcc	--	--	--	irrigation/ domestic	7	--	--	--	--
284w	Ventures	33/23-36 bba	--	300	--	irrigation/ stockwater	7	--	--	--	--
285w	Jameson	33/23-36 dbd	--	320	--	irrigation	7	--	--	--	--
286w	Broderick	33/23-36 ddb	--	350	--	domestic	7	--	--	--	--
287w	BLM	28/21-5 abc	--	600	--	stockwater	7	--	--	--	--
288w	Redd Ranches	28/21-16 bbc	--	360	--	stockwater	112	--	--	--	--
289w	BLM	28/21-16 bbc	--	400	--	stockwater	7	--	--	--	--
290w	City of Monticello	33/23-25 dbb	--	--	--	municipal	898	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 13 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
291w	El Paso Natural Gas Company	28/23-31 acb	--	55	--	industrial	11	--	--	--	--
292w	City of Monticello	33/23-25 cab	--	--	--	municipal	898	--	--	--	--
293w	Utah State Department of Lands and Forestry	29/22-36 baa	--	400	--	stockwater	7	--	--	--	--
294w	McDougald	29/23-4 bcc	--	712	--	commercial	7	--	--	--	--
295w	Utah State Department of Lands and Forestry	29/23-16 caa	--	300	--	stockwater	7	--	--	--	--
296w	BLM	29/23-20 cbc	--	425	--	stockwater	4	--	--	--	--
297w	BLM	29/23-29 daa	--	350	--	stockwater	4	--	--	--	--
298w	Redd	29/23-31 cda	--	100	--	stockwater	7	--	--	--	--
299w	Redd	29/23-32 ccc	--	275	--	stockwater	5	--	--	--	--
300w	BLM	29/23-33 dbb	--	340	--	stockwater	7	--	--	--	--
301w	Redd Ranches	29/23-35 aca	--	175	--	stockwater	14	--	--	--	--
302w	Scenic Canyonlands Resort, Inc.	30/20-16 cac	--	300	--	stockwater/ recreation	7	--	--	--	--
303w	BLM	30/22-30 cbc	--	--	--	stockwater	2	--	--	--	--
304w	BLM	30/22-31 ccc	--	378	--	stockwater	5	--	--	--	--
305w	Adams	30/23-3 bab	--	300	--	stockwater	4	--	--	--	--
306w	BLM	29/23-33 cac	--	2	--	stockwater	7	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 14 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
307w	City of Monticello	33/23-25 cab	--	--	--	municipal	898	--	--	--	--
308w	Utah State Road Commission	30/23-10 ada	--	47	--	stockwater	1	--	--	--	--
309w	Redd Ranches	30/23-13 bda	--	50	--	stockwater	8	--	--	--	--
310w	City of Monticello	33/23-36 acc	--	--	--	municipal	898	--	--	--	--
311w	City of Monticello	33/23-36 dda	--	280	--	municipal	224	--	--	--	--
312w	BLM	30/22-13 acc	--	450	--	stockwater/ recreation	10	--	--	--	--
313w	City of Monticello	33/23-36 dda	--	360	--	municipal	224	--	--	--	--
314w	BLM	30/23-25 bdb	--	350	--	stockwater	5	--	--	--	--
315w	BLM	30/23-30 cdc	--	--	--	stockwater	1	--	--	--	--
316w	BLM	31/23-17 bbb	--	50	--	stockwater	6	--	--	--	--
317w	BLM	31/23-10 dcd	--	352	--	stockwater	3	--	--	--	--
318w	BLM	30/23-32 dcc	--	--	--	stockwater	5	--	--	--	--
319w	City of Monticello	33/24-31 bdb	--	360	--	municipal	224	--	--	--	--
320w	Indian Creek Uranium and Oil Corp.	31/21-3 bdd	--	--	--	--	7	--	--	--	--
321w	Indian Creek Cattle Co.	31/21-24 dbb	--	34	--	domestic/ irrigation	7	--	--	--	--
322w	BLM	31/22-4 bcc	--	225	--	stockwater	5	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 15 of 16)

Well or Spring Number[a]	Owner or Name of Well/Spring[b]	Location[c]	Land Surface Altitude (feet)	Well Depth (feet)	SU[d]	Water Use	Yield (gpm)	Potentiometric Level (feet)[e]	Date Sampled	Hydrochemical Item Number[f]	TDS (mg/l)
323w	BLM	31/23-3 dbb	--	300	--	stockwater	7	--	--	--	--
324w	BLM	31/23-5 bdb	--	300	--	stockwater	7	--	--	--	--
325w	Nelson	33/24-6 cbb	--	54	--	stockwater	3	--	--	--	--
326w	Hyde	33/24-30 cba	--	315	--	stockwater	7	--	--	--	--
327w	Hyde	33/24-30 cba	--	--	--	stockwater	18	--	--	--	--
328w	Summers	31/23-24 cbb	--	164	--	stockwater	5	--	--	--	--
329w	Summers	31/23-24 ddb	--	--	--	stockwater	4	--	--	--	--
330w	City of Monticello	33/24-31 bbd	--	400	--	municipal	224	--	--	--	--
331w	Scorup	31/23-31 aac	--	46	--	stockwater	7	--	--	--	--
332w	Bar MK Ranches	31/23-32 bcc	--	1,480	--	stockwater/ domestic	3	--	--	--	--
333w	Bar MK Ranches	31/23-34 dbd	--	800	--	domestic	7	--	--	--	--
334w	State of Utah	31/23-35 daa	--	230	--	stockwater	10	--	--	--	--
335w	Redd	31/23-35 abc	--	300	--	stockwater	7	--	--	--	--
336w	Barton	31/23-36 acc	--	--	--	domestic	7	--	--	--	--
337w	BLM	32/23-7 abb	--	275	--	stockwater	5	--	--	--	--
338w	Ledwon	32/23-24 bca	--	250	--	irrigation	7	--	--	--	--
339w	Redd	32/23-24 cbb	--	200	--	domestic	7	--	--	--	--
340w	Musselman	32/23-24 bca	--	105	--	domestic	7	--	--	--	--
341w	Pipkin	32/23-25 bab	--	60	--	--	5	--	--	--	--
342w	Redd	32/23-25 ddd	--	30	--	--	898	--	--	--	--

Table 3-24. Available Data on Water Wells and Springs, Davis Canyon Area
(Page 16 of 16)

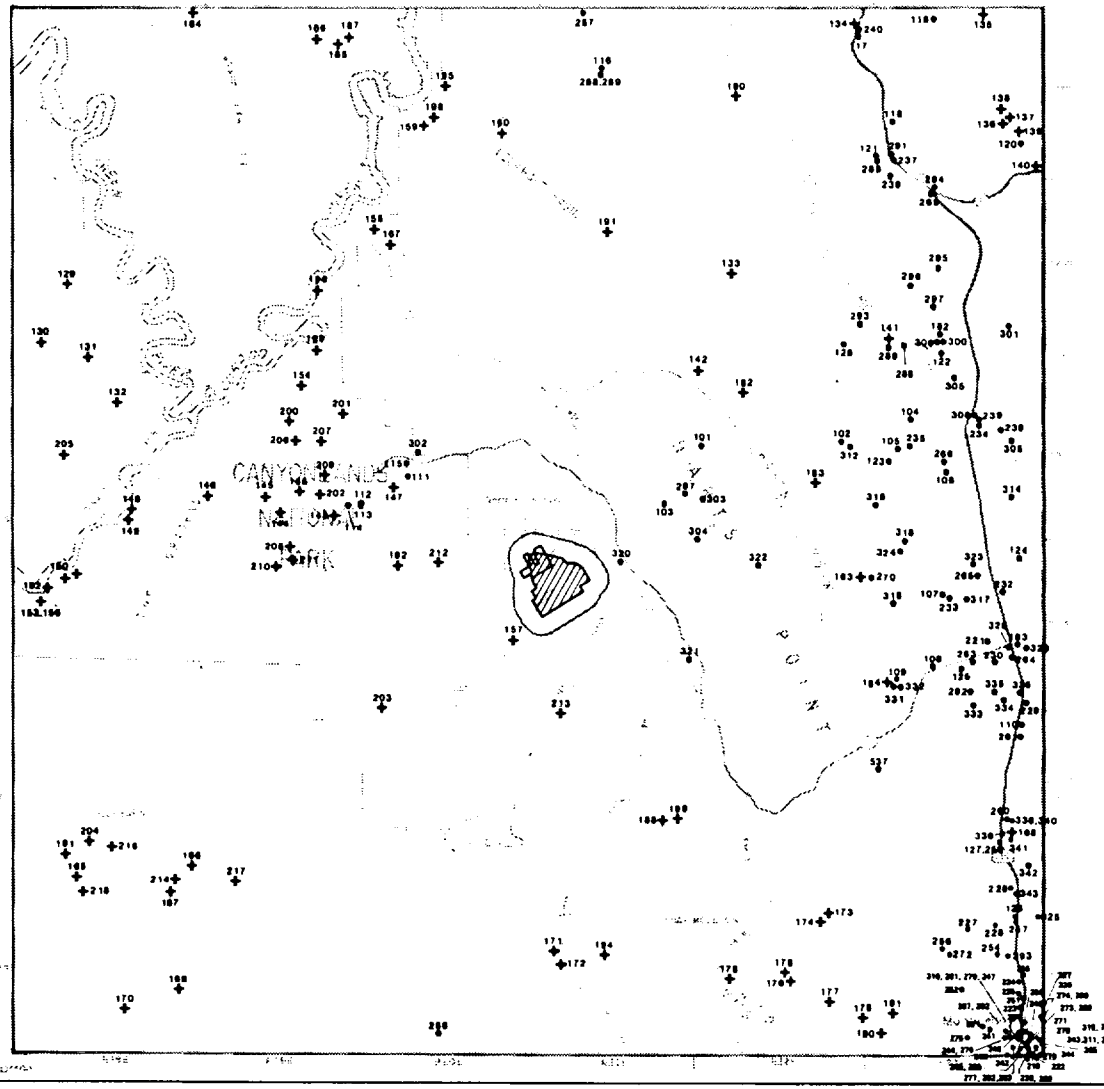
Well or Spring Number(a)	Owner or Name of Well/Spring(b)	Location(c)	Land Surface Altitude (feet)	Well Depth (feet)	SU(d)	Water Use	Yield (gpm)	Potentiometric Level (feet)(e)	Date Sampled	Hydrochemical Item Number(f)	TDS (mg/l)
343w	Redd	32/23-36 dcc	—	80	—	--	10	—	--	--	--
344w	AEC	33/24-31 bcc	—	343	DS/ BCF	--	22	--	08/05/55	195	292
345w	AEC	33/24-31 bdb	—	370	DS BCF	--	40	--	08/05/55	--	290

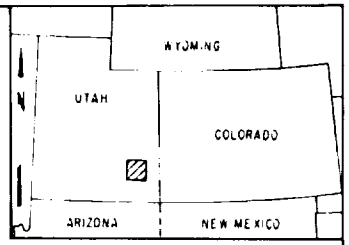
(a) Well (w) and spring (s) numbers correspond to locations shown on Figure 3-54.
(b) The state well-permit applicant is listed as owner where applicable, even though ownership may have changed subsequent to installation.
(c) Location designations utilize the standard USGS well numbering system (Rush et al., 1982, pp. 2-5).
(d) SU = Stratigraphic Unit:

NS	= Navajo Sandstone	HTF	- Honaker Trail Formation
WS	= Wingate Sandstone	ECF	= Elephant Canyon Formation
ES	= Entrada Sandstone	CMF	= Cedar Mesa Formation
J	= Jurassic	A	= Alluvium
CMS	= Cedar Mesa Sandstone	CUF	= Cutler Formation
KF	= Kayenta Formation	CHF	= Chinle Formation
BCF	= Burro Canyon Formation	WRS	= White Rim Sandstone
DS	= Dakota Sandstone	EC/HF	= Elephant Canyon/Halgaito Formations
DS/BCF	= Dakota Sandstone/Burro Canyon Formation.		

(e) The potentiometric level value represents the reported water level elevation above mean sea level for wells; for springs the value represents an estimate of ground surface elevation from U.S. Geological Survey 15-minute topographic maps.
(f) Hydrochemical item number refers to numbers assigned to the sample by WCC (1982, ONWI-290, Vol. V, Table A-2, Parts I and II, pp. A-5 to A-16).
(g) Refers to site designation assigned by WCC (1982, ONWI-290, Vol. V, Table A-2, Parts I and II, pp. A-5 to A-16).
(h) Less than 1.

Source: Thackston, 1984.





Explanation

101 Water wells. Number taken from Table 2 in Thackston (1985).

201 Springs. Number taken from Table 2 in Thackston (1985).

Proposed controlled area boundary

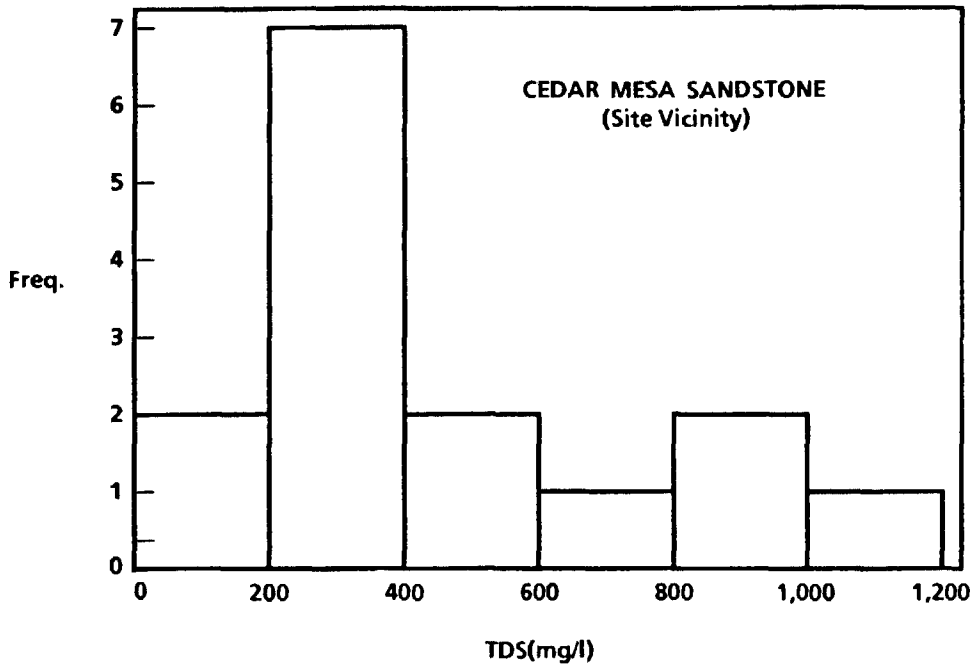
Geologic repository operations area

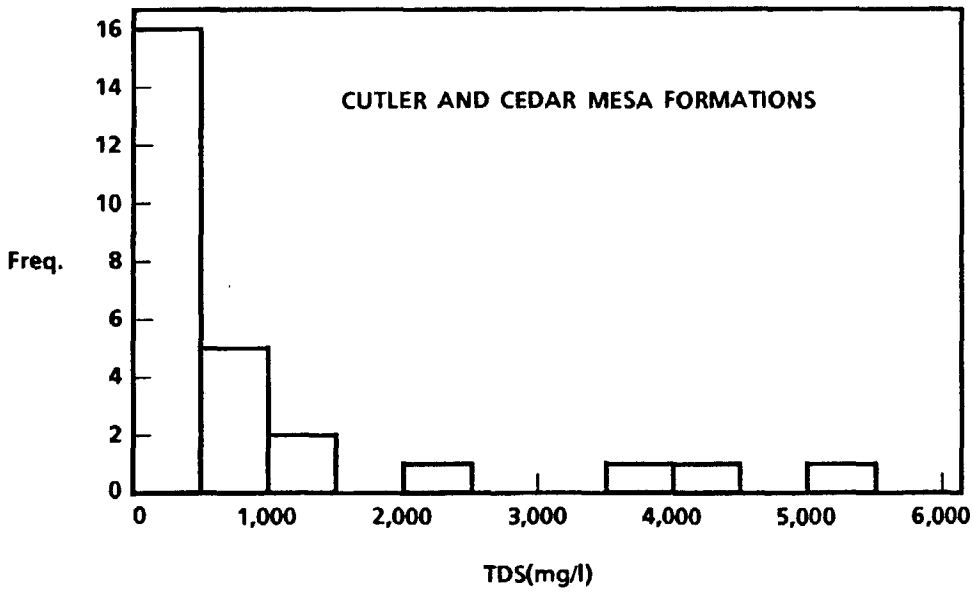
0 5 10 MI

0 5 10 Km

Water Wells and Springs Candidate Area

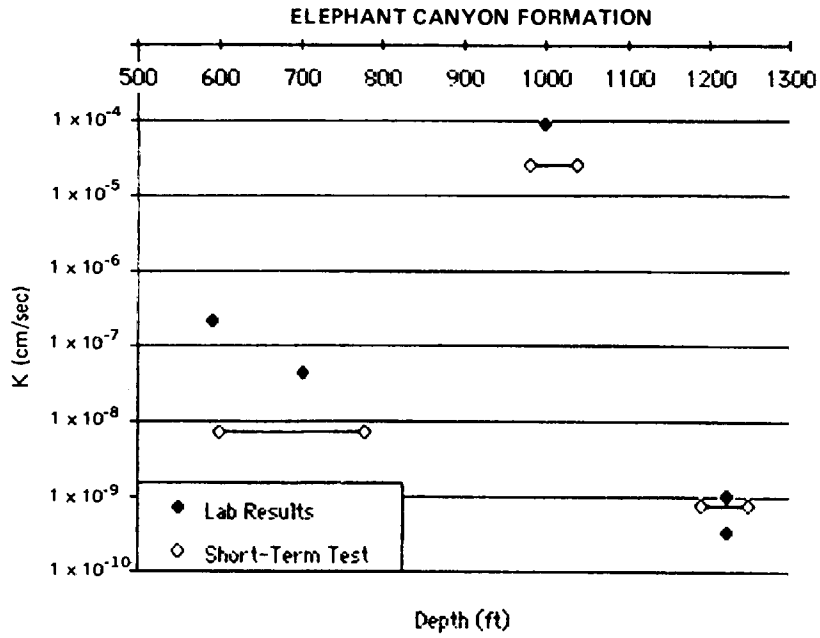
Figure 3-54

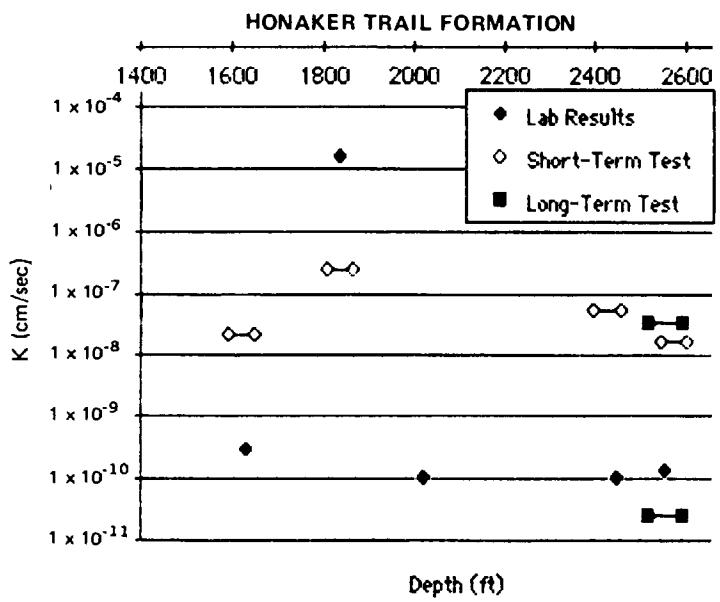




Frequency Plot Showing Total Dissolved Solids in Wells and Springs in the Candidate Area - Cedar Mesa and Cutler Formations

Figure 3-55





Comparison of Hydraulic Conductivity Data in the GD–1 Borehole – Elephant Canyon and Honaker Trail Formations

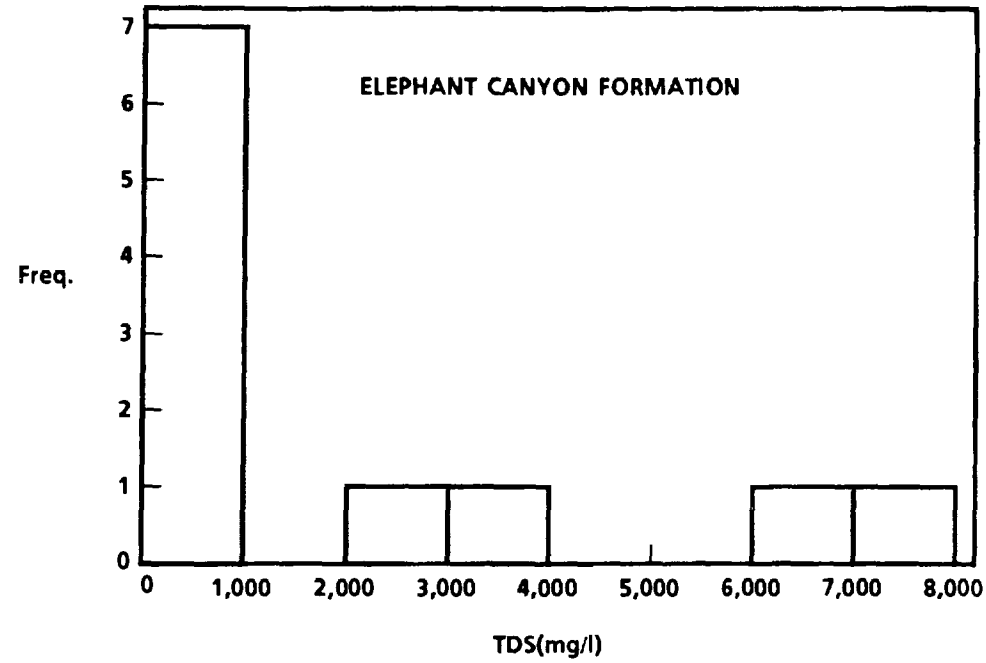
Figure 3-56

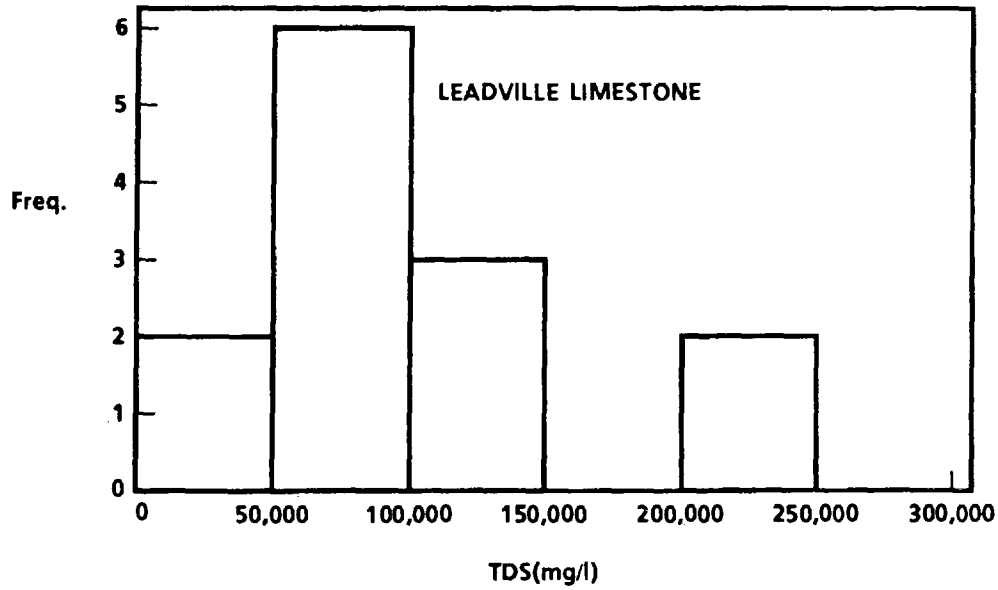
Figure 3-53. TDS values for the Elephant Canyon Formation in the candidate area are shown on Figure 3-57. TDS at the site is expected to be in the range of the two highest values shown on the chart, which are from the GD-1 borehole and a petroleum exploration borehole west of the site (Trident, Beef Basin Unit #2). The remaining values shown on the chart are from springs and are probably affected by the presence of local recharge.

Test results from the Honaker Trail Formation at borehole GD-1 show that these strata are primarily tight, dense, carbonate strata. Limited intergranular porosity is present in two sandstone zones tested (Table 3-23 and Figure 3-56). However, these zones produced minor amounts of water (less than 0.03 liter per second [0.5 gallon per minute]). These sandstones are interpreted as turbidite deposits. They make up less than 4 percent of the total thickness and occur in the upper two-thirds of the formation. Correlation with the logs of other boreholes in the area indicates that these beds have wide lateral extent (McCleary and Romie, 1985, p. 56). DSTs from the GD-1 borehole and laboratory tests on the core indicate that the permeability of these sandstones ranges from 0.24 to 17 millidarcies (2.3×10^{-16} to 1.7×10^{-14} square meter, hydraulic conductivity of 2.3×10^{-7} to 1.6×10^{-5} centimeter per second) (Table 3-23 and Figure 3-56) and that effective porosities probably range from 10 to 15.5 percent. The dense limestones and cherty limestones that comprise the bulk of the formation have much lower permeabilities than the sandstone beds. The data from the long-term shut-in test and pressurized slug test, the late-time data from the short-term DSTs, and the laboratory data on core (Table 3-23 and Figure 3-56) indicate that permeabilities in this interval of the formation range from 2.4×10^{-5} to 5.4×10^{-2} millidarcies (2.4×10^{-20} to 5.3×10^{-17} square meter, hydraulic conductivity of 2.3×10^{-11} to 5.3×10^{-8} centimeter per second). In this analysis, the late-time data from the short-term DSTs are considered more representative of actual formation conditions than the early-time data based on comparisons with the results of the long-term tests (Thackston et al., 1984, ONWI-491, p. 84). Effective porosities varied from 1.3 to 5.4 percent for these rock types (Table 3-23). The lower range of these values is considered more representative of the lower third of the formation where the chert content of the limestones is highest. TDS were 120,000 milligrams per liter in fluid samples recovered from the Honaker Trail Formation in the GD-1 borehole. At GD-1, jointing, fracturing, and solution porosity have not developed significant secondary permeability in the Honaker Trail Formation.

The fluid-transmitting capability of the lower Honaker Trail and Paradox Formations is generally smaller than that of the overlying strata because they are dense and have a low permeability. Dolomite, shale, and anhydrite interbeds within the Paradox Formation are also usually dense and of low permeability, except where the formation is fractured (Johnson and Gonzales, 1978, p. 136; WCC, 1982, ONWI-290, Vol. II, pp. 9-2 to 9-6). Because of the extremely tight nature of this portion of the stratigraphic section at GD-1, these formations are tentatively assigned to the middle hydrostratigraphic unit (Table 3-22) (Thackston et al., 1984, ONWI-491, Table 4-2). The data from the short-term DSTs, long-term borehole tests, and laboratory tests on core indicate that bulk permeabilities range from 5.4×10^{-5} to 1.1×10^{-1} millidarcies (5.3×10^{-20} to 1.1×10^{-16} square meter, hydraulic conductivity of 5.2×10^{-11} to 1.1×10^{-7} centimeter per second) in the interbeds of the Paradox Formation (Table 3-23 and Figure 3-58). In this analysis, the late-time data from the short-term DSTs are considered more representative of actual formation conditions than the early-time data based on comparisons with the results of the long-term tests (Thackston et al., 1984, ONWI-491, p. 84). Values for effective porosity ranged between 0.6 and 12.6 percent for the interbed rock types (Table 3-23). None of the test zones yielded sufficient fluid for chemical analysis. No TDS values are reported from the Paradox Formation in the other petroleum exploration boreholes in the candidate area (Thackston, 1985, Table 1) (Section 3.2.7.2).

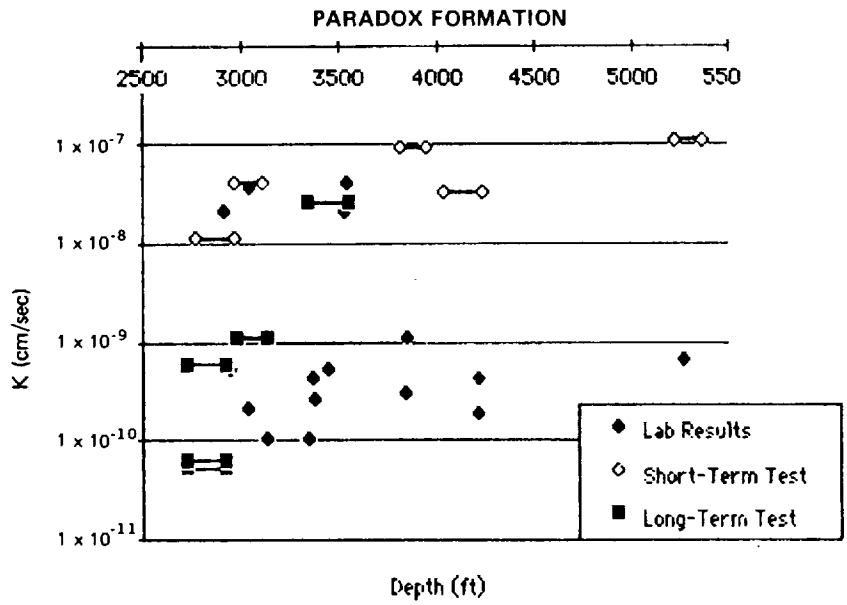
The Pinkerton Trail Formation, the uppermost formation of the lower hydrostratigraphic unit, consists primarily of dolomite, limestone, and shale; its variable lithology is likely to result in a wide range of porosities and permeabilities within the unit. Laboratory tests on core from GD-1 indicate that the Pinkerton Trail Formation is composed of strata that have very low matrix permeability (less than 1×10^{-7} darcy [1×10^{-15} square centimeter]) and is probably an aquitard in the candidate area, except where it is fractured (Table 3-23).

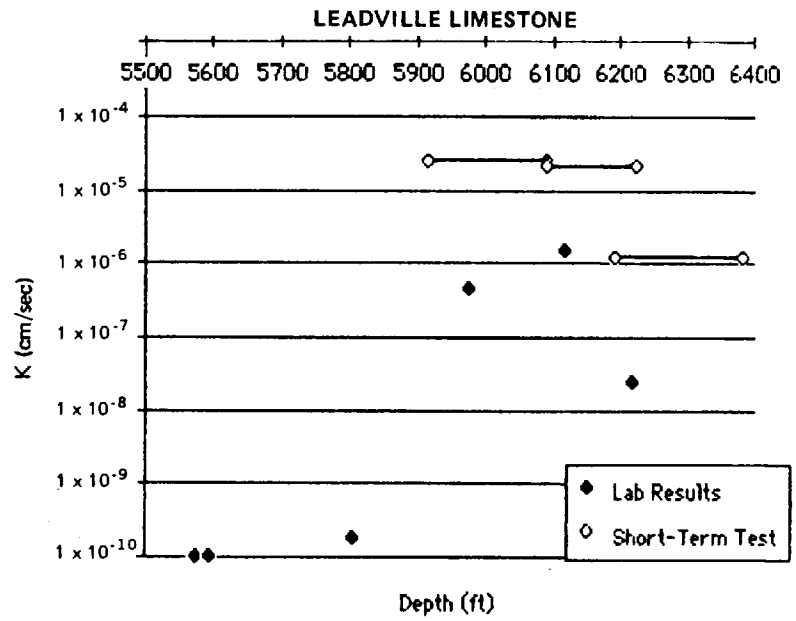




Frequency Plot Showing Total Dissolved Solids in Wells and Springs in the Candidate Area - Elephant Canyon Formation and Leadville Limestone

Figure 3-57





Comparison of Hydraulic Conductivity Data in the GD–1 Borehole – Paradox Formation and Leadville Limestone

Figure 3-58

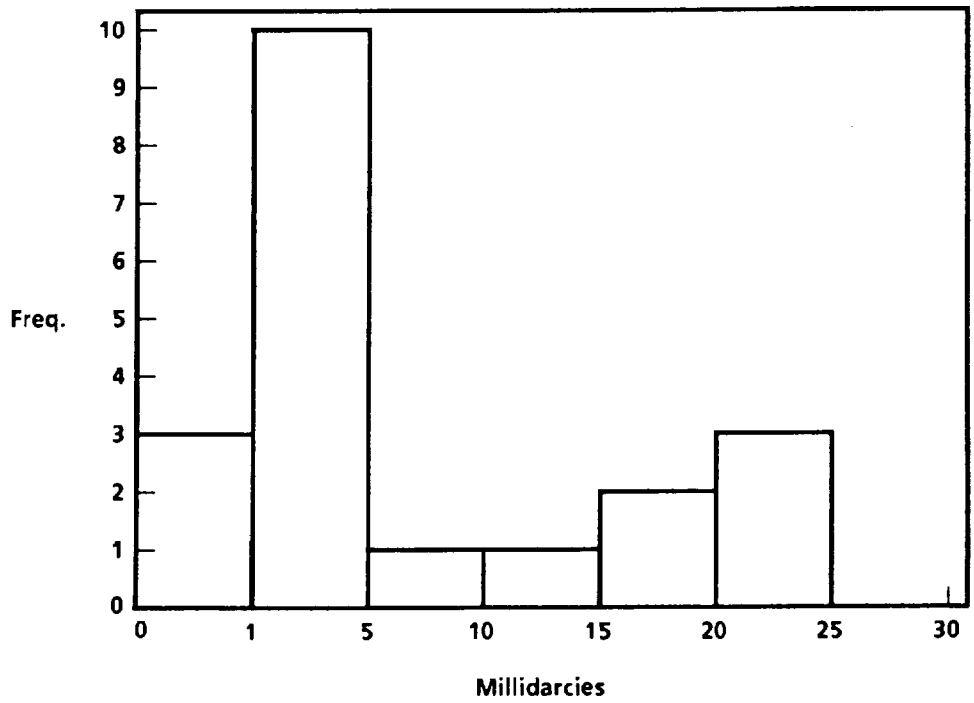
The Molas Formation, like the Pinkerton Trail Formation, probably acts as an aquitard in the vicinity of the Davis Canyon site.

The most widespread and transmissive water-bearing formation in the region is the Mississippian Leadville Limestone. Extensive dolomitization, fracturing, and leaching of the Leadville Limestone and primary facies-related porosity and permeability result in a variety of fluid-transmitting characteristics. Permeabilities for the lower hydrostratigraphic unit, which includes the Leadville Formation, were estimated from DSTs throughout the western Paradox Basin (Figure 3-53) (WCC, 1982, ONWI-290, Vol. V, Appendix A). They range from approximately 2×10^{-2} to 2×10^{3} millidarcies (2×10^{-11} to 2×10^{-8} square centimeter). Figure 3-59 shows the range of 20 permeability values for DSTs in the Leadville Formation in the GD-1 borehole and other petroleum exploration boreholes in the candidate area. The unusual cavernous conditions reported in the Placid DU-2 USA borehole in the Leadville Limestone are not reflected in the table since no tests were run in that borehole (see Section 3.2.5.6). Effective porosity values ranged from 11.2 to 15.0 percent in the GD-1 borehole. TDS values for the Leadville Limestone from boreholes in the candidate area are shown on Figure 3-57. The two highest values on the figure are from boreholes near Lockhart Basin and in the fold and fault belt; these values may indicate dissolution activity in those areas.

The results of the GD-1 boring program can provide some data on the potential for fracture flow in the controlled zone. Since fracturing and fracture spacing may not be uniform over the area, the data from a single borehole such as GD-1 may not be representative of the entire area. In this section, the potential for fracturing is estimated by several techniques: evidence of fracturing in the GD-1 core, drilling data from GD-1, and comparison of laboratory hydrologic tests with field tests in the borehole. Laboratory tests yielded primarily intergranular hydraulic conductivities, while in situ results also reflected the secondary hydraulic conductivity of fractures or dissolution voids. Therefore, laboratory results on core give estimates of matrix hydraulic conductivity (defined by the primary intergranular pores and small-scale secondary porosity) while in situ packertest results represent bulk hydraulic conductivity (defined to include all features that may create large-scale secondary porosity [e.g., fractures, dissolution voids, and faults]). Differences between the values for the laboratory and field tests may then indicate the contribution of fractures when field test values are higher.

In the Elephant Canyon Formation, fracturing does not appear to significantly affect ground-water flow. The core log (WCC, 1982, ONWI-388, Vol. III) indicates few widely spaced fractures, and water produced during the airmist coring of this interval correlated to the occurrence of permeable sandstone beds (e.g., the sandstone at a 302 to 308 meter [990 to 1,010 foot] depth) rather than fractures. The three short-term DSTs conducted in this interval yield hydraulic conductivity values lower than the laboratory values for the test intervals (Figure 3-56) (Thackston et al., 1984, ONWI-491, Tables 4-1, 4-2) indicating that matrix permeability is controlling flow. Hydrochemical data from the GD-1 borehole indicate that the Elephant Canyon Formation waters are part of the actively circulating shallow-aquifer system. The Elephant Canyon Formation water represents a dilute $NaClSO_4$-end-member and is presumed to be actively circulating ground water (McCulley et al., 1984). The delta deuterium versus delta O^{18} values of this water plot within the global meteoric water zone (McCulley et al., 1984, Figure 3-1). Thus the Elephant Canyon Formation water can be characterized as meteoric water. There are no data to indicate whether or not the recharge of meteoric water to this formation is occurring along fractures.

The core log indicates little fracturing in the Honaker Trail Formation. The log notes minor fractures occurring at intervals of 6 to 61 meters (20 to 200 feet). About 60 percent of these fractures were reported to be filled with clay, silt, or calcite. No zones of heavy fracturing were noted from the core. Four short-term DSTs were conducted in this formation in GD-1. In one of the tests (DST 5), the hydraulic conductivity value from the field test was lower (2.3×10^{-7} centimeter per second) than values obtained from laboratory testing of the core (3.5×10^{-6} centimeter per second). This zone straddled a sandstone bed that produced the most water recorded for this formation. The other three short-term tests yielded hydraulic conductivity values in the 10^{-8}-centimeter-per-second range. These values are about two



Frequency Plot Showing Distribution of Permeability Data in the Leadville Limestone from Tests in the Candidate Area

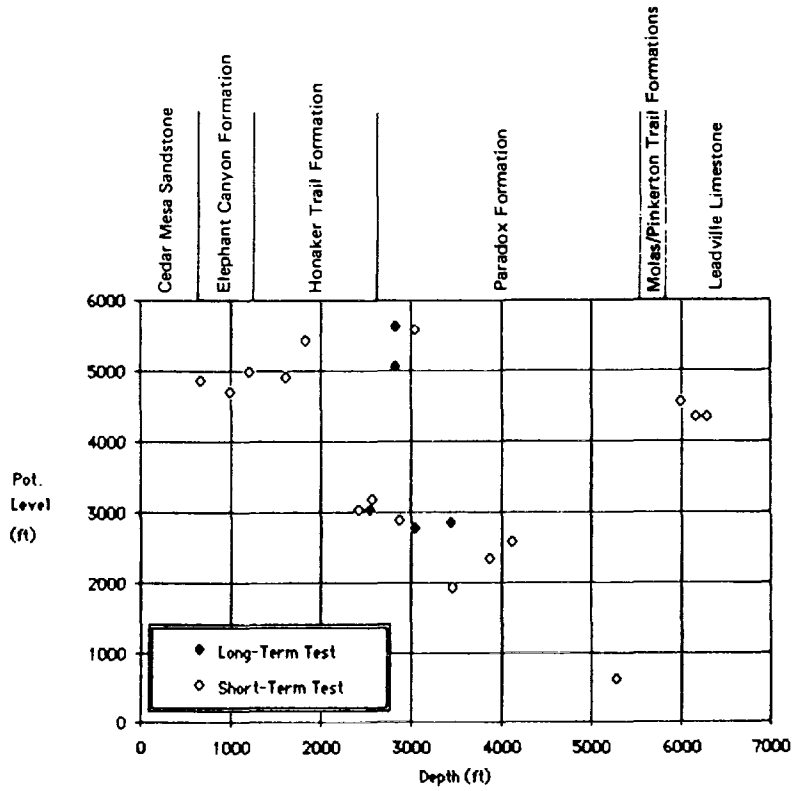
Source: Thackston, 1985, Table 1.

Figure 3-59

orders of magnitude higher than the results obtained from the laboratory tests. However, the values reported are at the lowest end of the range where these tests can be considered accurate, and may only be giving an upper bounding value for the true bulk hydraulic conductivity. One of the short-term test intervals (DST 6) was also tested during the long-term testing (LT 1) and hydraulic conductivity values as low as 2.3×10^{-11} centimeters per second were recorded. The long-term test value is about three orders of magnitude lower than the short-term test value and is in the range of the laboratory results (Figure 3-56) (Thackston et al., 1984, ONWI-491, Table 4-2). The long-term tests are considered more accurate than the short-term tests at these low values. The two lowest field test intervals in this formation (DST 6, DST 7, and LT 1) also have potentiometric levels considerably lower (918 meters [3,013 feet] and 922 meters [3,025 feet]) than the potentiometric levels (1,652 meters [5,420 feet] and 1,498 meters [4,914 feet]) of the two test intervals (DST 5 and DST 8) higher in the formation (Figure 3-60). These differences in potentiometric level indicate strata acting as aquitards or aquicludes within the formation, and indicate that there is no significant vertical interconnection via fractures. The hydrochemical data from the GD-1 borehole show that the Honaker Trail Formation water is considered to represent old formation water. In the delta deuterium versus delta O^{18} plot, the Honaker Trail water point is located well to the right of the meteoric waterline (McCulley et al., 1984), indicating an evaporated sea water component in the sample. This was also supported by the chlorine (Cl) versus bromine (Br) plot (McCulley et al., 1984, Figure 4-9). McCulley et al. (1984) examined six different hypotheses for the origin of Honaker Trail Formation water. These hypotheses consider mixtures of evaporated sea water and meteoric water, water of salt dissolution and gypsum dehydration, and chemically enriched water by ultrafiltration. However, a lower Cl-to-Br ratio (unlike the high ratios expected due to salt dissolution) and observed low magnesium, potassium, sodium, and sulphate and high calcium suggest that the Honaker Trail Formation water is an admixture of evaporated sea water and ancient meteoric water (McCulley et al., 1984, pp. 39-52). Potential sources of evaporated sea water include residual water of compaction and diagenesis or post-depositional sea water. The absence of meteoric water in the formation suggests the lack of significant vertical communication through fractures with the overlying formations.

There is no evidence in the GD-1 borehole that fractures contribute significantly to the bulk permeability of the interbeds in the Paradox Formation. A log of fractures in the non-salt strata of the GD-1 core is given in Thackston (1985, Table 3) for the depth interval of 798 to 1,133 meters (2,618 to 3,719 feet). This log indicates that some fracturing occurs in the depth interval of 798 to 825 meters (2,618 to 2,708 feet). Fractures in this interval are less than 1 millimeter wide. About 40 percent of the fractures were open; the remainder were filled with calcite. Fractures are much rarer below this interval and are filled with halite. These halite-filled fractures are interpreted as being diagenetic in origin. Any fractures occurring in the depth interval from 831 to 944 meters (2,727 to 3,098 feet) did not contribute fluids to the borehole, since this interval was cored with dry air after the overlying section was cased off. No moisture was observed at the end of the air-return line while coring this interval (WCC, 1982, ONWI-388, p. 33). The three long-term tests conducted in the Paradox Formation between depths of 830 to 1,083 meters (2,722 and 3,554 feet) generally yield ranges of values that overlap with the ranges of values reported from the laboratory tests (Thackston et al., 1984, ONWI-491, Tables 4-1, 4-2). The results from the late-time date in the short-term tests yield hydraulic conductivities close to the upper range of the laboratory values (Figure 3-58). The variability in the potentiometric level data (Figure 3-60) in the formation indicates that fracturing is not creating significant vertical connections between the interbeds. On a regional basis, some wells produce oil from fractures in the Cane Creek marker (interbed below Salt Cycle 21) in the basin. In the GD-1 borehole, little to moderate fracturing was noted in the siltstone beds within this interbed. The fractures were filled with halite. Short-term DST 10 straddled this interval and recorded hydraulic conductivity values similar to the other short-term test results in the formation and a very low potentiometric level.

The core from the GD-1 borehole indicates the Leadville Limestone is slightly to moderately fractured (interval between fractures 0.15 to 0.9 meter [0.5 to 3 feet]) with many of the fractures filled with clay or silt. The hydraulic conductivity values for the three short-term DSTs are 10 to 100 times greater than the laboratory data for the same intervals;



Potentiometric Level Data from the GD--1 Borehole

Figure 3-60

this difference is probably a reasonable indication of the contribution of fractures or secondary porosity resulting from dolomitization to the bulk hydraulic conductivity of the formation.

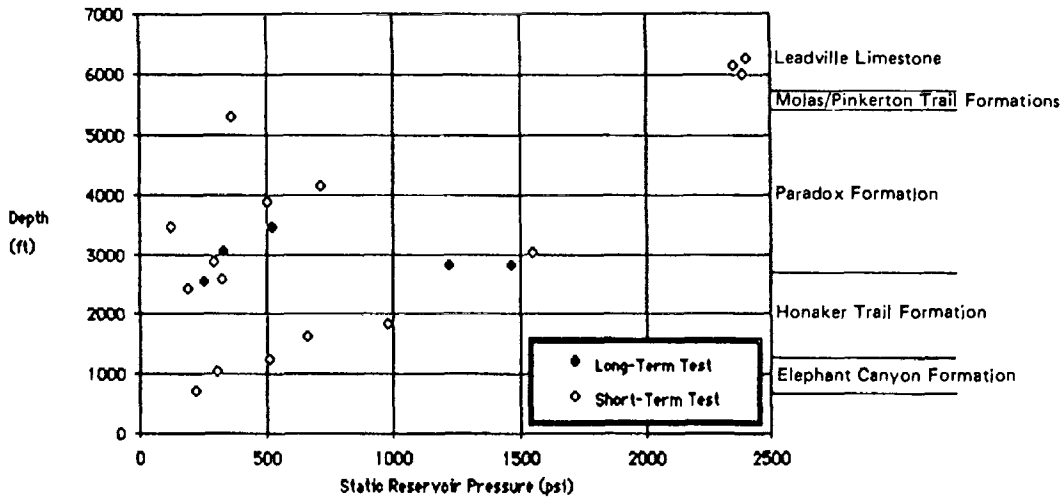
The hydrochemical and isotopic data from Leadville Formation water indicate the absence of meteoric water, suggesting that rapid recharge through vertical fractures is not occurring. The oxygen and deuterium isotopic values of Leadville water, the waters from Lisbon Valley, and salt-wash-oil-fields Leadville water plot below the meteoric waterline (McCulley et al., 1984, Figure 3-1). Such trends have been explained elsewhere as the result of dissolution and recrystallization processes in which lighter oxygen in meteoric water is exchanged by heavier oxygen in a marine-carbonate-aquifer matrix (Hitchon and Friedman, 1969; Clayton et al., 1966). Mineralogic and petrologic data from GD-1 Leadville core and the concentration of delta C^{13} in the ground water show minor solution and reprecipitation of dolomite which may be responsible for positive delta O^{18} shifts observed in the water samples. However, the high salinity of Leadville water sample at GD-1 (McCulley et al., 1984, Table 3-1) indicates dissolution of salts. This is also supported by the Na-to-Cl ratios (less than 0.6) and Cl-to-Br trends. These data suggest that the salinity of Leadville water is largely caused by dissolution of Paradox salts by circulating ground water. However, no mineralogic or petrologic evidence is seen in the GD-1 core to support the dissolution process in this locality. Similarly, no isotopic evidence (including tritium) is found to conclude that the circulating ground waters are modern meteoric waters. Dissolution by ancient circulating ground water may be taking place or might have taken place outside the study area in the folded and faulted zones where structural features juxtapose the Paradox and Leadville formations.

The upper hydrostratigraphic unit (composed of a heterogeneous mixture of lithologies with various permeabilities) may contain localized flow systems at the Davis Canyon site. Characteristics of the upper Honaker Trail Formation and Cutler Group strata show similarities that may suggest a single hydrostratigraphic unit. At borehole GD-1, the hydrostatic pressure gradient through this section (Figure 3-61) increases steadily with depth, consistent with increasing density and weight of the pore fluids. This consistent pressure increase with depth indicates some degree of hydrologic continuity within this section.

Although potentiometric data are limited, the ground-water flow in the upper hydrostratigraphic unit in the Davis Canyon site appears to be generally to the north and northwest (Figure 3-62). This flow system is complicated by local systems of ground-water flow that develop in areas where strata in the upper hydrostratigraphic unit are deeply incised. In contrast, regional potentiometric data from the lower hydrostratigraphic unit (Figure 3-63) indicate a west-southwestward flow at the Davis Canyon site. The contours on Figure 3-62 indicate a hydraulic gradient of 0.0137 for the upper hydrostratigraphic unit at the site. A regional potentiometric map by Weir et al. (1983, plate 2) gives a similar value of 0.0133 for the gradient in the upper unit in the site area. The average gradient for the entire flow path from the site to discharge points along the Colorado River is probably between 0.013 and 0.017. Figure 3-63 shows the potentiometric surface for the lower hydrostratigraphic unit in the candidate area. This map indicates that the hydraulic gradient is 0.0058 at the site for the lower unit.

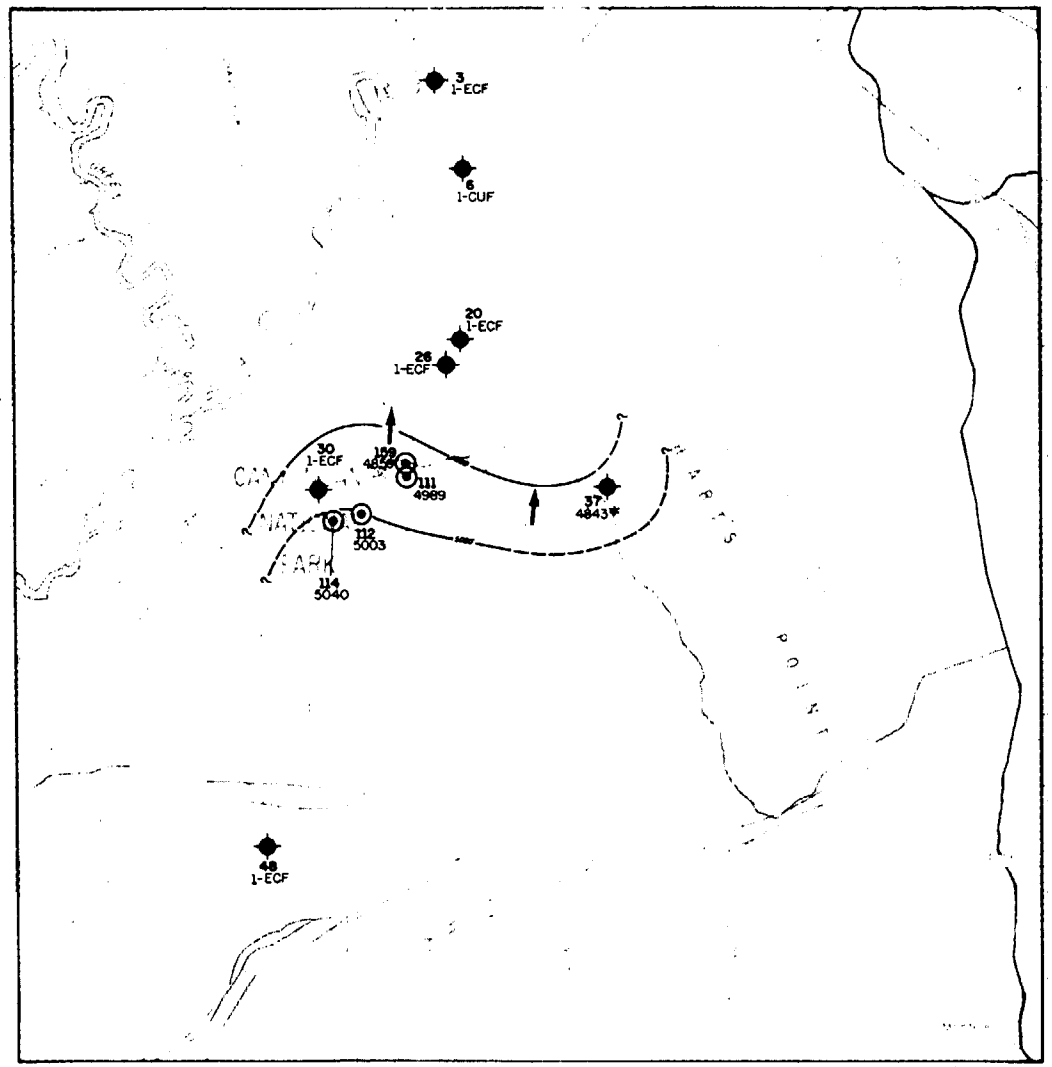
Some hydraulic connection may exist across the middle hydrostratigraphic unit in areas where salt flow, solutioning, or fracturing has occurred, such as in Shay Graben and Lockhart Basin. However, because the potentiometric surface of the upper hydrostratigraphic unit appears to be generally higher than that of the lower unit at the site, and considering the extensive thick sequence of evaporite beds, hydraulic interconnection is probably restricted between the upper and lower units.

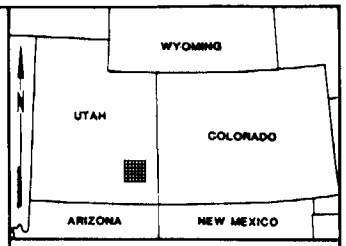
The potentiometric levels of the middle hydrostratigraphic unit also appear to support this lack of vertical hydraulic interconnection between the hydrostratigraphic units in the Davis Canyon candidate area. Regionally, the middle hydrostratigraphic unit contains areally limited zones of high permeability within generally low permeability strata (WCC, 1982, ONWI-290, Vol. I, pp. 9-8, 9-9). This observation is supported by the erratic distribution of potentiometric values for this unit in the region and the low permeability of halite



Static Reservoir Pressure Data
from the GD–1 Borehole

Figure 3-61





Explanation

37 4843* — EXPLORATION BOREHOLE, with number corresponding to data listing in Table 1 of Thackston, 1986. POTENTIOMETRIC LEVEL, estimated from Drill Stem Test (DST). If asterisk appears, the number in parentheses is an average of results from several tests in this hydrogeologic unit. Formations and depth intervals tested are listed in Table 1 of Thackston, 1986.

48 1-ECF — For boreholes not having DST data of sufficient quality to estimate a potentiometric level, the number of tests and formation code is provided. If a (T) is present, the data are judged to represent an extremely tight (low permeability) test zone.

112 5003 — WATER WELL, with number corresponding to data listing in Table 2 of Thackston, 1986. POTENTIOMETRIC LEVEL, based on water level measurement.

POTENTIOMETRIC LEVEL CONTOUR, in feet above sea level, dashed or queried where highly uncertain

APPARENT GENERAL GROUND-WATER FLOW DIRECTION

CANDIDATE AREA BOUNDARY

FAULT

STRUCTURE CONTOUR. Contour interval 500 feet.

ECF Elephant Canyon Fm.

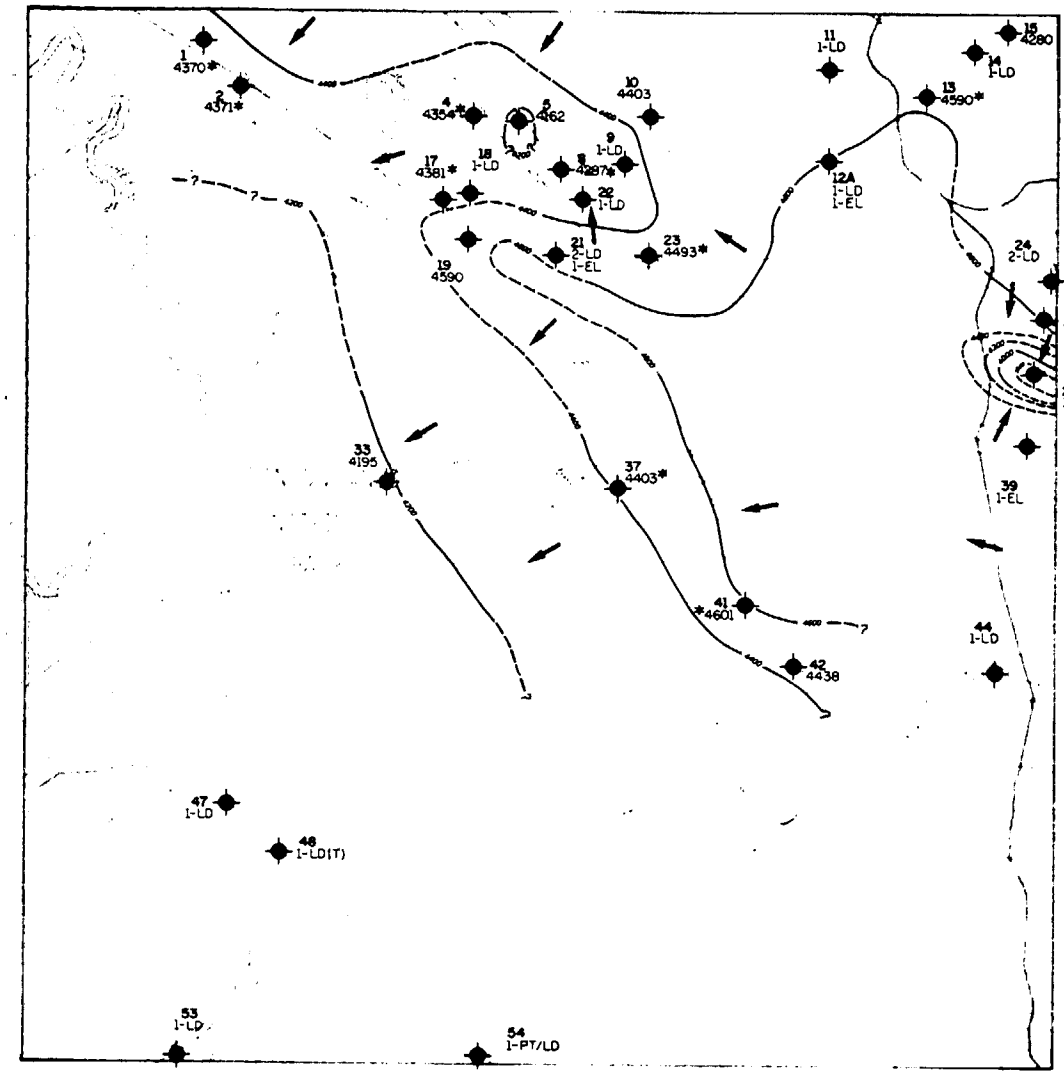
CUF Cutler Fm.

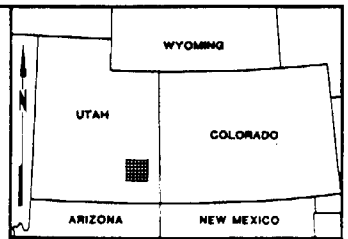
0 5 10 MI

0 5 10 15 Km

Preliminary Map of Potentiometric Surface Upper Hydrostratigraphic Unit

Figure 3-62





Explanation

41 *4601 — EXPLORATION BOREHOLE, with number corresponding to data listing in Table 1 of Thackston, 1985. POTENTIOMETRIC LEVEL, estimated from Drill Stem Test (DST). If asterisk appears, the number in parentheses is an average of results from several tests in this hydrogeologic unit. Formations and depth intervals tested are listed in Table 1 of Thackston, 1985.

47 1-LD — For boreholes not having DST data of sufficient quality to estimate a potentiometric level, the number of tests and formation code is provided. If a (T) is present, the data are judged to represent an extremely tight (low permeability) test zone.

4800 — ? POTENTIOMETRIC LEVEL CONTOUR, in feet above sea level, dashed or queried where highly uncertain

APPARENT GENERAL GROUND-WATER FLOW DIRECTION

CANDIDATE AREA BOUNDARY

FAULT

STRUCTURE CONTOUR, Contour interval 500 feet.

LD Leadville LS.

EL Elbert Fm.

PT Pinkerton Trail Fm.

0 5 10 MI

0 5 10 15 Km

Preliminary Map of Potentiometric Surface Lower Hydrostratigraphic Unit Candidate Area

Figure 3-63

(Gevantman, 1981, pp. 30-33). Potentiometric levels within Paradox Formation interbeds do not generally create a consistent areal pattern in the bedded salt area of the western Paradox Basin.

Within the candidate area, it is possible to produce a potentiometric map for part of the Ismay substage (Section 3.2.3.1) of the Paradox Formation (Figure 3-64.). (In this area the Ismay substage is considered to extend from the upper contact of the formation to the top of Salt Cycle 4.) This map indicates that flow is to the southwest across the site with a hydraulic gradient of approximately 0.014. With the uncertainties in measuring potentiometric levels in this unit, it is estimated that the actual gradient could vary between 0.012 and 0.033. Considering the highly variable potentiometric levels found within the middle hydrostratigraphic unit, it is not clear that the gradients and flow directions for other interbeds in the Paradox Formation would be similar to those reported for the Ismay substage.

Static reservoir pressures and equivalent fresh water potentiometric levels for the GD-1 borehole are shown on Figures 3-60 and 3-61 and Table 3-23. Comparison of the values from different short-term and long-term tests in the same interval illustrates the large degree of uncertainty inherent in measuring potentiometric levels in the extreme low-permeability formations of the middle hydrostratigraphic unit over relatively short time periods, especially when deformable strata such as salt beds are present within the test zones. All of these test zones produced little or no fluid during testing.

On a large scale basis, the gradient is downward between the upper hydrostratigraphic unit and the lower hydrostratigraphic unit because the potentiometric levels for all tests in the upper hydrostratigraphic unit are higher than those in the lower hydrostratigraphic unit (Figure 3-60). However, the anomalous trend of fluid pressure and potentiometric levels with depth in the middle hydrostratigraphic unit suggest a lack of hydraulic interconnection between the upper and lower hydrostratigraphic units in the site area. If the major hydrostratigraphic units are not interconnected, then the potential exists for local upward or downward gradients, depending on the actual hydraulic interconnections that exist and the pressure differences between the connected strata.

The upper hydrostratigraphic unit within the Davis Canyon candidate area is recharged by infiltration of precipitation and seepage from streams. Precipitation over most of the area ranges from 20 to 30 centimeters (8 to 12 inches) per year (Ritzma and Doelling, 1969, Figure 2). Only a small portion of this precipitation is thought to actually recharge the ground-water flow system (Dunbar and Thackston, 1985, BMI/ONWI-571, Figure 5-2).

Both perennial and ephemeral drainages recharge the upper unit. Indian Creek probably recharges the upper unit along at least part of its reach (WCC, 1982, ONWI-290, Vol. II, p. 9-5); ephemeral streams such as those in Lavender, Davis, and Rustler Canyons and Harts Draw (which occasionally flow in response to winter precipitation and summer thunderstorms) may also act as sources of recharge.

The major components of ground-water discharge from the upper hydrostratigraphic unit in the Davis Canyon candidate area are springs and subriver-level seeps to the Colorado River, and associated drainages and evapotranspiration. The Colorado River has incised through most of the upper hydrostratigraphic unit in the western part of the area, forming the major line sink or discharge zone.

Ground-water withdrawals from the upper unit in the Davis Canyon site are limited to scattered small-capacity livestock and domestic wells, including five* wells that supply Canyonlands National Park in the Needles area (Sumsion and Bolke, 1972, p. 51). These shallow wells, which are reportedly completed in Cedar Mesa Sandstone, are capable of producing approximately 0.2 to 3.7 liters per second (4 to 60 gallons per minute).

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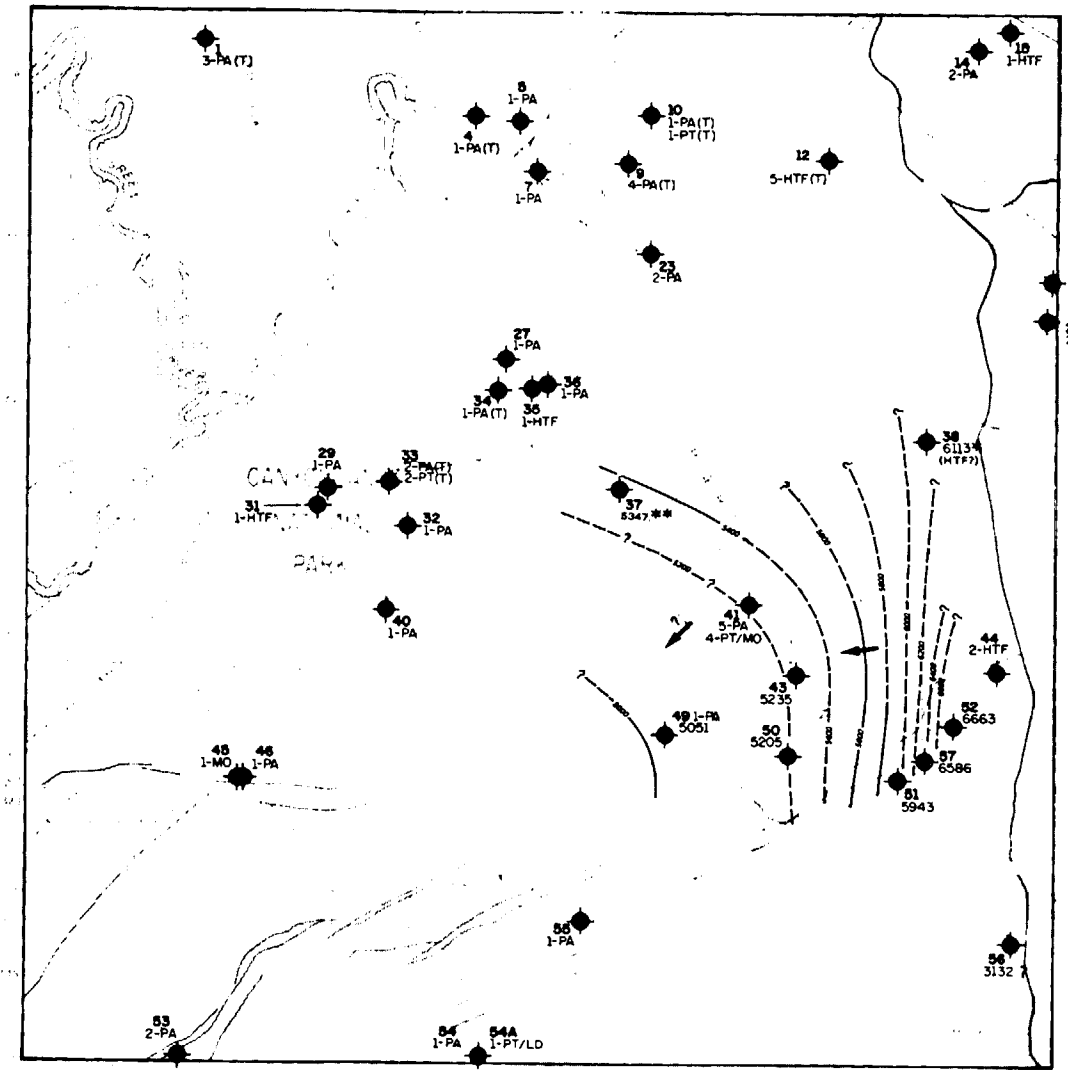
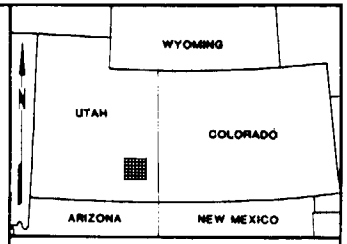
*Six wells were drilled; one was plugged and abandoned, and two are not presently used.





Explanation

38 6113* — EXPLORATION BOREHOLE, with number corresponding to data listing in Table 1 of Theckston, 1985.

POTENTIOMETRIC LEVEL, estimated from Drill Stem Test (DST). If asterisk appears, the number in parentheses is an average of results from several tests in this hydrogeologic unit. Formations and depth intervals tested are listed in Table 1 of Theckston, 1985.

40 1-PA — For boreholes not having DST data of sufficient quality to estimate a potentiometric level, the number of tests and formation code is provided. If a (T) is present, the data are judged to represent an extremely tight (low permeability) test zone.

POTENTIOMETRIC LEVEL CONTOUR, in feet above sea level, dashed or queried where highly uncertain

APPARENT GENERAL GROUND-WATER FLOW DIRECTION

CANDIDATE AREA BOUNDARY

FAULT

STRUCTURE CONTOUR. Contour interval 500 feet.

PA Paradox Fm.
HTF Honaker Trail Fm.
PT Pinkerton Trail Fm.
MO Moles Fm.

** *NOTE:* The value presented for this location is an average of values from GD-1, Long Term Test No. 2 (Theckston et al., 1984, Table 4-21).

0 5 10 MI
0 5 10 15 Km

Preliminary Map of Potentiometric Surface Ismay Subbasin Candidate Area

Figure 3-64

Significant recharge to or discharge from the middle and lower hydrostratigraphic units does not appear to occur in the Davis Canyon candidate area, except possibly where the normal stratigraphic sequence has been disrupted, such as in Lockhart Basin and along Shay Graben (WCC, 1982, ONWI-290, Vol. II, p. 9-82; Dunbar and Thackston, 1985, BMI/ONWI-571, Figure 5-2). Lateral recharge to and discharge from the middle and lower units are limited by overlying strata of low permeability.

Minor amounts of ground water discharge from the upper unit at springs and seeps in the candidate area. Many of them develop salt crusts around their margins. In Section 28, T30S, R20E, two springs (seeps) were identified with these salt crusts. These seeps had an extremely small amount of water flow. In the seepage area, there are encrusted salt precipitants. From the major ionic data, it appears that these precipitants are composed of salts such as halite, gypsum, calcite, and thenardite (Sayala, 1985). The ionic and isotopic data (Table 3-25) suggest that these salts are formed by the leaching of finely disseminated salts in the nearby Cedar Mesa Sandstone by local shallow ground water and the concentration of the salts by desert evaporation (Sayala, 1985). A similar conclusion was also drawn by the National Park Service's water resource field support lab (Kunkle, 1984). No deep ground-water source for this seep is apparent from the available data.

Preliminary numerical modeling of the ground-water flow system was performed for the region surrounding the candidate area (Dunbar and Thackston, 1985, BMI/ONWI-571, pp. 1-3). The basic conclusions from the study at this time are that the conceptual ground-water flow system model is realistic and that additional data are needed to adequately quantify the flow system parameters, especially transmissivities, hydraulic conductivities, recharge amounts, and potentiometric levels.

Geologic observations to date strongly suggest that flow rates are extremely low. The petrographic features of the Salt Cycle 6 in GD-1 core indicate that little or no influx of external ground water has occurred since early diagenesis of this salt deposit. For example, regular, rhythmic depositional banding of anhydrite is well preserved in Salt Cycle 6 along the length of the drill core from the GD-1 borehole (Hite, 1983, Figure 4). The preservation of carnallite beds (Hite, 1982, ONWI-9[82-1], p. 4, Figure 4), often only millimeters thick, in the upper third of Salt Cycle 6 would not remain if contacted by outside ground water because, at a minimum, the carnallite would have been converted to sylvite by incongruent dissolution (Braitsch, 1971, pp. 65-67). Furthermore, based on geophysical logs of petroleum exploration holes and the GD-1 borehole, the Paradox evaporite sequence is laterally extensive in the candidate area (McCleary et al., 1983, ONWI-485, Figure A-12; McCleary and Romie, 1985, Figures 4-7 to 4-10) and shows no dissolution of the salt in the site vicinity.

Laboratory tests (Table 3-23) and petrographic examination of core from GD-1 show that essentially all of the original porosity in the halite has been occluded by diagenetic products (McCulley et al., 1984, pp. 24-26). These tests confirm the conclusions reported by Gevantman (1981, pp. 29-31) regarding the effective porosity and permeability of halite: at burial depths of greater than approximately 12 meters (39 feet), the permeability and effective porosity of halite is effectively zero. Furthermore, the fact that halite beds have existed in the area since Pennsylvanian time implies little intrusion of fresh water into the salt or movement of water through it. Therefore, it is interpreted that essentially no movement of ground water exists through the proposed repository rock.

However, actual measured values of permeability and water movement in salt are highly uncertain and subject to debate. Permeability in salt has been measured in the following areas: the field at the WIPP site (Isherwood, 1981, NUREG/CR-0912, Vol. I, p. 194), and the laboratory (Gloyna and Reynolds, 1961; Aufricht and Howard, 1961; WCC, 1982, ONWI-388, p. 1118). Parameters such as stress release, microfracturing, test fluids, pressure gradient across samples, and temperature, affect the reliability of laboratory results on core samples. Researchers generally assert the following:

1. Permeability is directly related to the confining pressure on the salt.

Table 3-25. Analytical Results of Salt Sample

Ions (Total Sample)	% Composition	Isotopes (Gypsum Salt)	Concentration (Per Mil)
Na^+	19.4	Delta D	-71.00 (SMOW)
Ca^{2+}	3.09	Delta O^{18} (Sulfate)	6.6 ± 2 (SMOW)
K^+	0.85	Delta S^{34}	14.58 (CDT)
Mg^{2+}	0.66		
SO_4	6.8		
CO_3	4.0		
Cl^-	19.9		

Note: SMOW = standard mean ocean water
CDT = Canon Diablo troilite.

2. Testing with brine allows recrystallization of the salt, which reduces permeability with time.

3. In situ permeability is significantly lower than that measured on test samples in the laboratory.

4. Salt has very low permeability.

Data gathered to date indicate the following: (1) little or no hydraulic communication exists between the repository layer and surrounding units, and (2) the potentiometric levels of the lower hydrostratigraphic units are less than the levels of the upper hydrostratigraphic unit (WCC, 1982, ONWI-290, Vol. II, Figures 9-2, 9-5). However, vertical hydraulic gradients within the Paradox Formation are variable at the GD-1 borehole, and some test results suggest that upward flow could occur (Figure 3-60).

3.3.2.2 Ground-Water Quality

Ground-water quality is discussed in Sections 3.2.7.2 and 3.3.3. Additional data can be found in Table 3-24.

3.3.3 Ground-Water Supply

Ground-water use in the Davis Canyon candidate area is minimal. Water wells in the candidate area are shown on Figure 3-54 and described in Table 3-24. These wells are extracting from units well above the proposed repository horizon. Springs in the area also issue from rock strata above the proposed repository horizon and are the result of local recharge and subregional flow systems. See Figure 3-54 and Table 3-24 for location and description of springs.

Deep ground-water resources in the Davis Canyon candidate area are extremely limited in both quantity and quality. Based on the hydrologic parameters from tests conducted in GD-1 (See Figure 3-27 for location of borehole GD-1), small amounts of potable water (less than 2,000 parts per million total dissolved solids [TDS]) are available only from the Jurassic aquifers (restricted to areas several kilometers east of the site) and the Cedar Mesa Sandstone. Because of the very low permeability of the middle hydrostratigraphic unit, no samples from this unit have been obtained from oil and gas exploratory holes or project boreholes in the area (WCC, 1982, ONWI-290, Vol. II, pp. 9-2 to 9-6); Vol. V, Appendix A). Samples obtained from this unit elsewhere contained high TDS (greater than 10,000 parts per million). The lower hydrostratigraphic unit is capable of producing small to moderate quantities of highly saline water (greater than 10,000 parts per million TDS).

3.3.3.1 Shallow Wells and Springs

Potable ground water exists in small quantities in the Glen Canyon Group, several kilometers east of the site, and in the Cedar Mesa and Cutler sandstones in the site area. Shallow wells, springs, and seeps in the candidate area generally yield a small flow of water, usually less than a few gallons per minute. However, larger flows occur at some localities greater than 25 kilometers (16 miles) from the site. Measured flow in the area ranges approximately from 0.016 to 7.8 liters per second (0.25 to 125 gallons per minute) (Thackston et al., 1984, Table 3-3; Huntoon, 1979, p. 39). Table 3-24 summarizes available data on wells and springs in the site region; Figure 3-54 gives their locations.

3.3.3.2 Deep Wells

Substantial quantities of ground water exist in the deeper portions of the Honaker Trail Formation and Cutler Group strata, at depths between 300 and 910 meters (1,000 and 3,000 feet), and in the Leadville Limestone, 1,500 to 3,000 meters (5,000 to 10,000 feet) deep. Information concerning the potential yield of wells in these formations is limited, and the water is generally brackish to highly saline, with a TDS concentration ranging from

3,000 to over 100,000 parts per million (WCC, 1982, ONWI-290, Vol. II, Table 9-2; Vol. V, Appendix A).

3.4 ENVIRONMENTAL SETTING

This section describes the environmental setting of the Davis Canyon site with respect to land use, terrestrial and aquatic ecosystems, air quality and meteorology, noise, aesthetic resources, cultural and historic resources, and background radiation.

3.4.1 Land Use

Land ownership, land-use patterns, and land-use plans and controls within and around the Davis Canyon site are described below. Agricultural, recreational, and dedicated lands characterize the Davis Canyon site and candidate area.

Other land uses within Davis Canyon include mineral and hydrocarbon resources extraction. The majority of the mineral rights are federally owned; however, there are also privately and State-held mineral rights in this area. Uranium and vanadium are the principal mineral resources identified within the candidate area. Further information on resource production in the area is discussed in Section 3.2.8.2. Potential hydrocarbon resources consist of oil and gas in those subsurface formations that have been productive elsewhere in the Paradox Basin. No oil and gas production has occurred at the site. Further information on oil and gas exploration boreholes in the candidate area is presented in Section 3.2.8.1.

3.4.1.1 Land Ownership

The land within the Davis Canyon site is comprised of approximately 92 percent public lands managed by the Bureau of Land Management (BLM), 4 percent State lands, and 4 percent private lands belonging to the Indian Creek Cattle Company (WCC, 1982, ONWI-290, Vol. I). There are oil and gas leases, mineral leases, mining claims, and grazing rights including unrecorded stock watering rights. The site is defined as the land required for repository activities and the controlled area, a total of 2,331 hectares (5,760 acres).

The Davis Canyon site is located in northern San Juan County, which has a land area of 1,997,000 hectares (4,932,000 acres). Most of the land in San Juan County is federally controlled (Table 3-26). Consultation with the Fish and Wildlife Service (FWS) has confirmed that no existing or proposed units of the National Wildlife Refuge System occur within an 80-kilometer (50-mile) radius of the Davis Canyon site. The closest refuge is Ouray National Wildlife Refuge located approximately 248 kilometers (155 miles) north of the site (Young, 1985).

3.4.1.2 Land-Use Plans and Controls

Land use plans applicable to the area have been developed by San Juan County and the BLM. The San Juan County Master Plan for 1968 through 1985 zoned the Davis Canyon site for mining, grazing, and recreation purposes (BLM, 1982c, p. 68). The BLM Indian Creek-Dry Valley Management Plan guides BLM management of public lands in the northwest portion of San Juan County. The area is not designated for special use, and the management plan provides for multiple uses including livestock grazing, mining, oil and gas development, recreational vehicle use, and dispersed recreation (BLM, 1982c, p. 68). The BLM is currently preparing a new master plan called a Resource Management Plan (43 CFR Part 1610). The Davis Canyon site will be managed by the current land-use plan until the new plan becomes effective in 1987. The BLM, in consultation with the DOE, will determine whether a plan amendment would be necessary to address site characterization activities. The National Park Service (NPS) manages the Canyonlands National Park, which is near the Davis Canyon site, through its General Management Plan and the Statement for Management. The objectives of the Canyonlands Park programs are discussed in Section 3.4.1.3.2.

Table 3-26. Land Ownership: San Juan County

Ownership	San Juan County, hectares	
Federal	1,797,300	(90%)
State	119,800	(6%)
Private	59,900	(3%)
County	20,000	(1%)
Total	1,997,000	(100%)

Source: BGI, 1982, ONWI-144, p. 216.

3.4.1.3 Land-Use Patterns

Present uses of the site and surrounding area are divided between two principal uses, agriculture and recreation (including dedicated lands).

3.4.1.3.1 Agriculture. Areas within the vicinity of the Davis Canyon site are used for agricultural purposes, primarily cattle grazing. No alfalfa production occurs in the Davis Canyon site. There is a seeding project located just south of the site at Salt Creek Mesa. The seeding project covers 777 hectares (1,920 acres) (Sandberg, 1984). Rangeland of the Davis Canyon site is used for winter grazing for approximately 250 head of cattle. Average production is estimated to be 5.2 hectares (13 acres) of rangeland per animal-unit month (AUM) (Sandberg, 1984).

Approximately 2,397 hectares (5,920 acres) of BLM land are accessible to cattle in Davis Canyon; the estimated cattle grazing capacity is 500 AUMs, based on actual grazing use (Sandberg, 1984). The BLM has determined that the Davis Canyon site is located on the Indian Creek designated grazing allotment (Nodine, 1985). Further consultation with the BLM, including a review of repository project activities in light of the grazing plan, would be necessary to determine appropriate compliance actions to be followed by the DOE if the site is selected.

A land assessment completed by the Soil Conservation Service (SCS), in compliance with the Farmland Protection Policy Act (7 USC Sections 4201-4209), found that there is no prime farmland on the Davis Canyon site (Holt, 1985).

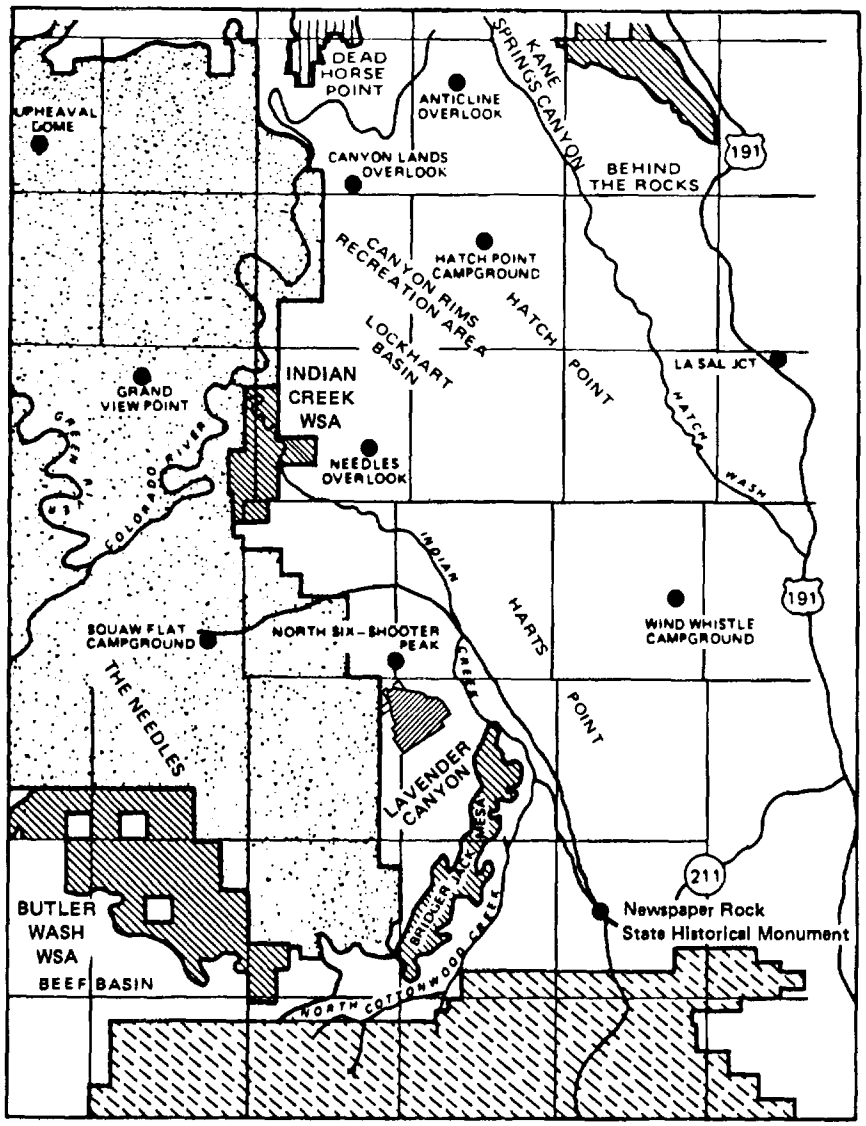
3.4.1.3.2 Recreation. Recreation is a major land use within and around the Davis Canyon site area. Important recreation resources include: Canyonlands National Park, Manti-La Sal National Forest, Newspaper Rock State Historical Monument, two areas managed by the BLM (Canyon Rims Recreation Area and Beef Basin) and three wilderness study areas (WSA) (Indian Creek WSA, Bridger Jack WSA, and the Butler Wash WSA). No designated wilderness or WSA has been identified at the site (see Section 3.4.1.3.3). Other major recreation resources include the Colorado and Green Rivers, the Glen Canyon National Recreation area, and Arches National Park. In general, this area is part of a larger group of national parks, National monuments, and State parks known as the "Golden Circle" or "Grand Circle" of parks. This group consists of the principal parks in the Colorado Plateau area of southern Utah, southwestern Colorado, and northern Arizona (Figures 3-65 and 3-66). All of these areas have a mixture of highly scenic natural areas, diversified recreational uses, cultural value, and scientific value.

The Monticello Ranger District of the Manti-La Sal National Forest, a significant recreational area, is located 14.4 kilometers (9 miles) south of the Davis Canyon site. This forest attracts visitors for sight-seeing, camping, picnicking, hunting, and fishing. In 1982, approximately 120,000 visitor days recreation use was reported for the district (Jenson, 1983).

Dead Horse Point State Park, located approximately 48 kilometers (30 miles) north of the site, offers year-round camping, picnicking, hiking and panoramic views of the Redrock canyonlands region from above the Colorado River. In 1982, there were 142,601 visitors at Dead Horse Point State Park, representing a four percent decline from 1981 (148,699 visitors). Eighty percent of these visitors were from out-of-state compared to 78 percent the previous year (Jensen, 1984).

The BLM's Canyon Rims Recreation Area located 16 to 24 kilometers (10 to 15 miles) north and east of the Davis Canyon site, includes the Wind Whistle Campground, the Hatch Point Campground and three overlooks: Canyonlands, Needles, and Anticline (BLM, 1982c, p. 62). The BLM has estimated the total use of the Canyon Rims Recreation Area for 1981 to be 47,370 persons. Estimated use of the five sites totals 15,650 as follows:

- Wind Whistle Campground - 1,600 visitors
- Hatch Point Campground - 950 visitors
- Needles Overlook - 10,000 visitors



Explanation

- REFERENCE POINTS
- CANYONLANDS NATIONAL PARK
- DEAD HORSE POINT STATE PARK
- MANTI–LA SAL NATIONAL FOREST
- WILDERNESS STUDY AREA
- GEOLOGIC REPOSITORY OPERATIONS AREA

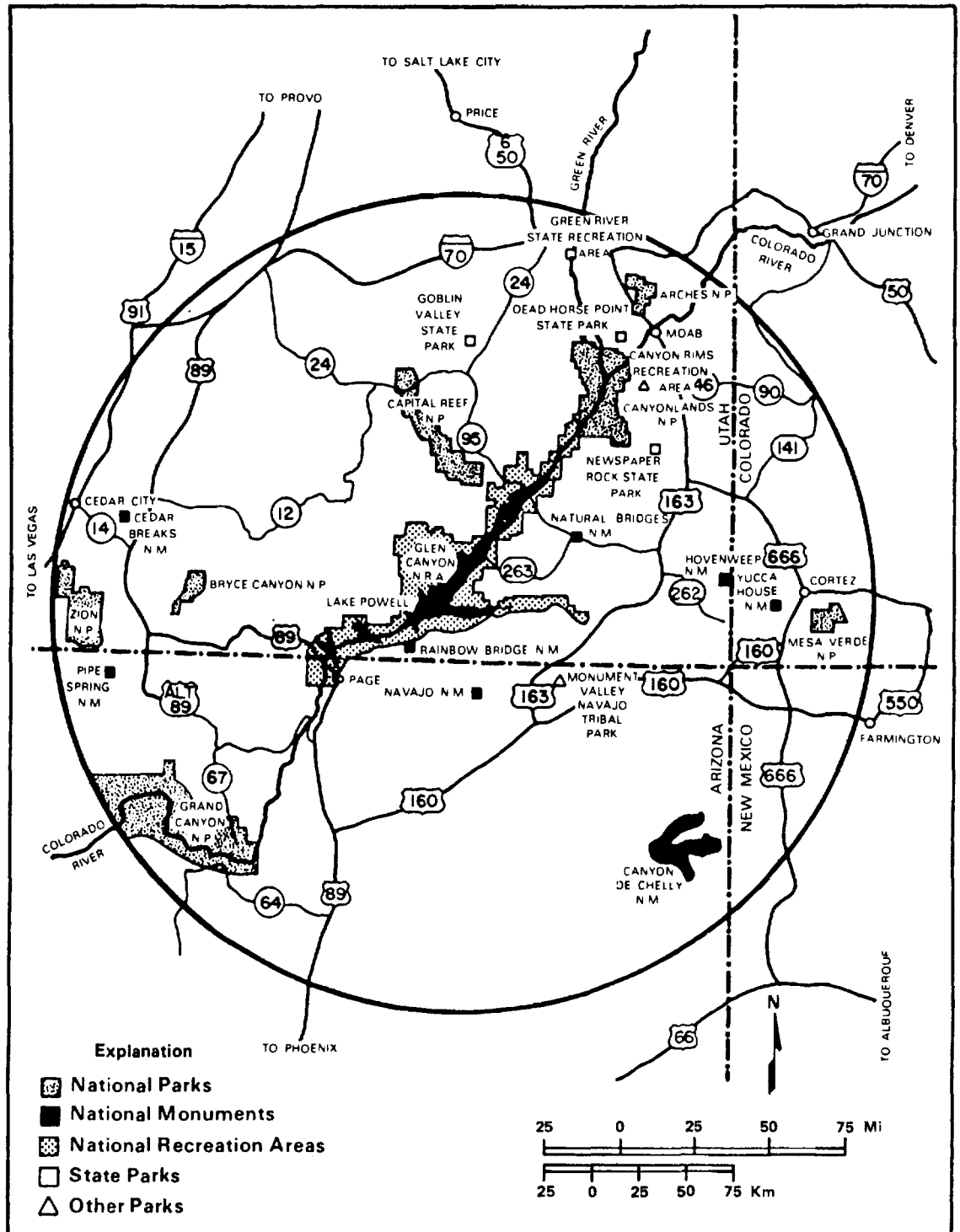
0 5 10 MI

0 5 10 15 Km

Existing Recreational Uses

Source: BGI, 1982, ONWI-144.

Figure 3-65



Golden Circle of Parks

Source: BNI, 1984b.

Figure 3-66

- Anticline Overlook - 3,000 visitors
- Canyonlands Overlook - 100 visitors.

Beef Basin is another popular recreation area managed by the BLM. It is located approximately 24 kilometers (15 miles) southwest of the Davis Canyon site. The BLM recorded 1,600 user days in Beef Basin in 1982. Actual use per year is estimated to be at least twice that amount (Van Hemert, 1984, p. B-43). There are no designated or proposed National Recreational, National Historic or National Scenic Trails within an 80-kilometer (50-mile) radius of the Davis Canyon site (Strait, 1984; NPS, 1984a; 1983a) as defined by the National Trails System (16 USC Sections 1241-1249).

Newspaper Rock State Historic Monument is located approximately 11 kilometers (7 miles) southeast of the site. It is a large cliff mural of petroglyphs, some of which were carved by Anasazi Indians (BGI, 1982, ONWI-144, p. 227). This archaeological site is listed in the National Register of Historic Places (BGI, 1982, ONWI-144, p. 227). In 1981 45,750 visitors came to the Newspaper Rock State Historic Monument (BLM, 1982a, p. 62), in 1982, visitors totaled 52,766 (Olsen, 1984), and in 1983 visitors totaled 61,045 (Jensen, 1984). Picnicking spots and eight to ten camping units are provided; in 1982 and 1983, 1,828 and 2,034 campers were recorded, respectively (Talley, 1984). The State of Utah Division of Parks and Recreation has proposed increasing the dedicated area from 4 hectares (10 acres) to 416 hectares (1,040 acres), including the canyon area of Indian Creek, downstream from the present location (Talley, 1984), and naming the area Indian Creek State Park. This proposal has been tentatively denied by the BLM (Nodine, 1985).

The Indian Creek area is used primarily for recreation. The main highway through the area (Utah 211) is traveled by more than 50,000 visitors annually to the Needles District of Canyonlands National Park (see Section 3.4.1.3.2). Several locations along Indian Creek, outside Canyonlands National Park, are used as overflow camping grounds when the park is full. A popular spot for camping, overland recreational vehicle use (ORV), hill climbing, and swimming (a prized activity in this desert region) is located at the "pot-holes" on Indian Creek, where it is crossed by the Lockhart Basin road. In 1982 there were 5,600 visitors (Van Hemert, 1984, p. B-44). Utah's designated areas of recreation, scenic beauty, and historical, scientific or archaeological interest are protected under the provisions of Utah's Parks and Recreation law and the State Land and Forestry Act.

Canyonlands National Park is located in the Colorado Plateau, a vast, high-desert upland and a geologically colorful region of panoramic vistas and striking landforms. The plateau, one of the major physiographic provinces of the United States, is pear-shaped and spreads over about 387,000 square kilometers (150,000 square miles) encompassing parts of four States: Colorado, Utah, New Mexico, and Arizona. Canyonlands occupies the most rugged and least accessible part of the Colorado Plateau, an area popularly called the "Canyon Country." Probably a quarter of this terrain is exposed rock.

Canyonlands National Park, established on September 12, 1964, with the signing of the Canyonlands National Park Act (16 USC Section 271) by President Lyndon B. Johnson, became the thirty-second national park to be added to the National Park System. The legislation establishing Canyonlands states the purpose of the park is "to preserve an area in the State of Utah possessing superlative scenic, scientific, and archaeological features for the inspiration, benefit, and use of the public...." Other important provisions are: (1) lands within the park are freed from reclamation and power withdrawals, (2) preexisting grazing leases shall continue through the term of said leases and for one period of renewal thereafter, and (3) the park is subject to other valid existing rights (e.g., mineral claims and leases). When established, Canyonlands contained 104,267 hectares (257,640 acres). On November 14, 1971, President Richard M. Nixon signed an amendment to Canyonlands National Park Act enlarging the park to 136,489 hectares (337,260 acres).

The General Management Plan for Canyonlands National Park (NPS, 1978) and the Statement for Management, Canyonlands National Park (NPS, 1981a) provide for the public use and protection of the park principally through National Park Service (NPS) programs for natural resource management, cultural resource preservation, and visitor use opportunities. This plan

includes: (1) preserving the clarity of the air in the park; (2) managing the Island-in-the-Sky District as a series of viewing platforms; (3) managing the Needles District to offer a wide range of interpretive and recreational activities focusing on hiking and four-wheel drive use; (4) preserving and protecting historic and archaeological resources, including the Salt Creek area; and (5) promoting efficient access to the park and facilitating circulation within the park via two and four-wheel drive roads, hiking trails, and river use (NPS, 1978; 1981a). The NPS has recommended 116,162 hectares (287,133 acres) of the Canyonlands National Park as wilderness areas, as defined under the Wilderness Act (16 USC Sections 1131-1136). Proposed wilderness areas are managed in a manner that will not impair the wilderness suitability.

Historically, public use of about 7,689 hectares (19,000 acres) in the park has been partially restricted due to experimental missile and space activities conducted by the U.S. Army at the Green River Complex. The complex where the firings originate is about 56 kilometers (35 miles) north of Canyonlands National Park near Green River, Utah. The Army has held a special use permit that authorizes the firing of projectiles over the park, and provides for the recovery of any debris that fall within the missile-recovery cooperative zone (the eastern edge of the Needles District). Various degrees of missile activities have occurred over portions of the eastern part of the park since 1963 (NPS, 1974; 1977). The Statement for Management for Canyonlands National Park indicates that the U.S. Army plans to reinstate missile test firing from the Green River, Utah site (NPS, 1981a). Consultation with the NPS indicates that this permit expired in 1978 and there is no current plan to reinstate the permit (Parry, 1985a).

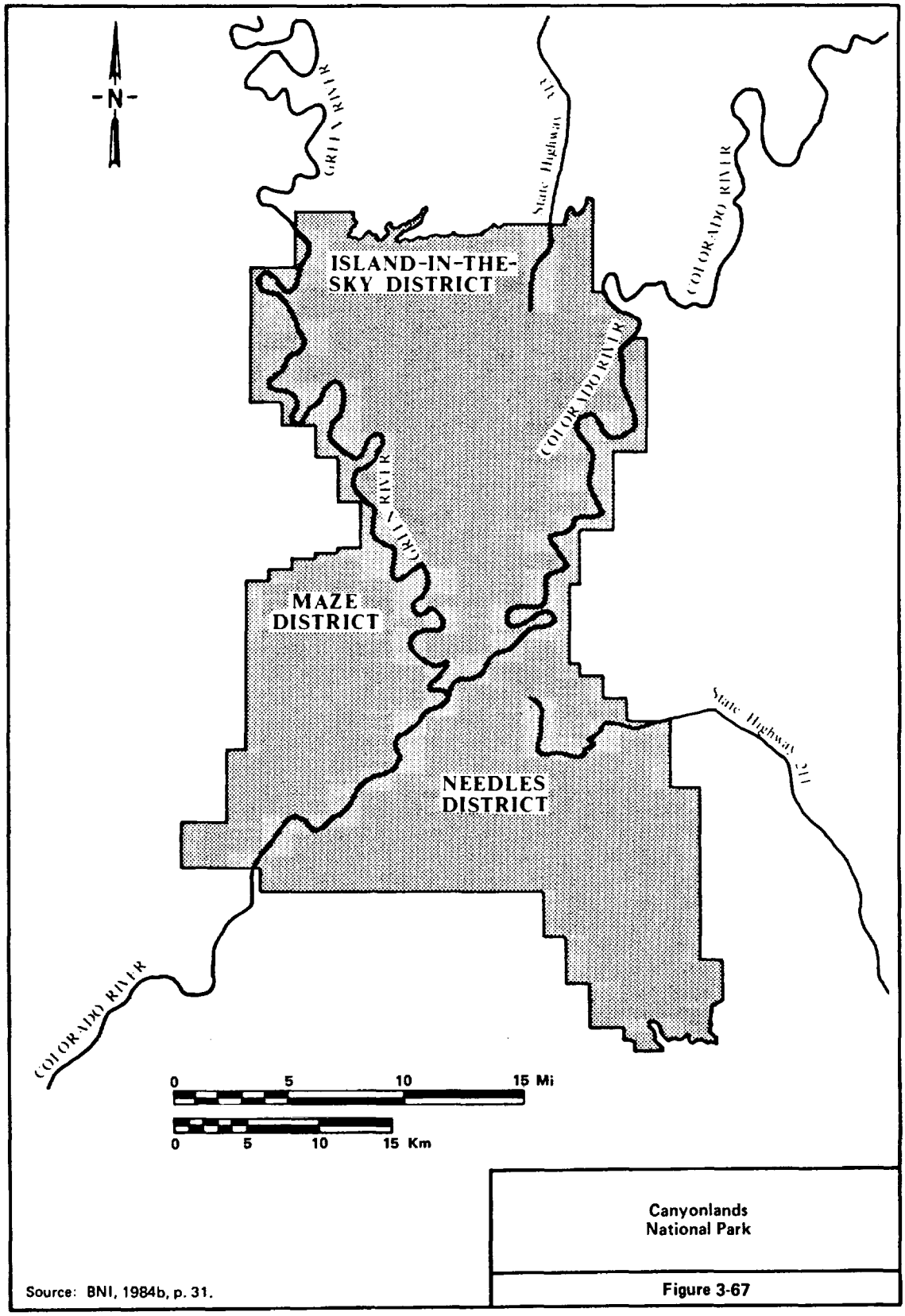
Canyonlands National Park presently surrounds the confluence of the Green and Colorado Rivers. The park is comprised of three districts: (1) the Needles District, (2) the Maze District, and (3) the Island-in-the-Sky District (Figure 3-67). Access to the park is shown in Figure 3-66. The principal access routes to the Canyonlands National Park in the vicinity of the site are Utah State Highway 211 (Utah 211) and an unimproved four-wheel drive route. Further information on transportation access routes is provided in Section 3.5.1.

The northern district is an elevated plateau known as the Island-in-the-Sky District. This region is accessible via a paved two-lane road that branches off State Route 313 leading from U.S. Highway 191 (U.S. 191) to Dead Horse Point State Park. The road ends at Grand View Point Overlook, which offers a panoramic view of the Green and Colorado River basins. This region of the park also contains the Green River Overlook, Upheaval Dome, and the White Rim Jeep Trail (DOE, 1984).

The southeastern district is the Needles District. This district is characterized by colorful stone spires and numerous arches. The Needles District is accessible by Utah 211, which branches off U.S. 191 about 24 kilometers (15 miles) north of Monticello, Utah. The National Park Service (NPS) extension of Utah 211 leads past the mouth of Davis Canyon into the park from the east. The road continues on to the Squaw Flat Campground and Big Spring Canyon Overlook. The Colorado River and Confluence Overlooks and Peekaboo Spring Campground are accessible by dirt roads (DOE, 1984).

To the west of the rivers is the Maze District, made up of twisting, branching gorges cut into layered sandstone strata. This district takes its name from the intricate, contorted canyon known as the Maze, and contains such features as Land-of-Standing-Rocks and Horseshoe Canyon. Horseshoe Canyon is a detached parcel which lies about 13 kilometers (8 miles) west of the northwest corner of the main area of the park. The walls of Horseshoe Canyon are adorned with pictographs. The Maze District, because of its rugged terrain, is accessible only by jeep trail (DOE, 1984).

Open year round, Canyonlands National Park is a wildlife sanctuary and a popular area for camping, hiking, off-road vehicle driving, wilderness backpacking, and river-rafting. Use of the park has increased since its establishment in 1964. In 1966, the total visits to the park were 20,234 while, in 1971, total visits jumped to 57,839, an increase of 186 percent in 5 years. The number of park visitors for 1983 totaled 101,779, an increase of 403 percent over the 17-year period from 1966 to 1983 (DOE, 1984).



Canyonlands National Park

Source: BNI, 1984b, p. 31.

Figure 3-67

The Needles District, on the western edge of the Davis Canyon site, had 51,100 visitors during 1983. The Needles District is near (within 0.3 kilometer [0.2 mile]) the Davis Canyon site. More than 90 percent of the visitation occurs within the Needles and Island-in-the-Sky Districts (DOE, 1984). April, May, and June had the highest number of visits that year (Table 3-27). The Needles District of Canyonlands National Park is accessible via Utah 211 and a NPS extension of Utah 211. Of the total visitors to the Needles District, 65 to 75 percent entered the back country. The number of reported visitors to Davis Canyon in 1983 was 829. These are regarded as conservative figures. Normally, jeep trail registers and back country permits are used to determine the number of visitors to Davis Canyon. During the latter half of 1983, however, several floods washed out the register boxes, and data are not available from that source for July through December. Because of these events and informal observations of nonregistrations, the NPS estimates that actual visitation was at least 50 percent higher (NPS, 1984b). Approximately 50 percent of all the visitors to the District use Horse Canyon or Salt Creek, located near the southeast boundary of the park. This area is also used extensively for outdoor education schools (Canyonlands National Park, General Management Plan [NPS, 1978]). Additional data and trends regarding park visitation to Canyonlands National Park are presented in Section 3.6.2.4, Tourism.

The Old Spanish trail, which runs through the Canyonlands National Park (Lohman, 1974) is not a designated or proposed National Scenic, National Recreational or National Historic Trail (Strait, 1984; NPS, 1984a; 1983a) as defined by the National Trails System (16 USC Sections 1241-1249).

3.4.1.3.3 Existing and Proposed Wilderness Areas and Wilderness Study Areas. The BLM, under the provisions of the Federal Land Policy and Management Act of 1976 (43 USC Sections 1701-1782) may designate wilderness study areas (WSA) for recommendation for inclusion in the wilderness preservation system. Although being identified as a WSA does not mean that an area will necessarily be designated a wilderness area in the National Wilderness Preservation System, the BLM interim management policy requires that the BLM manage the land so as not to impair wilderness suitability.

No designated wilderness areas lie within Davis Canyon. Three WSAs have been identified by the BLM near Davis Canyon: Indian Creek (formerly Lockhart Basin), Butler Wash, and Bridger Jack Mesa. Indian Creek WSA (UT-060-164)* is contiguous to Canyonlands National Park and the Maze proposed wilderness. It continues the Maze wilderness terrain in "finely dissected gullies and canyons cut into sparsely vegetated red rock" (BGI, 1982, ONWI-144, p. 228). The Indian Creek WSA covers approximately 2,950 hectares (6,870 acres). Although no official use figures exist for Indian Creek WSA, the BLM estimated less than 100 users per year (Van Hemert, 1984).

Private recreational activity in the Butler Wash WSA (8,915 hectare [22,030 acres]) has not been monitored by the BLM, and no accurate information is available as to type and numbers of recreational users. However, according to the Needles assistant district ranger (Canyonlands National Park), 344 user days were recorded in the unit from September 1981 through August 1982. This figure represents backpackers entering the WSA through Canyonlands National Park with permits issued by the NPS. Commercial use of the area has amounted to approximately 100 user-days in 1982, and 280 user-days in 1981 and 1980 (Van Hemert, 1984, p. B-47).

The Bridger Jack Mesa WSA (UT-060-167) is approximately 4.8 kilometers (3 miles) east of the Davis Canyon site. Bridger Jack Mesa WSA includes 2,145 hectares (5,290 acres) of the top of Bridger Jack Mesa. It has maintained its natural character and offers solitude and primitive recreation. Access to Bridger Jack Mesa is by two trails constructed in the 1920s; their current deteriorated condition limits their use to foot travel only (Van Hemert, 1984, p. B-48).

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*BLM WSA identification number.

Table 3-27. Visits to Needles District of Canyonlands National Park, 1983 (Seasonal Data)

January	739
February	987
March	3,613
April	6,173
May	12,149
June	7,354
July	5,294
August	4,628
September	4,406
October	3,575
November	1,464
December	747
Total	51,129

The Dark Canyon Wilderness, located approximately 40 kilometers (25 air miles) southwest of Davis Canyon in the Manti-La Sal National Forest, has been designated a wilderness area administered by the U.S. Forest Service (Griswold, 1985).

In Canyonlands National Park, 116,289 hectares (287,133 acres), or approximately 77 percent of the park's acreage, are recommended as wilderness (Parry, 1985b). These designated areas and associated acreage are shown below:

Area	Acreage
Needles	61,204
The Maze	105,473
White Rim	37,175
Little Bridge Canyon	5,082
Stillwater Canyon	6,700
Upheaval Dome	62,944
Horseshoe Canyon	3,049
Shafer Canyon	2,043
Elephant Canyon	3,463
	287,133

To date, Congress has not taken action on this NPS proposal.

3.4.2 Terrestrial and Aquatic Ecosystems

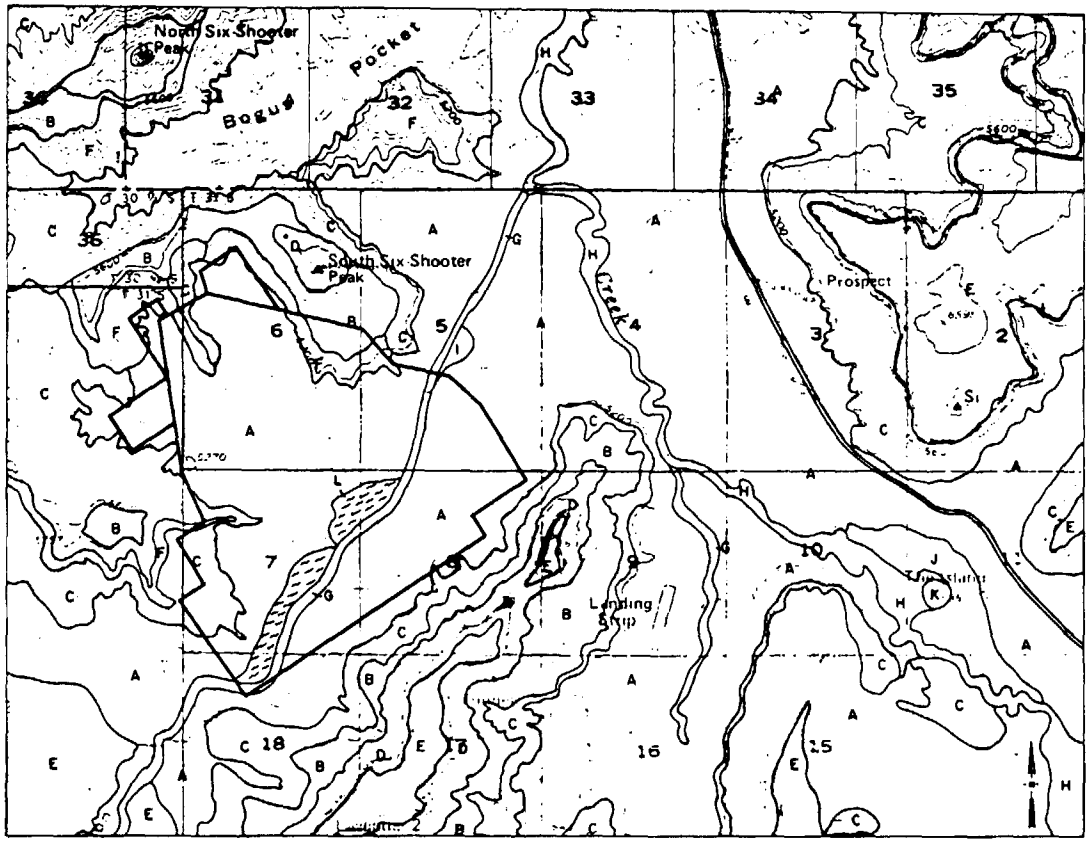
The Davis Canyon site lies within the Inner Canyonlands and Hatch Syncline physiographic subprovinces of the Colorado Plateau physiographic province, and is characterized by canyons, mesas, and buttes resulting from an incised drainage system. The distribution of plant communities within the site varies with elevation, soil type, and available moisture. Significant overgrazing and other human activity have altered the natural vegetation of the Davis Canyon site.

Descriptions of terrestrial and aquatic fauna provided below are based on existing published and unpublished data for the site and surrounding region. Preliminary onsite investigations indicate a high similarity between onsite habitats and habitats in the surrounding region (BNI, 1985a).

3.4.2.1 Terrestrial Ecosystems

The Davis Canyon site has been classified as part of the Intermountain Sagebrush Floral Province, wherein the Great Basin desert shrub and pinyon pine-juniper woodlands tend to prevail (Bailey, 1978). Much of the site is native pasture supporting open range livestock operations. The local vegetation profile in the vicinity of the site is influenced primarily by water availability, elevation, and soil type. The generally low diversity and productivity of the natural vegetation results in a corresponding low abundance and diversity in wildlife populations.

3.4.2.1.1 Flora. Site-specific field studies were conducted in 1983 to characterize the vegetation of the Davis Canyon site (BGI, 1983, ONWI-469). The reference Davis Canyon geologic repository operations area and vicinity are sparsely vegetated by 12 vegetation communities (Figure 3-68) from both the Great Basin desert shrub and pinyon pine-juniper woodland major vegetation types. No unique ecosystems have been identified at the Davis Canyon site. The Davis Canyon valley floor consists of various types of alluvial material supporting a plant community described as galleta-shadscale type, with *Hilaria jamesii* (galleta) and *Atriplex confertifolia* (shadscale) as the visual dominants. Various other species are also common (Table 3-28). The 162-hectare (400-acre) surface facility site in Davis Canyon is comprised approximately of 95 percent galleta-shadscale vegetation and 5 percent juniper-shadscale-ephedra and shadscale-ephedra vegetation types. Table 3-29 is a list of flora within Canyonlands National Park (Shaver, 1985). Because of the site's proximity to the park, many of the species on the list may also be present on the site.



Vegetation Communities in Davis Canyon

Figure 3-68

Table 3-28. Galleta-Shadscale Community

Scientific Name	Common Name
Chrysothamnus viscidiflorus	stickyleaf rabbitbrush
Xanthocephalum sarothrae	matchweed
Atriplex confertifolia	shadscale
Eriogonum inflatum	desert trumpet
Cryptantha flava	yellow cryptantha
Bromus tectorum	cheatgrass
Abronia fragrans	(none)
Oenothera caespitosa	evening primrose
Sclerocactus terrae-canyonae	canyon fishhook cactus
Grindelia asphanactis	gumweed
Cryptantha tenuis	slender cryptantha
Lupinus pusillus	low lupine
Swertia albomarginata	(none)
Muhlenbergia pungens	sandhill muhly
Euphorbia fendleri	Fendler euphorbia
Hymenopappus filifolius	(none)
Leucocrinum albomarginatum	(none)
Townsendia annua	(none)
Cryptantha (annual)	(none)
Malacothrix sp.	(none)
Suaeda torreyana	Torrey seepweed
Hilaria jamesii	galleta
Chenactis stevioides	(none)
Sarcobatus vermiculatus	greaseweed
Cymopterus purpurascens	(none)
Lepidium montanum	mountain pepperweed
Sporobolus airoides	alkali saccaton
Sporobolus cryptandrus	sand dropseed
Sphaeralcea parvifolia	globe mallow
Asclepias macrosperma	milkweed
Stanleya pinnata	prince plume
Xylorrhiza glabriuscula	woody aster
Opuntia polyacantha	plains pricklypear
Asclepias cryptocerus	hiddenhorn milkweed

Source: Welsh et al., 1981.

Table 3-29. Flora List for Canyonlands National Park

Family	Genus	Species
Aceraceae	Acer	glabrum
		negundo
Amaranthaceae	Amaranthus	blitoides
Anacardiaceae	Rhus	trilobata
	Toxicodendron	radicans
Apocynaceae	Amsonia	eastwoodiana
	Apocynum	cannabinum
Asclepiadaceae	Asclepias	fascicularis
		involucrata
		labriformis
		macrosperma
		speciosa
		tuberosa
Berberidaceae	Berberis	fendleri
		fremontii
Betulaceae	Betula	occidentalis
	Ostrya	knowltonii
Boraginaceae	Coldenia	hispidissima
	Cryptantha	confertiflora
		crassisepala
		flava
	Heliotropium	convolvulaceum
	Lappula	redowskii
	Lithospermum	incisum
Cactaceae	Echinocereus	triglochidiatus
	Sclerocactus	whipplei
Capparidaceae	Cleome	lutea
		serrulata
Caprifoliaceae	Symphoricarpos	longiflorus
Caryophyllaceae	Arenaria	fendleri
	Silene	antirrhina
Chenopodiaceae	Atriplex	canescens
		confertifolia
		cuneata
		garrettii
	Bassia	hyssopifolia
	Chenopodium	album
	Corisphermum	hyssopifolium
	Eurotia	lanata
	Grayia	brandegei
	Kochia	americana
	Salsola	kali
	Sarcobatus	vermiculatus
	Suaeda	torreyana
Compositae	Acroptilon	repens
	Ambrosia	acanthicarpa
	Artemisia	bigelovii
		dracunculoides
		filifolia
		frigida
		ludoviciana
		spinescens
		tridentata

Source: Shaver, 1985.

A dry wash vegetation type occurs along the full length of Davis Canyon. It is predominantly a rabbitbrush vegetative type consisting of rubber rabbitbrush, stickyleaf rabbitbrush, fourwing saltbush, sand sagebrush, matchweed, and alkali saccaton. Salt cedar and sagewort occur sporadically in this community type, and greasewood is often found at the wash margin. Eolian sand accumulations in the valley bottom toward the southern end of Davis Canyon have produced a series of small semistabilized dune community types consisting of greasewood, fourwing saltbush, Russian thistle, and cheatgrass.

The Indian Creek drainage, which passes through Dugout Ranch and traverses the mouth of Davis Canyon, is intermittent below Donally Canyon (4 kilometers [2.5 miles] upstream from Dugout Ranch) and is covered with riparian species such as rush, horsetail, and salt grass, and other species such as copperweed, saltgrass, greasewood, and occasional stands of salt cedar and Fremont poplar.

A greasewood community generally exists wherever silty deposits from the Moenkopi and Chinle Formations crop out. A large patch of this type occurs on the east side of the Davis Canyon wash directly across from South Six-Shooter Peak.

Along north-facing slopes of the adjacent mesas, the Moenkopi Formation supports a scattered juniper-shadscale-ephedra community. Other frequently occurring species are narrowleaf yucca, stickyleaf rabbitbrush, Utah serviceberry, Torrey ephedra, and spineless hopsage. The south-facing slopes of the exposed Moenkopi Formation support the same composition of species, but without juniper.

The Moss Back platform, which sets atop the Moenkopi Formation and extends around South Six-Shooter Peak and Lavender Mesa, is basically a juniper-blackbrush community. Other species important to the community are green ephedra, Torrey ephedra, cliffrose, narrowleaf yucca, Bigelow sagebrush, and Utah serviceberry.

The steep and eroded face of the Chinle Formation supports a galleta-shadscale plant community on South and North Six-Shooter Peaks. Widely scattered occurrences of spineless hopsage and shadscale are the only vegetation on these steep slopes between the Wingate vertical cliffs and the Moss Back platform. On top of Lavender Mesa, the rim rock exposures of the Kayenta Formation support a pinyon pine-juniper plant community.

3.4.2.1.2 Fauna. Site-specific data on the presence and distribution of animal species are not available for the Davis Canyon site. However, data are available on species commonly associated with the identified vegetative communities, and area-wide animal sightings have been reported by the BLM (1982c, pp. 56-61).

The most abundant mammals within the desert shrub community are various species of rats and mice. Larger mammals include the desert kit fox, coyote, black-tailed jackrabbit, and spotted skunk. Birds within the community vary according to the different plant associations. Representative species include loggerhead shrike, horned lark, rock wren, and various owls, including the Mexican spotted owl in the Big Pocket area, several miles to the southwest (BNI, 1985a). Raptors are also abundant (Garrison et al., 1977).

The largest mammal inhabiting the pinyon pine-juniper woodlands is the mule deer, and smaller mammals are the wood rat, pinyon mouse, least chipmunk, jackrabbit, cottontail, rock squirrel, porcupine, and fox. Representative avifauna include plain titmouse, pinyon jay, red-tailed hawk, golden eagle, common flicker, various nuthatches, and rock wren. Seasonal residents may include the chipping sparrow, various warblers, hairy woodpecker, and mountain bluebird (Garrison et al., 1977).

Area-wide, the most common species include various lizards and snakes, the mourning dove, horned lark, common raven, pinyon jay, various bat species, desert cottontail, bobcat, and gray fox (BGI, 1982, ONWI-144, pp. 96-115). Larger mammals such as the coyote, antelope, and mule deer are also present in low numbers. Chukars, a gamebird introduced from Asia, can be

found along rocky slopes. Raptors, including golden eagles, red-tailed hawks, prairie falcons, peregrine falcons, and great horned owls occur and nest in the vicinity of the site. There are no known nesting or roosting areas for falcons or bald eagles within or near the geologic repository operations area, although peregrine falcons have been sighted along the upper reaches of Davis Canyon (BNI, 1985a). Golden eagles have nested in the vicinity of Davis Canyon. Figures 3-69 and 3-70 show the major areas used by several important species of birds, fish, and small mammals (BGI, 1983, ONWI-470, p. 4-6).

3.4.2.2 Aquatic Ecosystems

There are no aquatic communities or wetlands on the site. Desert washes and the lower reaches of Indian Creek drain the site toward the Colorado River. Water flow in the lower reaches of Indian Creek, the Davis Canyon wash, and the wash nearest the geologic repository operations area is limited to brief periods of heavy rainfall. Riparian vegetation occurs along Indian Creek and along the Colorado River. Above elevations of 1,524 meters (5,000 feet) mean sea level (MSL), cold water stream habitats may be found along Indian Creek and some of its major tributaries. Only the upper 19-kilometer (12-mile) section of Indian Creek has been classified as having Class 2 (high priority) fishery resources (FWS, 1978). Small cutthroat trout occur in this section of the creek from Kelly Ranch to the Manti-La Sal National Forest boundary in the Abajo Mountains (BLM, 1982a, p. 61). Cottonwood Creek, most of the intermittent drainages into Indian Creek, and the intermittent portions of Indian Creek (below Donally Canyon) do not support fish populations.

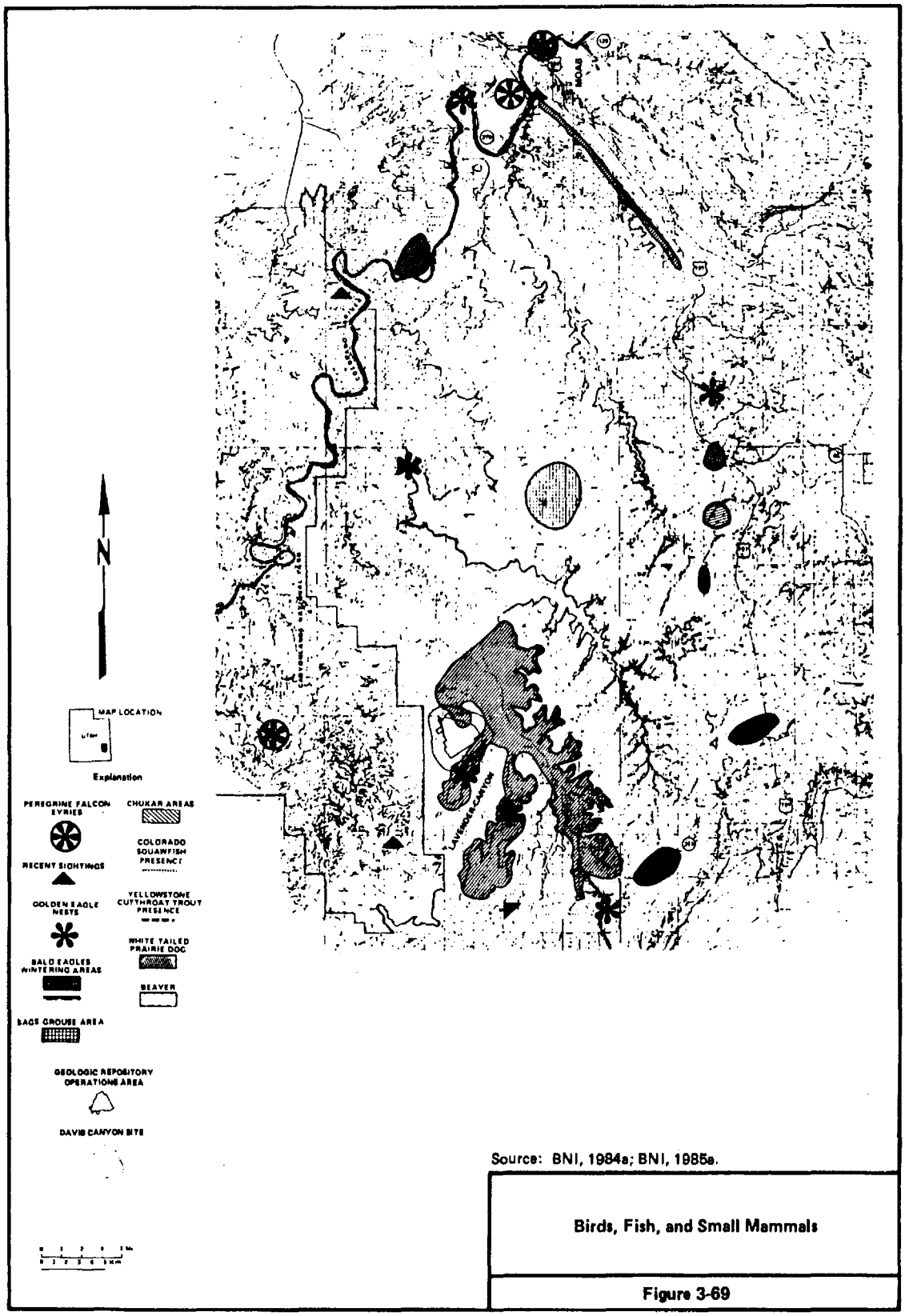
3.4.2.3 Threatened and Endangered, and Other Special Status Species

Based on habitat description, literature review, and consultation with the Fish and Wildlife Service, several protected plant and wildlife species were identified as potential inhabitants of Davis Canyon (Tables 3-30 and 3-31) (BGI, 1983, ONWI-470; FWS, 1983; FWS, 1984). Based on the results of literature review and agency consultation, field surveys were performed to identify threatened and endangered species present in the 3,626-hectare (14-square-mile) Gibson Dome Study Area (BGI, 1983, ONWI-470). These surveys, which occurred during the late summer and fall of 1981 and spring of 1982, were performed by systematically walking over and sampling the designated study area. Recognized local experts were contracted for this work. No threatened or endangered species were found during these surveys in Davis Canyon or anywhere in the larger Gibson Dome study area (BGI, 1983, ONWI-470).

Two federally listed threatened or endangered plant species are known to occur in San Juan County (Echinocereus triclochidiatus var. inermis and Sclerocactus glaucus), and 20 other rare plants have been found in San Juan and/or Grand Counties (Table 3-30). The Monument Valley milkvetch (Astragalus monumentalis), a sensitive species recommended by the Utah Native Plant Society for threatened status, is the only one of these 23 plants found near the site. It was identified in Beef Basin during field surveys in May, 1982 (BGI, 1983, ONWI-470, pp. 3-4). However, it grows on ridges and is not on or adjacent to the site.

The Davis Canyon candidate area environs are favorable for six animal species listed as federally endangered or under review. One active peregrine falcon eyrie has been observed in Canyonlands National Park, another is located about 3.2 kilometers (2 miles) west of Moab (BNI, 1985a), and one historic eyrie is also located near Moab (Figure 3-69). A pair of peregrines has been sighted along North Cottonwood Creek (BNI, 1985a). Bald eagles (in winter months) roost along the Colorado River. Bald eagles are occasionally seen on Harts Draw, Hatch Point, east of Six-Shooter Peaks, between the heads of Rustler and Horse Thief Canyons (BLM, 1982a, p. 61), and along the Colorado River. No evidence of black-footed ferret activity has been found; however, scattered burrows of their prey species (prairie dog) occur in the area (Figure 3-69).

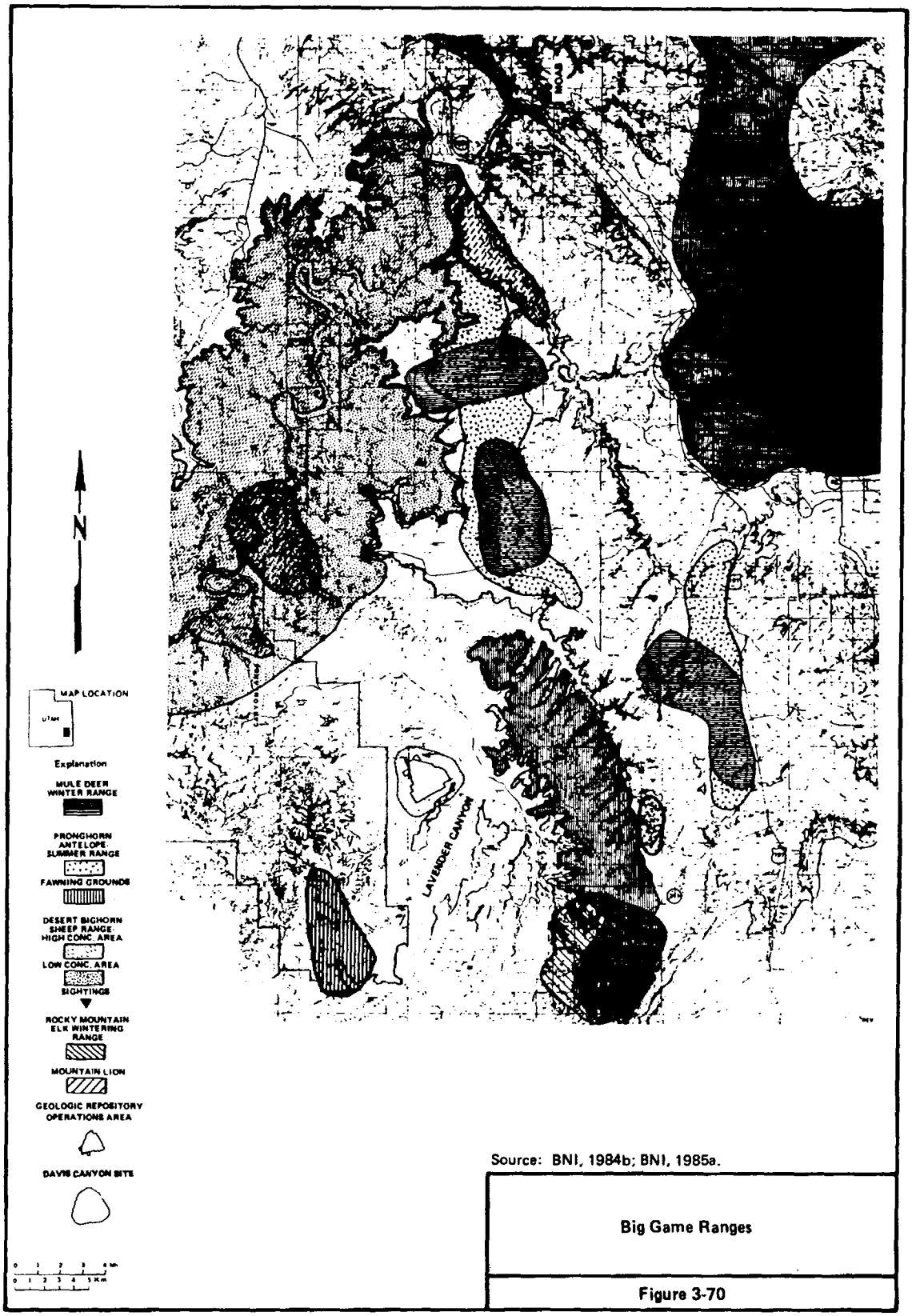
Tnree endangered fish (the Colorado squawfish, humpback chub, and bonytail chub) may occur roughly 40 kilometers (25 miles) downstream of the Davis Canyon geologic repository operations area in the Colorado River (FWS, 1982, p. 5-37) (Table 3-30). However, no bonytail chub have been recovered in the Colorado River in recent times, and the FWS (1982) considered the species to be on the edge of extinction. The BLM has indicated that the razorback sucker,



Source: BNI, 1984a; BNI, 1985a.

Birds, Fish, and Small Mammals

Figure 3-69



Source: BNI, 1984b; BNI, 1985a.

Big Game Ranges

Figure 3-70

Table 3-30. Rare Plants Known to Occur in Grand and San Juan Counties, Utah and Their Federal Status

Species	Designation[a]
GRAND COUNTY	
Asclepias cutleri	2
Astragalus iselyi	3C
Astragalus sabulosus	2
Cryptantha elata	3C
Cycladenia humilis var. jonesii	PE
Erigeron mancus	2
Gaillardia flava	2
Lomatium latilobum	2
Lygodesmia entrada	2
SAN JUAN COUNTY	
Asclepias cutleri	2
Astragalus cottamii	3C
Astragalus cronquistii	2
Astragalus iselyi	3C
Astragalus monumentalis	3C
Dalea flavescens var. epica	2
Echinocereus triglochidiatus var. inermis	E
Erigeron kachinensis	2
Erigeron mancus	2
Eriogonum clavellatum	3C
Eriogonum humivagans	1
Lomatium latilobum	2
Phacelia howelliana	3C
Phacelia indecora	3C
Sclerocactus glaucus	T
Senecio dimorphophyllis var. intermedius	2
Yucca toftiae	3

(a) Designations:
T - Officially listed as threatened by the U.S. Fish and Wildlife Service.
E - Officially listed as endangered by the U.S. Fish and Wildlife Service.
PE - Proposed endangered by the U.S. Fish and Wildlife Service.
1 - Category 1 status. These are plants that are under review for official listing as threatened or endangered and that have substantial information on their biological vulnerability.
2 - Category 2 status. These are plants that are under review for official listing as threatened or endangered but lack substantial information on their biological vulnerability.
3 - Category 3 status. These are plants that are no longer being considered for listing as threatened or endangered, but may later be considered for listing based on the results of further investigation.

Sources: EPSI, 1983, pp. 3, 5, 8; Welsh, 1984; Chatterly, 1984; Federal Register, 1983; Welsh and Chatterley, 1985; BNI, 1985a; England, 1985.

Table 3-31. Endangered Animal Species, for Which There is Favorable Habitat, Near the Davis Canyon Site

Common Name	Scientific Name
Bald eagle	*Haliaeetus leucocephalus*
Peregrine falcon	*Falco peregrinus*
Black-footed ferret	*Mustela nigripes*
Colorado squawfish	*Ptychocheilus lucius*
Humpback chub	*Gila cypha*
Bonytail chub	*Gila elegans*

Source: Bolwahnn, 1984; Benton, 1985.

which is still protected by the States of Utah and Colorado, may also occur in the Colorado River (BLM, 1982a, p. 61). The endangered Colorado squawfish is known to occur in the neighboring section of the Colorado River. Although adult squawfish are not known to frequent this area, young-of-the-year and juveniles do occur near there and have been collected at the mouth of Indian Creek (BNI, 1985a). Indian Creek does not meet minimum requirements to support these endangered fish species, and actual fish collections have not revealed the presence of any endangered species (BGI, 1983, ONWI-470, pp. 4-1 to 4-13).

3.4.2.4 Recreationally and Commercially Important Species

The Davis Canyon site is not known to harbor significant populations of recreationally and commercially important species. The BLM and the Utah Division of Wildlife Resources estimate that 10 to 15 mule deer overwinter in Davis Canyon, including one or two permanent residents; thus, the geologic repository operations area is not considered to be a crucial winter mule deer range (Sandberg and McClure, 1983). Mountain lions also use nearby areas. Figure 3-70 shows nearby big game ranges, including the crucial wintering areas for mule deer (BGI, 1983, ONWI-470, Figure 4-1; BNI, 1985a). Information obtained from the BLM and the Forest Service on the presence of wild, free-roaming horses and burros and specifically designated range on site and in the vicinity states that wild horses and burros do not occur at the proposed site or site vicinity.

Areas being considered for potential transportation and utility corridors (see Section 5.3.2) contain wildlife populations of commercially or recreationally valuable species (e.g., desert bighorn sheep, mule deer and pronghorn antelope; Figure 3-70) as well as those federally protected species. Drainages near the Colorado River provide the most sensitive biological resource in the area; its drainages provide valuable riparian habitat. Cottonwood trees provide hunting perches and roosts for the endangered bald eagle. Cliff habitats for the desert bighorn sheep and other species may also be found near the Colorado River. Hatch Point is the site of two pronghorn antelope fawning grounds, and includes sage grouse habitat, which is relatively scarce in the area. Harts Point provides winter forage to a moderately sized mule deer herd. Kane Springs Canyon also provides riparian and bighorn sheep habitat. Several areas to the south of Harts Draw are considered valuable as antelope range (BNI, 1985a). Canyonlands National Park is considering a desert bighorn sheep reintroduction into the southeast corner of the park adjacent to the Davis Canyon site. Further study by the National Park Service will be required before a decision is made (NPS, 1984b).

3.4.3 Air Quality and Climatology

The air quality of the Davis Canyon site is described in terms of attainment status as determined by the U.S. Environmental Protection Agency (EPA) relative to Federal and State air quality standards, and in terms of available ambient air quality monitoring data. These data were collected in some remote areas of southern Utah, and are considered to be representative of ambient conditions in remote areas like the Davis Canyon site.

Climatological data sources in southeastern Utah are sparse. The nearest long-term (i.e., 30-year) National Oceanic and Atmospheric Administration (NOAA) climatological stations are at Moab, 52 kilometers (33 miles) north of the site in Grand County, and at Monticello, approximately 39 kilometers (24 miles) southeast of the site in San Juan County. The nearest first-order National Weather Service (NWS) station is at Grand Junction, Colorado, approximately 145 kilometers (90 miles) northeast of the site. Temperature and precipitation have been reported since 1965 from the Needles District in Canyonlands National Park, approximately 11 kilometers (7 miles) northwest of the site; however, some years have insufficient temperature data to produce a reliable annual average, and some reported precipitation data have been estimated.

3.4.3.1 Existing Air Quality

The Davis Canyon site is located in Air Quality Control Region 14 and is designated "attainment" or is unclassified by EPA for total suspended particulates (TSP), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (40 CFR 81.345). These are the

pollutants emitted during site characterization and during repository construction and operation activities. Table 3-32 lists the National Ambient Air Quality Standards (NAAQS) for these criteria air pollutants which establish limits for the protection of public health (Primary Standard) and welfare (Secondary Standard) (40 CFR Part 50). These same limits apply within the State of Utah.

The EPA's Prevention of Significant Deterioration (PSD) program under the Clean Air Act (42 USC Sections 7470-7479) applies to major sources located in areas determined to be in attainment with the NAAQS. The project is not considered to be a major source during site characterization or during repository construction and operation activities (Sections 4.2.1.3.3 and 5.2.5.3). Therefore, for the purposes of this EA, the DOE concludes that the project is not subject to Federal PSD requirements. However, Canyonlands National Park is a Mandatory Class I PSD area and is within 1.6 kilometers (1.0 mile) of the site. Class I areas have very strict requirements regarding PSD increment consumption and air quality-related values (AQRVs). In Utah, these areas are protected from emissions from both major and minor sources. The applicability of PSD increment consumption to this project and impacts to AQRVs are addressed in Sections 4.2.1.3.3 and 5.2.5.3.

The Utah State Department of Health (1982) has monitored air quality in some remote areas in southern Utah. Data obtained at the Bullfrog station in the Glen Canyon National Recreation Area (approximately 87 kilometers [54 miles] southwest of the site) from 1971 to 1977 indicate ambient total suspended particulate (TSP) concentrations ranging from 11 to 21 micrograms per cubic meter (annual geometric mean); sulfur dioxide concentrations are "nil." No data are available for nitrogen dioxide or carbon monoxide at this station. However, at other remote Utah stations, such as Wahweap near Lake Powell and Huntington Canyon, approximately 40 kilometers (25 miles) south of Price, annual arithmetic mean concentrations of nitrogen dioxide vary from "nil" to approximately 10 micrograms per cubic meter. Though not site-specific, these data constitute the best available. Therefore, for the purpose of the air-quality analysis, conservative background values of 21 micrograms per cubic meter for TSP, and 10 micrograms per cubic meter for NO_x, are assumed for the Davis Canyon site.

Background visual range for the Davis Canyon site is estimated to average 170 kilometers (106 miles) (Latimer and Ireson, 1980, p. 59). The National Park Service (NPS) has measured visibility from Canyonlands National Park (Island-in-the-Sky District) since the fall of 1978. Generally, the average visibility is greater in winter than in summer. Results from the NPS monitoring program are presented in Figure 3-71. Because of its greater elevation, visibility from Island-in-the-Sky is probably better than at the Davis Canyon site.

3.4.3.2 Climate

The climate of southeastern Utah is predominantly cool and semiarid. However, southeastern Utah is known for high summer temperatures. The prevailing westerly air currents lose much of their moisture as they cross the Pacific Coast mountain ranges and are comparatively dry by the time they reach Utah.

Annual mean temperatures (30-year basis) are 13.3 C (55.9 F) at Moab and 8.2 C (46.8 F) at Monticello (U.S. Weather Bureau, 1965). At the Needles station, due east of the Squaw Flat Campground (Figure 3-65), the annual mean temperature is 11.6 C (52.8 F), based on data for 12 years out of the 15 years between 1966 and 1980 (NOAA, 1966-1981, Vols. 67-82). These values reflect the temperature decrease with station elevation expected from 1,209 meters (3,965 feet) mean sea level (MSL) at Moab, 2,079 meters (6,820 feet) MSL at Monticello, and 1,537 meters (5,040 feet) MSL at the Needles station. Temperatures at the Needles station should be representative of Davis Canyon because the site elevation is similar (1,561 meters [5,120 feet] MSL), and it is only 11 kilometers (7 miles) away. For all stations, July is the warmest month, with mean temperatures ranging from low- to mid-20s C (high 60s to high 70s F), and January is the coldest month, with mean temperatures a few degrees below freezing. Moab has greater extreme temperatures; a record high of 45 C (113 F) in June and a record low of -31 C (-24 F) in January (U.S. Weather Bureau, 1965, p. 53).

Table 3-32. National and Utah State Ambient Air Quality Standards

Criteria Pollutant	Averaging Time	Primary Standards[a] $\mu g/m^3$	Secondary Standards[a] $\mu g/m^3$
Carbon Monoxide (CO)	8-hour[b]	10,000	10,000
	1-hour[b]	40,000	40,000
Nitrogen Dioxide (NO_2)	Annual	100	100
Total Suspended Particulates (TSP)	Annual[c]	75	60[d]
	24-hour[b]	260	150
Sulfur Dioxide (SO_2)	Annual	80	--
	24-hour[b]	365	--
	3-hour[b]	--	1,300

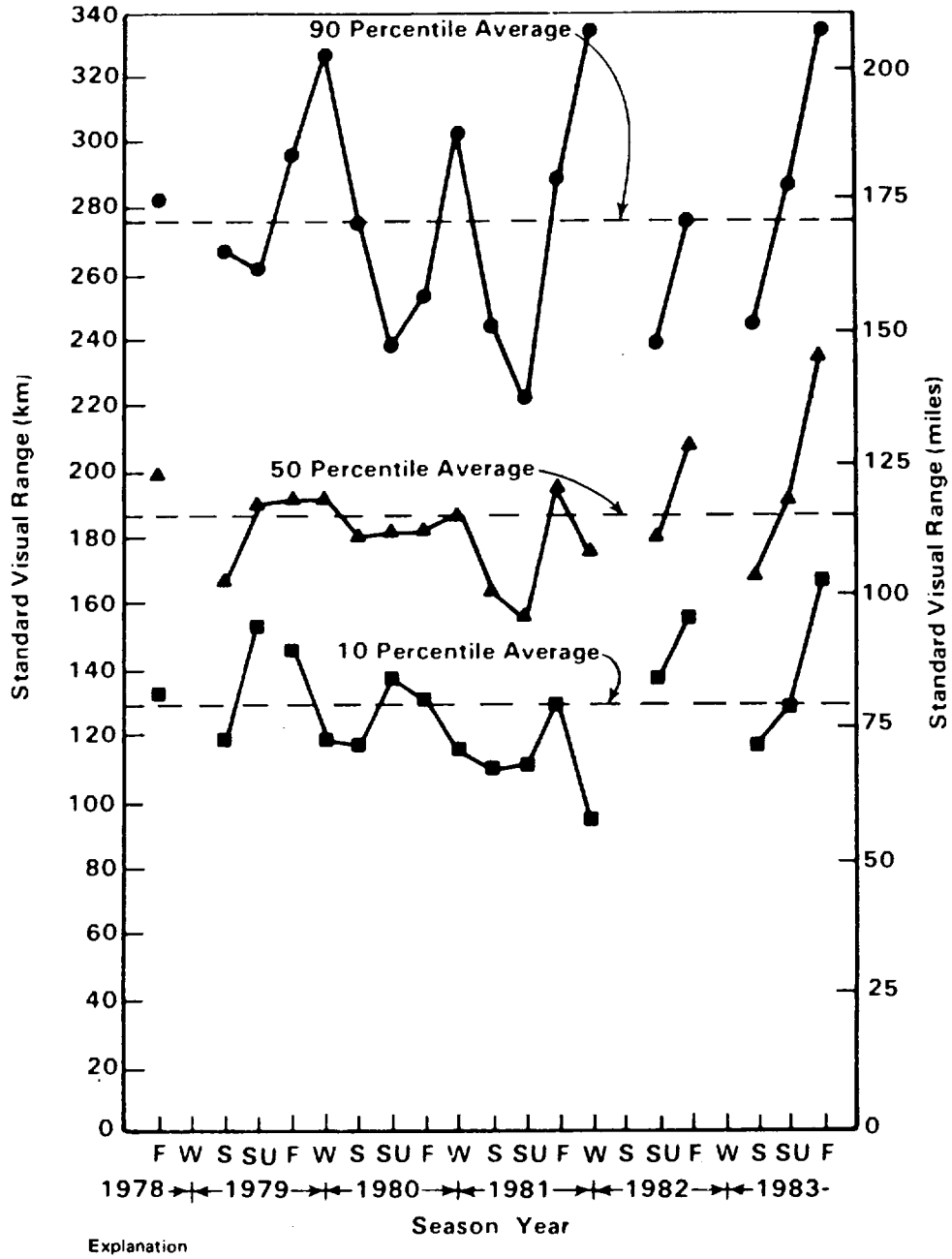
(a) Primary standards are for protection of health; secondary standards are for protection of welfare. Concentration units: $\mu g/m^3$ = micrograms per cubic meter.

(b) Not to be exceeded more than once per year.

(c) Geometric mean; all other annual standards are arithmetic means.

(d) Guideline; not a standard. To be used in assessing implementation plans to achieve the 24-hour standard.

Sources: Clean Air Act (42 USC Sections 7401-7642); 40 CFR Part 50; Air Conservation Act, Utah Code Annotated, Sections 26-13-1 to 26-13-30.



Explanation

- ● 90 Percentile Seasonal Average (the Standard Visual Range Exceeded 10 Percent of the Time During the Season)
- ▲ 50 Percentile Seasonal Average (the Standard Visual Range Exceeded 50 percent of the Time During the Season)
- ■ 10 Percentile Seasonal Average (the Standard Visual Range Exceeded 90 Percent of the Time During the Season)
- — Averages of 90, 50, and 10 Percentile Values are 275 km, 185 km, and 128 km, respectively

Note: Disconnected Lines Indicate Seasons with Insufficient Data for a Seasonal Average or Unavailable Data

Seasonal Baseline Visibilities in Canyonlands National Park, Island-in-the-Sky District

Figure 3-71

Monthly precipitation varies little, and annual averages are low: 20.8 centimeters (8.2 inches) at Moab and 35.1 centimeters (13.8 inches) at Monticello (30-year basis) (U.S. Weather Bureau, 1965, p. 14). At the Needles station, the annual average precipitation is 21.3 centimeters (8.4 inches), based on 15 years of data from 1966 to 1980; however, many of these data are reported as "wholly or partially estimated" (NOAA, 1966-1981, Vols. 67-82). For all stations, October is the wettest month and June is the driest month. Snowfall occurs from October through May with 31.5 centimeters (12.4 inches) at Moab (U.S. Weather Bureau, 1965, p. 24); no snowfall data are available for Monticello. The maximum 24-hour snowfall recorded at Grand Junction, Colorado, was 23.1 centimeters (9.1 inches) (NOAA, 1981b). On the average, snowfalls greater than or equal to 2.5 centimeters (1.0 inch) occur 10 to 20 days per year in the site area (Baldwin, 1973).

Annual average relative humidity at Grand County Airport, south of Moab, is 45 percent. The highest monthly relative humidity, 69 percent, occurs in January; the lowest, 24 percent, occurs in June (U.S. Naval Weather Service, 1969, p. 286).

Long-term climatology (paleoclimate) is discussed in Section 3.2.2.4. The possible effects of future climatic changes are discussed in Section 6.3.1.4.

3.4.3.3 Severe Weather

Weather extremes are important in the structural design of surface repository facilities. The annual fastest mile wind* and maximum 24-hour rainfall, each associated with a 100-year mean recurrence interval, are approximately 32 meters per second (71 miles per hour) (Simiu et al., 1979) and 7.6 centimeters (3.0 inches) (Hershfield, 1961, p. 56), respectively.

Tornadoes are infrequent in Utah. In the 28-year period between 1953 and 1980, only 32 tornadoes were sighted in the entire state (NOAA, 1981a, p. 65). In 1969, three tornadoes occurred in one day in Wayne County, west of San Juan County (ESSA, 1970, pp. 53, 58), and in 1970 a tornado occurred in Grand County, north of San Juan County (NOAA, 1971, p. 58). Based on the work of Thom (1963), the mean probability of a tornado stiking a point in any year in a 1-degree-square area surrounding the site is on the order of 7.6×10^{-5}; the mean recurrence interval for this event is about 13,000 years.

Weather extremes are also important in assessing the potential for interruption of normal facility operations. On the average, the area can expect thunderstorms about 45 days per year, hail 3 days per year, freezing rain 2 days per year, and heavy fog (with visibility less than 0.40 kilometer [0.25 mile]) 10 days per year (Baldwin, 1973).

3.4.3.4 Atmospheric Transport and Diffusion

Representative atmospheric transport and diffusion data are required to perform an air quality analysis. Specifically, data required for modeling are wind speed and direction, atmospheric stability, and mixing level. The analysis of short-term impacts (i.e., 24-hour averaging times) requires sequential hourly data as model input for at least a 1-year period.

The nearest available hourly data were collected in 1975 for the Inter-mountain Power Project at Salt Wash, Utah. The 100-meter (328-foot) tower was located on Factory Bench near the Fremont River, a site approximately 110 kilometers (70 miles) west of Davis Canyon, and 90 kilometers (55 miles) west of Canyonlands National Park. These data were used in a recent National Park Service study to assess the air-quality impact of the Tar Sand Triangle Project on Canyonlands National Park and surrounding areas (Bowers et al., 1983).

The Davis Canyon area is similar in many respects to the Salt Wash Tower site. Davis Canyon is approximately 3 kilometers (2 miles) wide, while the Salt Wash Tower site on Factory Bench is one-half to 1 mile north (on a flat horizontal plain) and above an equally wide

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*Defined as the fastest passage of 1.6 kilometers (1.0 mile) of wind at 9.1 meters (30.0 feet) above the ground.

Canyon (Fremont River Valley). Although the large-scale character of both canyons is similar, local differences in terrain features are present. The ESF and repository facilities in Davis Canyon are to be positioned in a cul de sac formed by irregular mesa escarpments rising 61 to 91 meters (200 to 300 feet). The influence of this locally irregular terrain at the site will lead to some site-specific differences in the flow patterns between the Salt Wash Tower site and the proposed site.

The surrounding high terrain at both sites rises approximately 300 to 400 meters (1,000 to 1,300 feet) above the canyon floor. Moreover, canyon orientations at both Davis Canyon and the Salt Wash tower site are southwest to northeast with entrances to the east, thus, direction of nighttime drainage flow should be similar at both locations. The DOE acknowledges that there are meteorological differences; however, it is believed Salt Wash Tower data are the most representative of existing data for the Davis Canyon site.

Annual average TSP and NO_2 concentrations are estimated (Sections 4.2.13 and 5.2.5) using as input the annual joint frequency of occurrence of wind direction, wind speed, and atmospheric stability class, derived from the hourly Salt Wash data (Bowers et al., 1983).

Wind speed and direction data for the Salt Wash tower are summarized and presented in the form of a wind rose in Figure 3-72.

Turbulent characteristics of the atmosphere can be described in terms of varying stability classes as listed below:

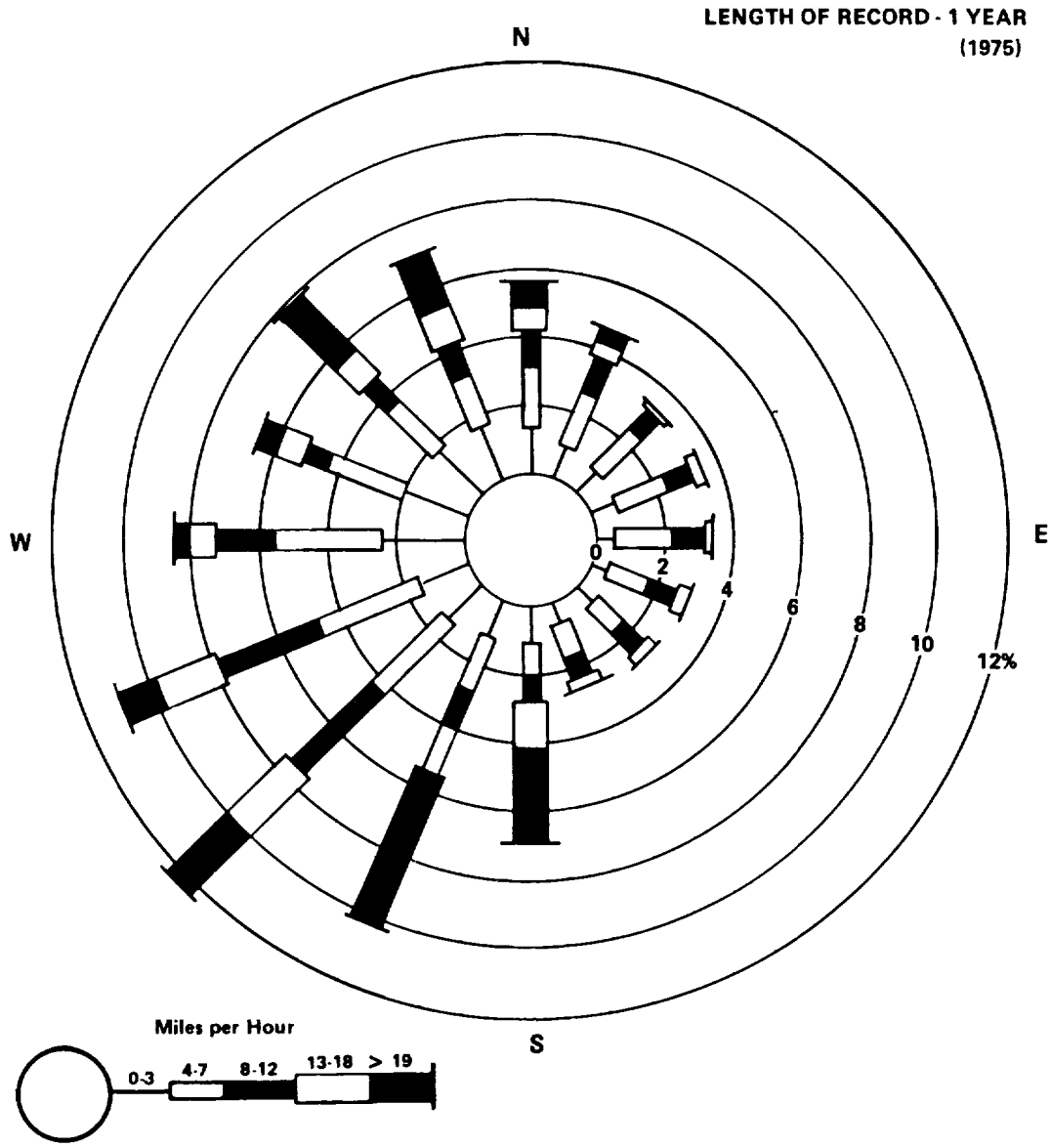
- Class A -- extremely unstable
- Class B -- moderately unstable
- Class C -- slightly unstable
- Class D -- neutral
- Class E -- slightly stable
- Class F -- moderately to extremely stable.

Table 3-33 presents the seasonal and annual distribution of atmospheric stability classes from the Salt Wash meteorological tower (BNI, 1985b). The frequency of occurrence of Class F stability (on an annual basis) indicates the potential for reduced dispersion conditions at night. The data show that Class F stability occurs about 8 percent of the time.

Mixing level (depth) represents the potential vertical limit of pollutant dispersion. The mixed layer develops during the day as a result of surface heating by the sun. In general, the higher the mixing level, the greater the dispersion potential. The annual average afternoon mixing level for Grand Junction is 2,600 meters (8,530 feet). Seasonal average afternoon mixing levels are 1,160 meters (3,806 feet) for winter, 3,166 meters (10,387 feet) for spring, 3,940 meters (12,926 feet) for summer, and 2,133 meters (6,998 feet) for fall. The annual average morning mixing level for Grand Junction is 384 meters (1,260 feet). Seasonal average morning mixing levels are 329 meters (1,079 feet) for winter, 682 meters (2,238 feet) for spring, 307 meters (1,007 feet) for summer, and 273 meters (896 feet) for fall (Holzworth, 1972).

In a similar manner as done in Bowers et al. (1983), mixing levels required for input to the analyses (Sections 4.2.1.3 and 5.2.5) were estimated based on mixing level data and wind speed data (BNI, 1985b).

Poor dispersion conditions (episodes) that persist for several days can result in a buildup of ground-level ambient concentrations. An episode is defined as the occurrence of mixing levels of less than 1,500 meters (4,921 feet) on at least two consecutive days, wind speeds of less than 4 meters per second (8.9 miles per hour), and no significant precipitation. For example, Grand Junction, Colorado reported 43 episodes totaling 193 days during a 5-year period (Holzworth, 1972, p. 83). Fourteen of these episodes were at least 5 days long, totaling 111 days. Winter episodes were longest.



Note: Calms are distributed in first wind speed category.

Source: BNI, 1985b.

Annual Wind Rose
Salt Wash Tower

Figure 3-72

Table 3-33. Atmospheric Stability Distribution (Percent) for Salt Wash

Period	Stability Class					
	Unstable			Neutral	Stable	
	A	B	C	D	E	F
Winter	2.51	4.27	8.28	40.01	35.59	9.34
Spring	3.17	4.83	12.50	43.58	31.83	4.08
Summer	18.40	11.90	10.50	40.21	12.07	6.93
Fall	12.77	7.20	7.79	41.26	22.19	8.79
Annual	9.80	7.20	9.40	41.03	24.89	7.68

Source: Bowers et al., 1983.

3.4.4 Noise

Noise levels at the Davis Canyon site are low, which is characteristic of rural open rangeland. The source of noise in this sparsely populated area is primarily wind passing over terrain and vegetation. Additional noise is created by birds and insects, and occasional human-related sources such as aircraft and surface vehicles. Areas in the vicinity of jeep trails experience higher noise levels from recreational vehicle activity. The rugged topography in the area can result in both increased attenuation of noise between adjacent canyons because of barrier effects, and reduced attenuation within a canyon as a result of noise reflection.

The measures used to describe the time-varying noise in this EA are described in Table 3-34.

Background sound-level measurements have been made at Peekaboo Spring campground in Canyonlands National Park, Davis Canyon, and Dugout Ranch (BGI, 1983, ONWI-460). One-third octave band and overall A-weighted sound levels have also been measured in Canyonlands National Park for the National Park Service by Bolt Beranek and Newman Inc. (Pearsons, 1984a, b; 1985a, b) during the month of December, 1983 and are similar to the levels found and reported by BGI. Noise levels are widely varied, depending on the time of day, specific location, and effects of wind, birds, streams, and airplanes. For example, commercial aircraft flyovers typically result in noise levels in the park of 30 to 50 dBA lasting two to four minutes each. Sound levels measured in Canyonlands National Park are similar to those measured in other parks in this region, such as Bryce Canyon (Foch and Oliver, 1980, pp. 10-12).

The minimum hourly L_{eq} measured in Canyonlands National Park during the winter months, when background sound levels are the lowest, was 19 dBA. The L_{dn} was found to range from 28 dBA in Canyonlands National Park to 46 dBA at Dugout Ranch, the nearest residence (see Figure 3-5) (BGI, 1983, ONWI-460; Pearsons, 1985b).

The L_{99} values in Davis Canyon were 18 dBA during daytime hours and 17 dBA during nighttime hours. The average of L_{99} values collected at six sites in Canyonlands National Park were 21 dBA during the day and 16 dBA during the night. The averages of the one-third octave band levels corresponding to the daytime levels and the nighttime levels measured at these six sites are used in the impact analyses discussed in Sections 4.2.1.6 and 5.2.7.

Assuming that these residual levels (L_{99}) persist throughout the day and night, the computed L_{dn} reported in Sections 4.2.1.6 and 5.2.7 would be 24 dBA. Natural occurrences (wind and wildlife) and noise caused by humans, such as from airplanes and distant traffic, would account for the higher measured L_{dn} values reported above.

3.4.5 Aesthetic Resources

The scenic character of the Davis Canyon area is one of open spaces with unusual rock formations and color contrasts. The landscape includes broad basins, prominent cliffs, isolated buttes, mesas, spires, and deeply entrenched meandering canyons. Various cultural modifications have occurred in the area such as access roads, mining developments, livestock grazing, and recreational developments (BLM, 1982a, p. 63). Davis Canyon is characterized by red rock open desertland, contrasted by high cliffs, mesas, and spires. Predominant colors are red, orange, brown, and lavender. Vegetation is sparse, with low shrubs and grass in the flatlands and scattered pinyon pine and juniper in the higher areas.

Major scenic attractions near Davis Canyon include Canyonlands National Park, Needles Overlook in the Canyon Rims Recreation Area, and the Newspaper Rock State Historical Monument (Section 3.4.1.3). According to the Canyonlands National Park Act (16 USC Section 271), Canyonlands National Park was established to preserve an area in the State of Utah "possessing superlative scenic, scientific, and archaeological features, for the inspiration, benefit, and use of the public." The same wording was used for the park boundary revision included in the amendment to the Canyonlands National Park Act on November 12, 1971 (Parry, 1981, p. SFM-1).

Table 3-34. Sound-Level Measures and Assumed Ambient Noise Levels

Measure	Sound Level Measures Description
L_{99}	The A-weighted level (dBA) which is exceeded 99 percent of the time. This level is a measure of residual sound and quantifies how quiet the area may be.
L_{eq}	The energy equivalent A-weighted level (dBA). The average of the time-varying sound energy.
L_{dn}	The day/night energy equivalent level (dBA). The 24-hour A-weighted energy equivalent level with 10 dB added to the nighttime levels (10:00 pm to 7:00 am).

Ambient Noise Levels Assumed in Modeling
(One-Third Octave-Band Spectra[b] Residual Ambient)
Center Frequency (Hz)

	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	1500	3150	4000	5000	6300[c]	8000[c]	10000[c]
Daytime	12.8	10.3	8.0	6.3	4.6	3.2	2.1	1.9	1.8	1.1	0.6	1.5	1.7	1.8	2.0	3.3	4.9	5.8	7.4	8.3	10.1	10.1	10.1	10.1
Nighttime	8.0	5.9	4.5	4.5	3.6	2.5	1.9	1.5	0.9	0.0	-0.3	0.6	1.2	1.3	1.6	3.1	4.7	5.4	6.6	7.3	8.7	8.7	8.7	8.7

Note: Each one-third octave-band sound pressure level is an average (from the six measurement locations in Canyonlands National Park [Pearsons, 1985a]) exceeded 99 percent of the time (i.e., the L_{99} value). Note that the Ldn of 24 dBA was not a measured value; measured Ldn for five locations (BGI, 1983, ONWI-460) including one in Canyonlands National Park, one at the park boundary, and three just outside the park varied from 28 dBA (in Canyonlands National Park) to 46 dBA (at Dugout Ranch).

(a) See Sections 4.2.1.6 and 5.2.7.
(b) An Ldn value of 24 dBA was computed from these daytime and nighttime one-third octave-band spectra.
(c) Extrapolated not measured values.

Canyonlands National Park is an area of rugged, scenic lands surrounding the confluence of the Green and Colorado Rivers. By erosional processes and structural deformation, the intricate array of canyons at the Park has been transformed into lands of arches, needles, spires, standing rock fins, mesas, and broad basins. These scenic resources are of primary significance and provide the main attraction to visitors (Parry, 1981, p. SFM-1). The Needles Overlook, 16 kilometers (10 miles) north of the geologic repository operations area (GROA) in the southern portion of the Canyon Rims Recreation Area, is accessible via the Canyon Rims road, which leaves U.S. Highway 191 approximately 53 kilometers (33 miles) south of Moab. A paved road leads to the overlook, a jutting promontory on a high rim that provides a view across most of Canyonlands National Park and the canyon rim. Newspaper Rock State Historical Monument, located southeast of Davis Canyon, is a large display of Indian petroglyphs on a wall in Indian Creek Canyon. Access to the monument is from Utah State Highway 211 (Utah 211), which goes directly through the developed part of the monument. For more information regarding Newspaper Rock State Historical Monument see Section 3.4.1.3.

Several areas other than Davis Canyon may be affected by project activities and proposed transportation routes. These areas include portions of the Canyon Rims Recreation Area, the Colorado River Canyon, Indian Creek Valley, Cottonwood Canyon, Lavender Canyon, Beer Basin, Harts Point, Lockhart Basin, Harts Draw, and Newspaper Rock State Historical Monument. The Canyon Rims area, managed by the Bureau of Land Management (BLM), is accessible via the Canyon Rims Road. The recreation area includes scenic rimlands of an elevated plateau and three scenic overlooks including Needles, Anticline, and Canyonlands overlooks. The deeply carved Colorado River Canyon is a major visual resource which may be affected by a proposed access route. Dead Horse Point State Park is one of the major viewing points. All BLM lands in the area have scenic value and are accessible by four-wheel-drive roads that afford viewing access to recreational visitors.

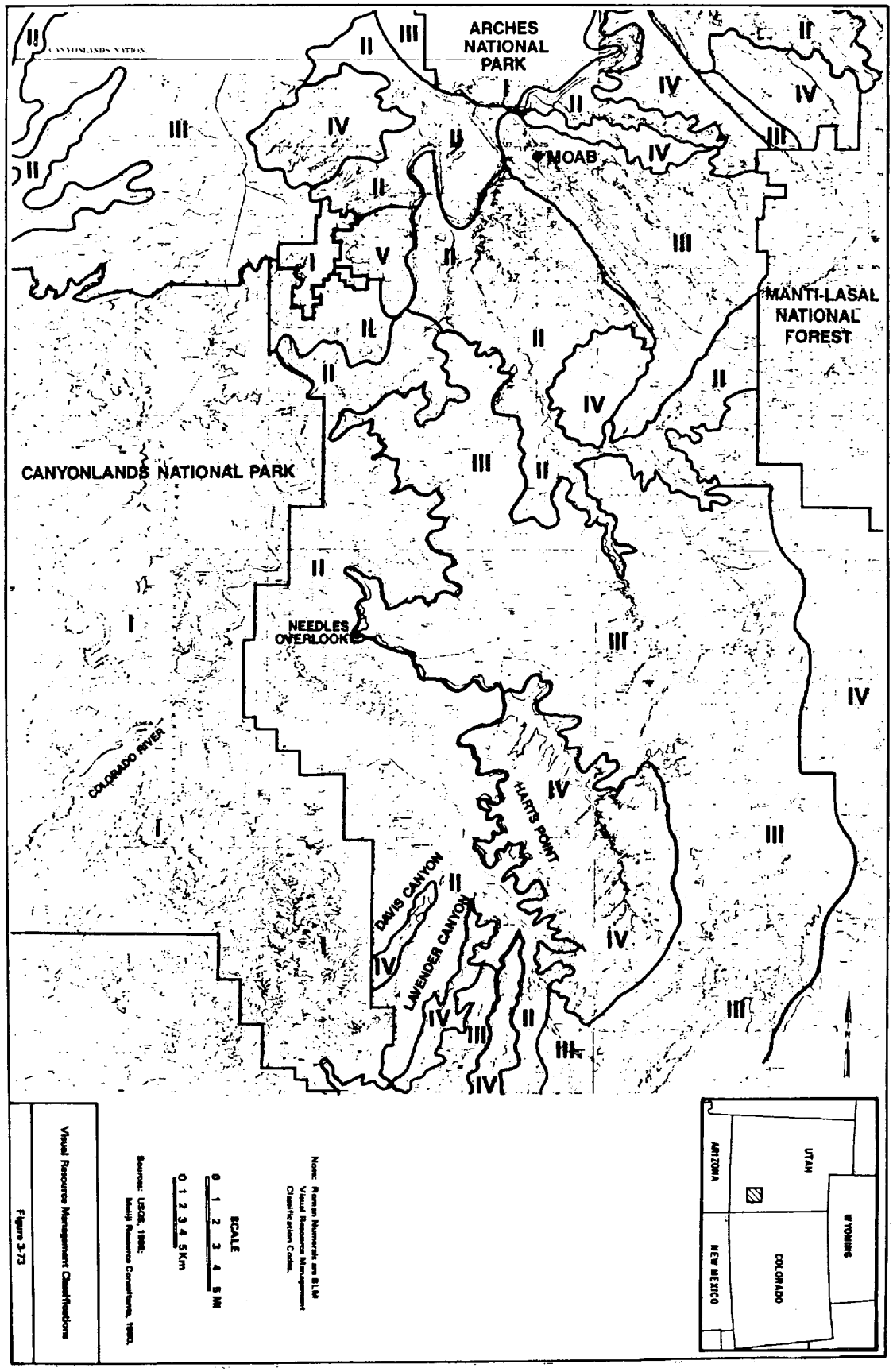
Both the National Forest Service and the BLM have developed methods for evaluating visual resources and assessing visual impact for activities on lands under their control. However, the National Park Service has not developed, and does not endorse, the use of a visual resource evaluation system. The system for evaluating visual resources developed by the BLM is used in this assessment.

The BLM system is called Visual Resource Management (VRM) (BLM, 1978). The VRM system rates land for scenic quality, visual sensitivity, and distance zone. The determination of scenic quality involves an assessment of landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications; a scenic quality rating is designated A, B, or C (from high to low). The visual sensitivity rating relates user volume and user attitude toward change; a rating of high, medium, or low is designated. The distance zone rating involves the selection of key observation points and a determination of the distance between the viewer and the viewed area; ratings are foreground-middleground, background, and seldom-seen. Once ratings for scenic quality, visual sensitivity, and distance zone are determined, the land is assigned a management classification, Class I through V. The management classification describes the degree of modification allowed of the basic elements of the landscape, with Class I allowing the least modification. Figure 3-73 shows the visual management classifications of the Davis Canyon area.

Canyonlands National Park is not classified by the BLM since it is not located on BLM land. However, it is assumed that Canyonlands would be included in a Class I category, since this classification is applied to wilderness areas, some natural areas, portions of wild and scenic rivers, and other similar areas where management activities are to be restricted. By definition any contrast created within a Class I characteristic landscape must not attract attention (Meiiji Resource Consultants, 1980, p. 7).

The Davis Canyon site is located in a VRM Class II area, rated "B" in scenic quality, "high" in visual sensitivity, and "foreground-middleground" in distance zone (Meiiji Resource Consultants, 1980). The Canyon Rims area is a VRM Class III area, rated "C" in scenic quality, "high" in visual sensitivity, and "foreground-middleground" in distance zone. The Colorado River Canyon area, adjacent to and east of Canyonlands National Park, is a VRM Class II area, rated "A" in scenic quality, "high" in visual sensitivity, and "foreground-

A larger reproduction of this figure appears at the back of this volume.



Visual Resource Management Classifications

Figure 3-73

middleground" in distance zone. Harts Draw is a VRM Class II area, rated "A" in scenic quality, "high" in visual sensitivity, and "foreground-middleground" in distance zone.

3.4.6 Cultural Resources

The site lies within the high plateau country of the northern Colorado Plateau, an area with a diverse and abundant cultural resource base. The cultural sequence of the region may be outlined as follows (Jennings, 1978):

Aboriginal Period

Preformative	Paleo-Indian	9500 to 5500 BC
	Archaic	6050 BC to AD 450
Formative	Anasazi	AD 1 to 1300
	Fremont	AD 700 to 1275
Postformative	Ute	AD 1150 (?) to present
	Navajo	AD 1600 to present

Historic Period (AD 1765 to present)

Euro-American	Exploration and early settlement
	Livestock and farming frontier
	Mineral exploration
	Government activities.

The earliest eras of this sequence, encompassing the big-game hunting Paleo-Indians and the subsequent Archaic hunters and collectors, are poorly represented in the archaeological record of southeastern Utah; however, adjoining regions were used extensively by these groups. The Paleo-Indians, noted for production of finely worked and highly distinctive projectile points, have only been identified through widely scattered, isolated diagnostic artifacts. These finds are so scarce in the vicinity of the candidate area that it is doubtful that the Paleo-Indians extensively used the southeastern Utah region (Jennings, 1978, p. 21).

The Archaic Era was characterized by more diverse technological and economic pursuits than was the Paleo-Indian Era. The Archaic lifestyle included seasonal movements by small groups, during which maximum use was made of the local plants and animals. Archaic utilization is evident in southeastern Utah, but is relatively scant south and east of the Colorado River compared to surrounding regions.

The Formative Era on the northern Colorado Plateau was dominated by groups classified as agriculturalists who grew corn, beans, and squash, and occupied year-round settlements. These groups are known generally as Puebloans and more specifically as Mesa Verde Anasazi. The Anasazi cultural remains dominate the cultural resource base in the project area.

Researchers have developed a chronological sequence for the Anasazi in southeastern Utah that may be summarized as follows (Jennings, 1978, p. 97):

- Basketmaker II - AD 1 to 500
- Basketmaker III - AD 450 to 750
- Pueblo I - AD 750 to 900
- Pueblo II - AD 900 to 1100
- Pueblo III - AD 1100 to 1300.

This sequence is characterized by trends through time toward increasing dependence on agriculture, more permanent and larger settlements, and certain technological developments, especially distinctive pottery types.

Another Formative group, known as the Fremont, occupied all of Utah west of the Colorado River; the river itself appears to have served as a natural boundary between the Anasazi and the Fremont. In Davis Canyon, some Fremont traits can be identified along with the Anasazi

evidence, notably in rock art styles. The presently ill-defined boundary and area of interaction between the Fremont and Anasazi in southeastern Utah requires additional study before a better understanding of their histories can be realized. By AD 1300, both the Anasazi and Fremont had effectively abandoned southeastern Utah.

Following the demise of the Formative agriculturalists, the area was occupied sporadically by the Numic-speaking Ute and the Athabaskan-speaking Navajo. Based on available data, the Ute appear to have been the primary historical aboriginal occupants of the area; evidence for the Navajo is sparse. The Ute represented a return to a seasonal hunting and gathering lifestyle; as a consequence, the archaeological record for this group is limited. Rock art depicting figures on horseback and some sparsely recorded artifacts (e.g., specific pottery and projectile-point types) are representative of Ute sites in the project area. While the specific time of arrival for both the Ute and Navajo in southeastern Utah is unknown, both continue to occupy the extreme southeastern corner of Utah.

The known diversity and density of aboriginal cultural resource types in the vicinity of the Davis Canyon site is scientifically significant in terms of the potential for addressing both local and regional research topics. Locally, the variety of archaeological sites with potential research significance provides an opportunity for research into many aspects of prehistoric settlement patterns, material culture, lithic technology, cultural affiliation, and communication systems, including rock art. In the larger setting, the cultural resources in the vicinity of the site hold potential for examining relationships to other Archaic and Formative Anasazi cultural areas on the northern Colorado Plateau and the Fremont to the north and northwest.

The historic Euro-American period in southeastern Utah began with early Spanish expeditions such as the 1765 Rivera and 1776 Dominguez and Escalante expeditions. In the mid-1800s, American expeditions, most notably the Macomb Expedition of 1859, helped to map and provide initial descriptions of the area. In the 1860s, other important explorations included the Hayden Expeditions of 1875 and 1876, and the various explorations of John Wesley Powell along the Colorado River. From the 1870s through the end of the 19th century, southeastern Utah was settled, primarily by Mormon colonists from southwestern Utah. The settlement activities included large-scale livestock ventures, beginning in the early 1880s, and mining activities, a decade later.

The livestock frontier of this era is especially important in the project area because the Scorup brothers, "J.A." and James, gradually developed extensive land holdings and grazing rights in the Indian Creek valley and surrounding areas during this time (Peterson, 1975, p. 100). This ranching enterprise continues to be the dominant historic resource in the area today, and its headquarters, the Dugout Ranch, is a significant part of the area's historical resources.

Near the turn of the century and in subsequent decades, the quest for uranium and oil dominated the economic scene in parts of southeastern Utah. The first oil well was drilled and the initial discoveries of uranium and vanadium were mined, just before 1900 (Pierson, 1980, pp. 91, 93). While these and other mineral interests continue to be important in the region today, as are farming and livestock, Federal government activities have also been critical to the recent history of southeastern Utah, including the establishment of the La Sal National Forest (1906), Canyonlands National Park (1964), Natural Bridges National Monument (1908), Arches National Monument (1929, later to be designated a Park), and the Glen Canyon National Recreation Area (1965) (Crampton, 1964; Peterson, 1975; Pierson, 1980).

Historic resources in the vicinity of the Davis Canyon site have potential for addressing important research topics such as early exploration, settlement, ranching, and mining themes. The relationship of the local historical sequence and events with those of San Juan County and southeastern Utah is also a critical research topic.

3.4.6.1 Previous Work

Several archaeological studies have been completed in the Davis Canyon candidate area that point to the presence of an abundant and important cultural resource base. None of these specific studies have encompassed large areas, however, and significant sections of the candidate area remain unstudied. General studies that have been completed include archaeological or historical overviews of the following:

- Canyonlands National Park (Anderson, 1978)
- Bureau of Land Management lands in northern San Juan County (Pierson, 1980)
- Bureau of Land Management lands in southern San Juan County (Nickens, 1982)
- The Manti-La Sal National Forest and surrounding areas (Peterson, 1975)
- The Canyonlands country (Crampton, 1964)
- San Juan County (Perkins et al., 1968)
- San Juan County (Powell, 1983).

Formal archaeological surveys in the candidate area began in 1930 with the Claflin-Emerson Expedition. In that year, the party recorded 12 prehistoric sites in the River Park area of Beef Basin (approximately 13 kilometers [8 miles] south of Davis Canyon) and 14 sites in the Salt Creek drainage (immediately west of Davis Canyon), including three along Indian Creek just east of the present Canyonlands National Park boundary (Gunnerson, 1969, Figure 2A). Since the establishment of Canyonlands National Park, archaeological studies have sporadically occurred in the Needles District, immediately west of Davis Canyon.

In 1965, the University of Utah recorded or reexamined 239 archaeological sites in the Needles District (Sharrock, 1966, p. 64). The study noted that the sites were predominantly affiliated with Mesa Verde Anasazi, and were subdivided into eight basic site types (Sharrock, 1966, pp. 64-67):

- Chipping sites
- Transient camps
- Alcove camps
- Storage sites
- Open habitations
- Alcove habitations
- Petroglyph/pictograph rock art sites
- Rock shelters.

In 1975, the Salt Creek Archaeological District was listed on the National Register of Historic Places (NRHP). As of 1978, some 304 sites had been formally recorded in the Needles District (Anderson, 1978, p. 41) based on limited survey data.

Recently, additional archaeological survey and ruins stabilization projects have been conducted in the Needles District of the park. Personnel from the National Park Service (NPS) have also completed surveys of the upper portions of Davis and Lavender Canyons in the Salt Creek Archaeological District, recording 78 new sites (Griffin, 1984). Stabilization of ruins in upper Salt Creek occurred in 1983 (Metzger, 1983) and is continuing in both Salt Creek and Horse Canyons.

Until recently, archaeological work outside Canyonlands National Park in the Davis Canyon candidate area had not been intensive. Surveys and excavation were undertaken in Beef Basin in the early 1950s by the University of Utah (Rudy, 1955). This work, still the only substantive excavation project in the candidate area, established a Mesa Verde Anasazi affiliation to the Beef Basin ruins, dating to the late Pueblo II through early Pueblo III time frame (approximately AD 1000 to 1150). Some of these ruins were stabilized or reconstructed in 1966 by the Utah State University (Anderson, 1978, p. 123).

Two large-scale cultural resource surveys have been conducted in the candidate area. Davis (1975) performed a nonsystematic survey of Cottonwood Canyon, noting that prehistoric occupation of that area also dated primarily to the late Pueblo II through early Pueblo III

period. In 1977, a Class II (sample-oriented), 1-percent, cultural resource survey was conducted in the Bureau of Land Management's (BLM's) Indian Creek Planning Unit. According to Thompson (1979, p. 155), the entire Indian Creek Planning Unit would have an average site density of 11.8 sites per square kilometer (19 sites per square mile), varying according to vegetation and topography. No sites are found in wasteland (e.g., talus) areas; one site per 9 hectares (22 acres) is projected for the juniper-pinyon pine zone; one site per 40 hectares (98 acres) is projected in brushland. The sites recorded by Thompson (1979, pp. 137-146) are of many types and cultural affiliations: chipping sites, campsites, ceramic sites, habitation and storage sites, rock shelters, and rock art, dating from Basketmaker II, Pueblo II and III, and Anasazi periods. Chipping sites and campsites occur with the greatest frequency; habitation and Basketmaker II sites are least common. The results of this survey should be used with caution because of the small sample size, but the survey did record a total of 121 sites in the planning unit, dating to the Basketmaker II, Pueblo II, and Pueblo III periods (Thompson, 1979, p. 152).

Within the past 2 years, several cultural resource surveys have been conducted in the Indian Creek area, in addition to the NPS survey in Davis and Lavender Canyons. Local individuals have been actively recording archaeological sites throughout Indian Creek and have noted the presence of approximately 175 prehistoric sites. Forms for these sites have been submitted to the BLM San Juan Resource Area and Utah State Antiquities Section offices. The State of Utah also conducted an inventory of an area around Indian Creek State Park in upper Indian Creek as part of a proposed expansion of the park. This work resulted in the recording of 64 sites, primarily associated with Anasazi occupation (Emery, 1983, p. 3).

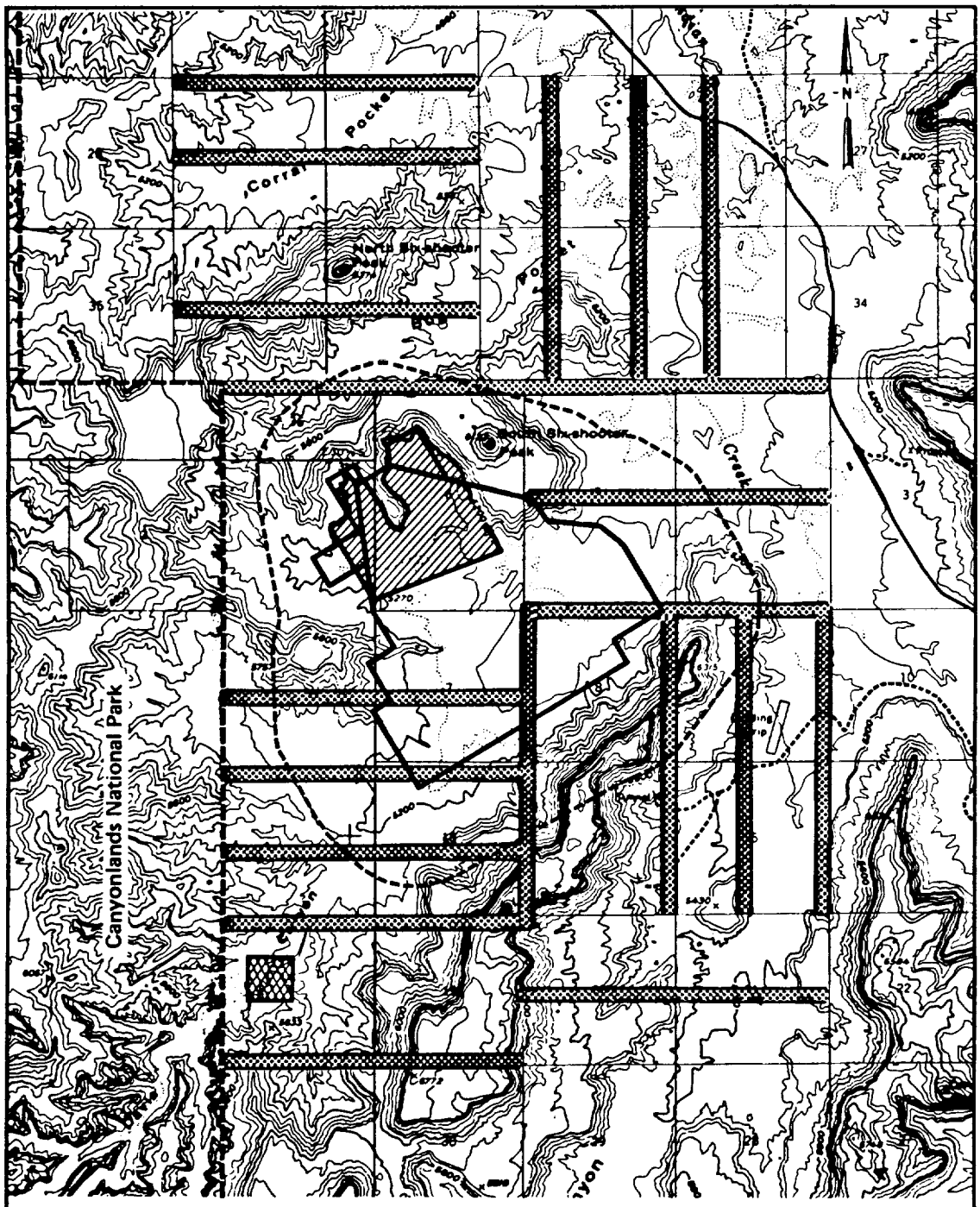
Previous historical research is generally lacking in the study area; only a few of the potential sites have been recorded and evaluated. Both Dugout Ranch in Indian Creek and Kelly Ranch may be eligible for the NRHP. Many abandoned historic structures and other sites associated with the area's livestock frontier are known to exist in the study area, as are historic features associated with early mining ventures.

Two NRHP sites are known to exist in the Davis Canyon vicinity: Newspaper Rock State Historical Monument, southeast of the proposed site on Utah State Highway 211 (Utah 211); and Salt Creek Archaeological District, bordering the area in the eastern section of Canyonlands National Park. Newspaper Rock is a large, unique display of Indian petroglyphs on a wall of Indian Creek Canyon; many other petroglyphs are known to occur throughout the canyon. Access to the monument is from Utah 211, which goes directly through the developed part of the monument. Salt Creek Archaeological District, located in the Salt Creek area of eastern Canyonlands National Park, contains hundreds of recorded archaeological sites. These range from scattered lithic debris to multiroomed, little disturbed ruins, and some of the most numerous and best developed petroglyphs and pictographs in North America.

3.4.6.2 Davis Canyon Site and Vicinity

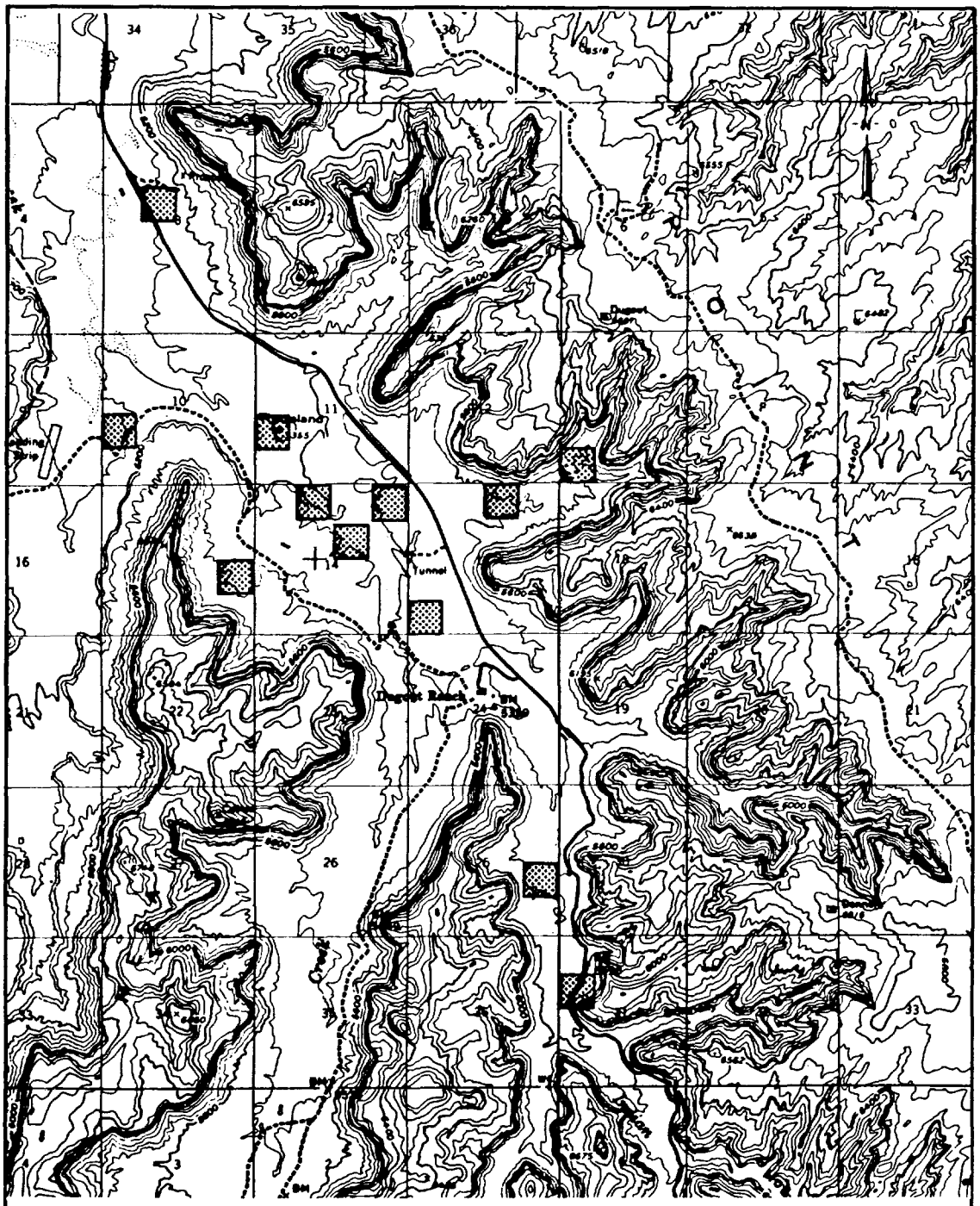
Several cultural resource surveys associated with the Paradox Basin project have been completed within the Davis Canyon vicinity (BGI, 1983, ONWI-468; Nickens and Associates, 1984). Site file searches of six alternative transportation corridors have also indicated a high potential for cultural resources along those project features. There are 237 cultural resource sites documented in the BLM and State of Utah files along the corridor alternative (Nickens and Associates, 1985). NPS archaeologists have surveyed 1,295 hectares (3,200 acres) within Canyonlands National Park; 648 hectares (1,600 acres) of this survey included the head of Davis Canyon within the park. Unknown acreages have also been surveyed in Davis Canyon by local individuals.

Three groups of cultural resource surveys have been performed in the project vicinity: a Class II, 10 percent sample of an 8,418-hectare (20,800-acre) area; a Class III, 259-hectare (640-acre) block survey in Davis; and a survey of numerous specific locations. Figure 3-74 shows the 259-hectare (640-acre) block survey location, and sample survey transects. Figure 3-75 shows additional sample survey units near Indian Creek.



Locations of the Survey Area Surrounding Davis Canyon

Figure 3-74



Locations of Survey Areas Near Indian Creek

Figure 3-75

Class II Sample Survey. The Class II survey was completed in the Davis and Lavender Canyon and Indian Creek areas (BGI, 1983). More than 8,418 hectares (20,800 acres) were sampled at 10 percent, resulting in an intensive inventory of 842 hectares (2,080 acres). Utilizing a sampling strategy consisting of transects in the Davis and Lavender Canyon area and 16-hectare (40-acre) blocks in the narrower Indian Creek drainage, the survey identified 19 previously unrecorded sites, 3 previously recorded sites, and 35 isolated artifacts. There are 21 prehistoric sites; these range from chipping sites to limited activity structural remains, open habitation sites, alcove campsites, and a rock art site. The historic site appears to be associated with ranching activity in the valley.

Although only 10 percent of the 8,418-hectare (20,800-acre) area was surveyed intensively, some estimations of site type, density, and placement can be based on the results of the survey. The validity of the estimates is subject to verification through additional work. The apparent site density in the overall Davis and Lavender Canyon and Indian Creek areas is 6.8 sites per 2.6 square kilometers (1 square mile), or one site per 38 hectares (94 acres). This density is roughly equivalent to Thompson's (1979, p. 154) brushland site density. The cultural affiliation of the sites is predominantly Anasazi (59 percent), although earlier and later sites also exist. The preferred topographic settings for sites appear to be canyon bottoms and benches, although these areas were surveyed to a greater degree. No clear distribution pattern is evident when the sites are compared by gross topographic setting (e.g., bench and canyon bottom).

Several independent variables were examined to ascertain their possible influence on site placement, including vegetation, slope, aspect, elevation, and distance to permanent water. Vegetation did not vary between sites; all sites occur in the salt shrub community. The slopes of sites varied considerably, averaging 14 degrees; most of the sites were found on relatively flat slopes. There was no variation in slope between Davis Canyon and Indian Creek. The mean aspect of all sites (regardless of survey area) was 154 degrees; most of the sites had a southerly aspect. Elevation appeared to have no discernable influence on site placement. Sites near Davis Canyon average 11.4 kilometers (7.1 miles) from permanent water, whereas sites in Indian Creek average 6.6 kilometers (4.1 miles). The Indian Creek area's proximity to permanent water may explain the higher percentage of transient and alcove camps and open habitation sites. The presence of alluvial soils associated with the stream course may also have been important.

Because of the restricted size of the survey area, little pinyon pine-juniper community was included within the survey traverse. Site densities are known to be higher there (one site per 9 hectares [22 acres] according to Thompson's [1979, p. 154] data), although additional studies are needed to substantiate this observation.

These sample studies, along with site survey records from the Utah State Division of History, the BLM, and the U.S. Geological Survey topographic maps (USGS, 1954; 1968), reveal the existence of several hundred archaeological sites in the Davis Canyon area. These sites are located along upper and lower Indian Creek, in Titus Canyon, North Cottonwood Circle, Lavender Canyon, Davis Canyon, and Beef Basin. Inside Canyonlands, Tower Ruin, Keyhole Ruin, and the ruin at Paul Bunyan's Potty are found in Horse Canyon; cliff dwellings are found in the Salt Creek Archaeological District. Additional sites are located throughout the remainder of the park.

Although formal determinations of eligibility to the NRHP have not yet been obtained for the recently recorded sites in the project vicinity, some of these sites may be judged eligible for listing. The comments of the State Historic Preservation Office and Keeper of the National Register will be sought regarding the eligibility of those sites recorded during project-sponsored surveys in the area.

Geotechnical/Environmental Activity Area Surveys. Numerous specific proposed activity locations have been surveyed since 1981. These locations are widely dispersed throughout the project area from Beef Basin north to Potash and from the Canyonlands boundary east beyond Harts Point.

3.4.7 Background Radiation

Data on estimated annual dose equivalent rates from natural and human-introduced radiation in the area are presented in Table 3-35 (Beck, 1979, EML-362).

Background radiation has four components: (1) terrestrial radiation (external), resulting from the presence of naturally occurring radionuclides in the earth; (2) cosmic radiation (external) from extraterrestrial sources; (3) natural radiation (internal) from environmental media (e.g., air, water, milk); and (4) radiation from global weapons testing.

Internal radiation is not included in this analysis, but Klement et al. (1972) estimated an internal radiation dose equivalent rate of 24 millirem per year for the United States. External dose equivalent rate is 113 millirem per year,* which is about 50 percent higher than the average dose rate of 76 millirem per year for all residents of the United States, and is comparable with that listed for the State of Utah by the EPA (1977, EPA-520/1-77-009). The annual population dose to the 16,500 people who lived within 80 kilometers (50 miles) of the center of the site in 1980 was under 1,900 man-rem. This is about 0.01 percent of the 1.7×10^7 man-rem received by the entire population of the United States in 1980.

3.5 TRANSPORTATION AND UTILITIES

This section identifies and describes the existing transportation network providing access to the site, and the major utilities serving the area. The information is based on data supplied by the State of Utah, published reports, and site visits. The information is provided to give a general description of existing transportation and utility networks.

3.5.1 Roads

The nearest paved road (Figures 3-76 and 3-77) in the vicinity of Davis Canyon is Utah State Highway 211 (Utah 211). This two-lane blacktop road extends west from U.S. Highway 191 (U.S. 191) for a total of 51 kilometers (32 miles) to provide access to Canyonlands National Park. This road includes a 21-kilometer (13-mile) National Park Service (NPS) extension. The turn-off to Davis Canyon, which is a dirt road, is approximately 40 kilometers (25 miles) from the junction of U.S. 191. A State pavement testing program indicated that the pavement and the subgrade were considered strong, and that the road would be structurally sound for 10 years or more, given existing traffic volumes (Martinez, 1985a,b).

Annual average daily traffic (AADT) (Figure 3-78) on Utah 211 in 1983 was 45 vehicles. There are occasional days when traffic exceeds the annual average by a considerable amount. On May 26, 1985 (Memorial Day) the park service estimated, by using traffic counters and manual counts, that 1,020 vehicles had used Utah 211 to access the park or nearby areas (Parry, 1985c). The capacity of Utah 211 is between 1,286 and 2,313 vehicles per hour (total in both directions) at a level of service E (Table 4-36) except for the 3.2-kilometer (2.0-mile) section south of Newspaper Rock State Historical Monument having steep grades and sharp curves, where capacity is reduced to 482 vehicles per hour (Martinez, 1985b).

The junction of Utah 211 and U.S. 191 is approximately 64 kilometers (40 miles) south of Moab and 22 kilometers (14 miles) north of Monticello. U.S. 191 runs north-south in southeastern Utah and northeastern Arizona, connecting east-west Interstate 70 (I-70) in Utah and Interstate 40 (I-40) in Arizona. The length of U.S. 191 between I-70 and I-40 is 474 kilometers (296 miles).

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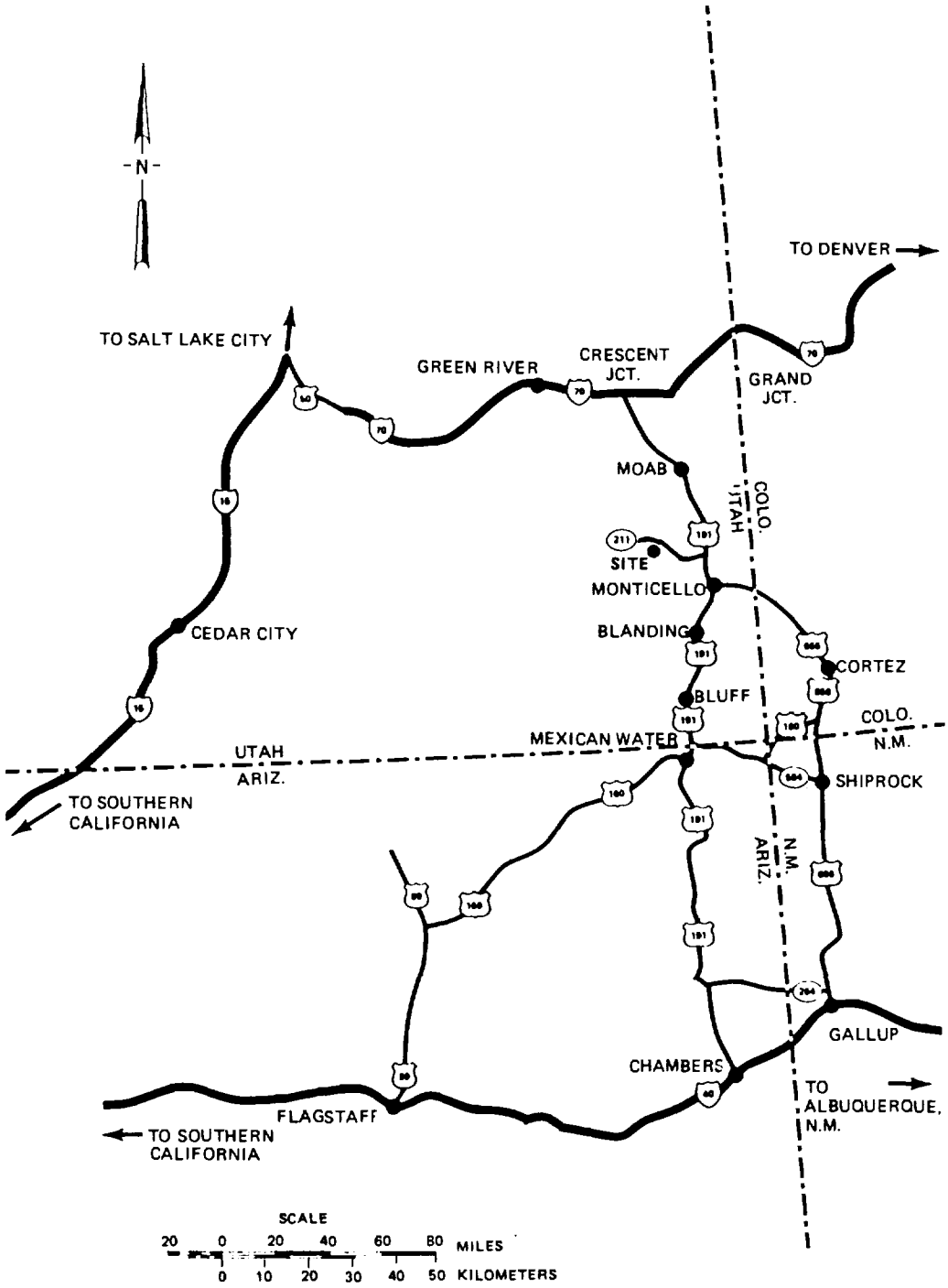
*The dose equivalent rate from background radiation at the site can also be compared with the limit of 25 millirem per year to the whole body from normal operations as given in 40 CFR Part 191.

Table 3-35. Dose Equivalent Rates From Background Radiation, Monticello, Utah

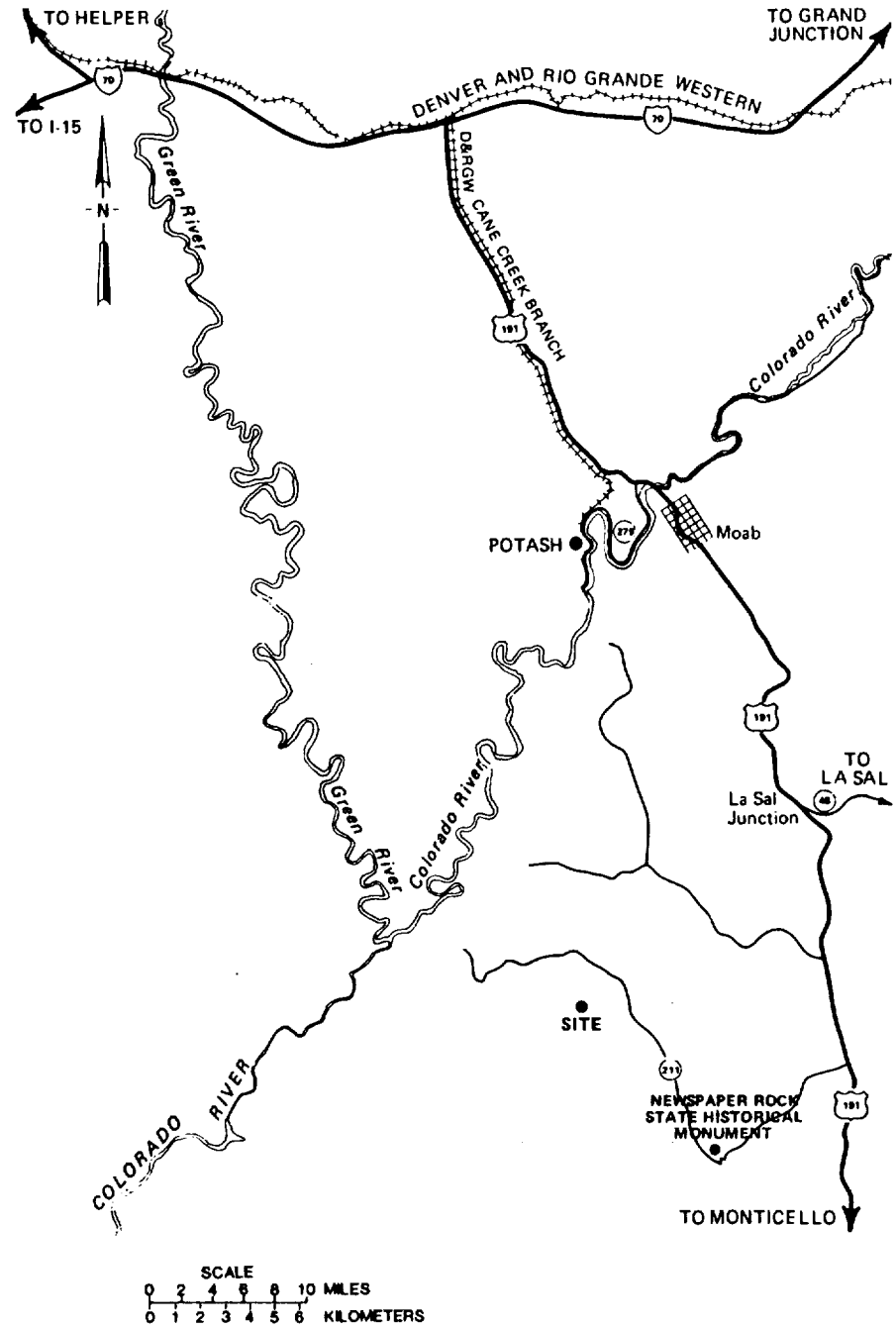
Source	Dose Equivalent Rate (millirem per year)
Cosmic rays	57
External terrestrial radiation	54
Weapons-test fallout	2
Total	113

Source: Beck, 1979, EML-362.



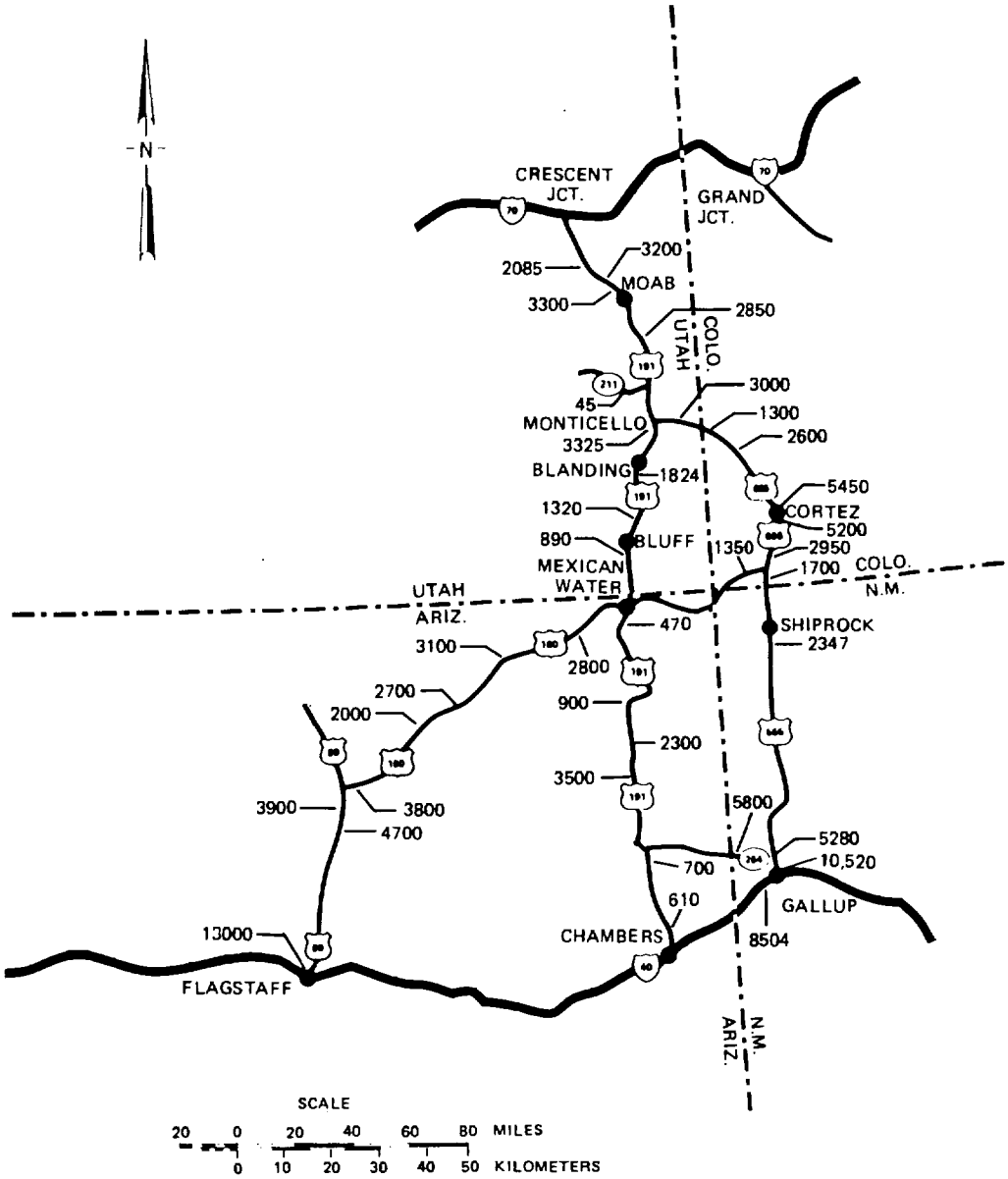
Regional Highway Network
Davis Canyon Area

Figure 3-76



Highways and Railroads
Davis Canyon Area

Figure 3-77



Sources: Arizona DOT, 1984;
Colorado DOT, 1984;
New Mexico DOT, 1983;
Martinez, 1985a,b.

Regional Highway Network
Traffic Counts
Annual Average Daily Traffic

Figure 3-78

The only direct route to the Davis Canyon area from I-70 is via U.S. 191 and Utah 211, a distance of 155 kilometers (97 miles). Most of U.S. 191 between I-70 and Utah 211 is a two-lane blacktop road with passing lanes on some grades. The capacity of U.S. 191 between Moab and the Utah 211 junction ranges from 1,000 to 1,820 vehicles per hour (level of service E; see Table 4-37 for levels of service definitions) except for five segments where capacity drops to 310 to 680 vehicles per hour. The aggregate length of these latter sections is approximately 6 kilometers (4 miles) (Martinez, 1985b). Commercial traffic accounted for 10 to 20 percent of the total AADT on this section.

The 1983 pavement testing program showed some sections of U.S. 191 to be in need of immediate (1 to 2 years) and near term (2 to 5 years) repair. Based on rideability, pavement on U.S. 191 between Utah 211 and I-70 is generally in poor condition (Martinez, 1985a).

From I-40 in New Mexico and Arizona, there are a number of alternative routes to the Davis Canyon area including: U.S. Highway 666 (U.S. 666) from Gallup, New Mexico, to its junction with U.S. 191 at Monticello, Utah; U.S. Highway 89 (U.S. 89) and U.S. Highway 160 (U.S. 160) from Flagstaff, Arizona to the junction of U.S. 191 at Mexican Water, Arizona; and an all U.S. 191 routing from Chambers, Arizona. The distances from these I-40 junctions to Davis Canyon range from 320 kilometers (200 miles) to 480 kilometers (300 miles).

Based on observations made during visits to the area, U.S. 666 appears to be the route preferred by truckers. It is the shortest route for traffic from the east via I-40. Between Gallup, New Mexico, and Monticello, U.S. 666 passes through Shiprock, New Mexico and Cortez, Colorado. It is a two-lane blacktop road with truck passing lanes on most hills. It has wider lanes and shoulders than most of U.S. 191 and, based on rideability, the pavement is in fair to good condition. Figure 3-78 shows the AADT on U.S. 666; truck traffic represents 5 to 11 percent of this total.

Most of U.S. 191 between I-40 at Chambers, Arizona, and its junction with Utah 211 in Utah is a two-lane blacktop road with passing lanes on some hills. The AADT on this section of U.S. 191 is also shown on Figure 3-78. Commercial vehicles accounted for 10 to 20 percent of the traffic. Between Chambers, Arizona and Utah 211 in Utah, U.S. 191 passes through Mexican Water, Arizona, and Bluff, Blanding, and Monticello, Utah.

U.S. 89 between Flagstaff, Arizona and the junction of U.S. 160 is a two-lane blacktop road with passing lanes on most hills. Commercial traffic comprises 7 to 11 percent of the AADT shown on Figure 3-78. U.S. 160 is a two-lane blacktop road passing through Tuba City and Kayenta, Arizona.

Major regional routes which could provide access to I-70 and I-40 consist of Interstate 15 (I-15) which runs through western Utah and the northwestern tip of Arizona and on into Nevada and southern California; and Interstate 25 (I-25), a north-south interstate in eastern Colorado and New Mexico connecting I-70 at Denver, Colorado, and I-40 at Albuquerque, New Mexico.

All of the roads described above, with the exception of Utah 211, have 36,400-kilogram (80,000-pound) load limits.

Table 3-36 shows the accidents on U.S. 191 and U.S. 666 from 1980 to 1984, and on Utah 211 in 1983. For comparison, the national rates in 1983 (the latest available data at the time of this writing) were 4.1 accidents per million vehicle miles, and 2.7 fatal accidents per 100 million vehicle miles.

3.5.2 Railroads

The nearest rail line to the site (Figure 3-77) is the Cane Creek branch of the Denver & Rio Grande Western Railroad (D&RGW). This 57.5-kilometer (35.7-mile) line extends south from the D&RGW main line at Crescent Junction, Utah (Railroad station, Brendel) to Potash, the

Table 3-36. Accident History, Area Highways

Route	Year	Between	Accidents		Fatal Accidents	
			Number	Rate[a]	Number	Rate[b]
U.S. 191	1984	Monticello and I-70	82	1.06	1	1.29
	1983	Monticello and I-70	64	0.80	1	1.24
	1983	Utah 211 and I-70	55	0.83	1	1.15
	1982	Monticello and I-70	84	1.04	-	-
	1981	Utah 211 and I-70	95	-	1	-
	1980	Utah 211 and I-70	96	1.24	4	5.18
U.S. 666	1984	Monticello and Colorado State Line	15	1.78	0	0
	1983	Monticello and Colorado State Line	8	0.94	0	0
	1982	Monticello and Colorado State Line	6	0.70	-	-
	1981	Monticello and Colorado State Line	8	0.91	1	11.44
	1980	Monticello and Colorado State Line	8	1.0	0	0
Utah 211	1983	U.S. 191 Junction and Junction of NPS extension	0	0	0	0

(a) Per million vehicle miles.
(b) Per 100 million vehicle miles.

Source: Martinez, 1985b.

line's southern terminus located on the north bank of the Colorado River west of Moab (BGI, 1984, ONWI-471, pp. 13-29).

Train service is provided on an "as needed" basis (1 to 3 times per week), normally by local trains originating in Grand Junction, Colorado, or Helper, Utah. The rail line can handle 4-axle cars grossing 119,300 kilograms (263,000 pounds), equivalent to a nominal 90-metric ton (100-ton) payload.

Potash is approximately 47 straight-line kilometers (29 miles) north of Davis Canyon, and the connection with the main line is 57.5 rail-line kilometers (35.7 miles) farther. No other rail lines are near the site. A Union Pacific mainline is approximately 270 straight-line kilometers (168 miles) to the west in western Utah, and an Atchison, Topeka, and Santa Fe main-line is approximately 338 straight-line kilometers (210 miles) to the south in Arizona.

3.5.3 Airports

Figure 3-79 shows the location of airports in southeastern Utah and western Colorado relative to the Davis Canyon site. Descriptions of the airports are provided in Table 3-37.

The largest of these airports are in western Colorado at Grand Junction and Cortez. Walker Field Regional Airport (serving Grand Junction) is the largest airport between Denver, Colorado, and Salt Lake City, Utah. Its 3,200-meter (10,500-foot) runway can accommodate a Boeing 727-200 aircraft. Four scheduled airlines provide 15 daily round trips to Denver, Colorado; Salt Lake City, Utah; Durango, Colorado; and Phoenix, Arizona (Official Airline Guides, 1985).

The Cortez-Montezuma County Airport is located 6 kilometers (4 miles) southwest of Cortez. It is owned jointly by the city of Cortez and Montezuma County. Trans Colorado Airlines provides three daily round-trip flights to Durango and Denver (Official Airline Guides, 1985). Airport facilities will be upgraded during the next 15 years to include a parallel runway and a cross-wind runway. Additional hangars will be added as traffic warrants (Hager, 1984).

Southeastern Utah airports are all located west of and adjacent to U.S. 191. These include: Canyonland Field (27 kilometers [17 miles] northwest of Moab); San Juan County Airport (6 kilometers [4 miles] north of Monticello); Blanding Municipal (5 kilometers [3 miles] south of Blanding); and Bluff Airport (8 kilometers [5 miles] southwest of Bluff).

Commercial airline service between Salt Lake City and the airports at Moab (Canyonland Field) Monticello and Blanding is currently (June, 1985) provided by Alpine Air, offering two round-trips daily, Monday through Friday.

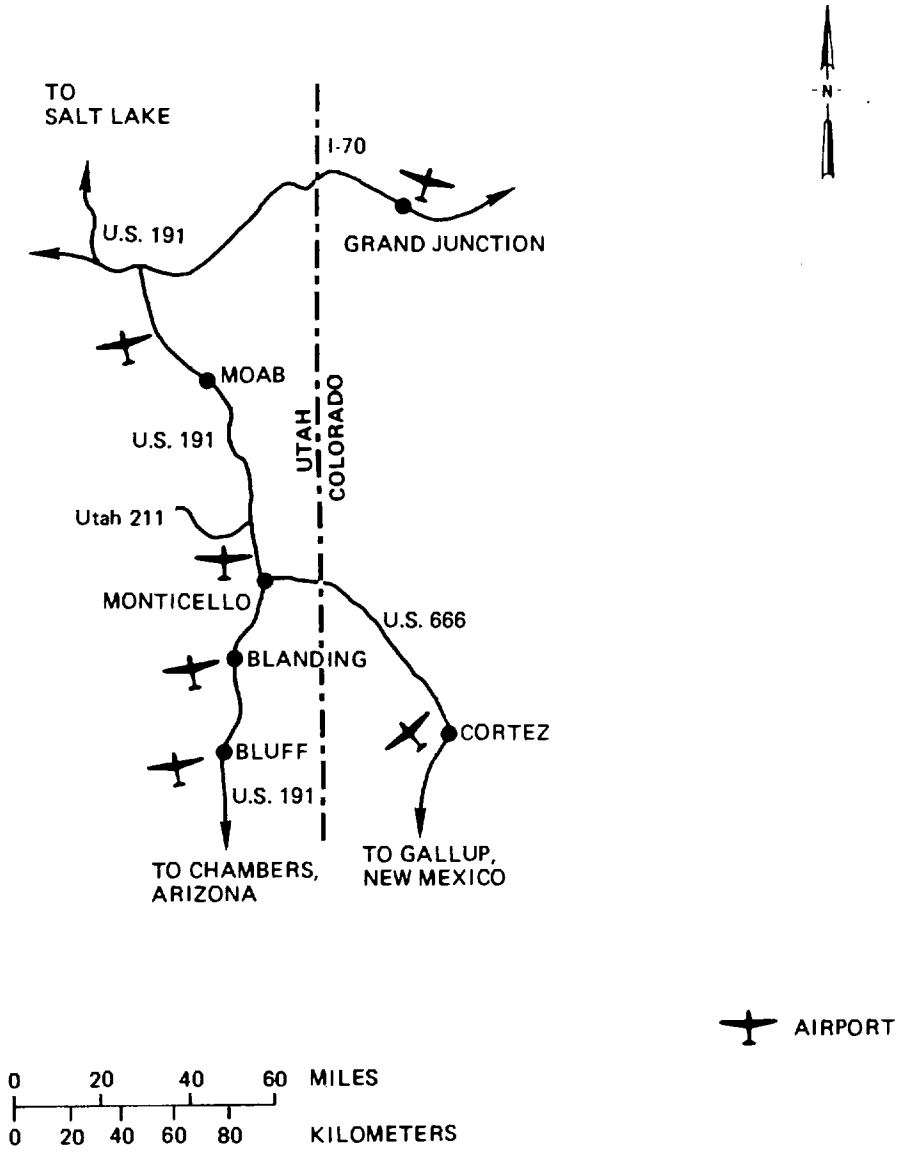
A privately owned airstrip at La Sal Junction was previously, but is not now, open to the public. A 1,460-meter (4,800-foot) dirt airstrip at the eastern edge of Canyonlands National Park, approximately 10 kilometers (6 miles) from the Davis Canyon site, is occasionally used.

3.5.4 Waterways

No navigable waterways for commercial use are located in the vicinity of Davis Canyon.

3.5.5 Utilities

No major utility lines exist within Davis Canyon. Three electrical transmission lines (Figure 3-80) (345 kV, 135 kV, and 69 kV) run roughly parallel to U.S. Highway 191. These lines are owned by Utah Power and Light and are 26 to 29 kilometers (16 to 18 miles) east of the Davis Canyon site (BGI, 1982, ONWI-144, p. 225). Two gas lines are located approximately 29 kilometers (18 miles) east of the site. A 26-inch line, owned by the Northwest Pipeline Company, runs in a southeast to northwest direction and crosses the electrical transmission



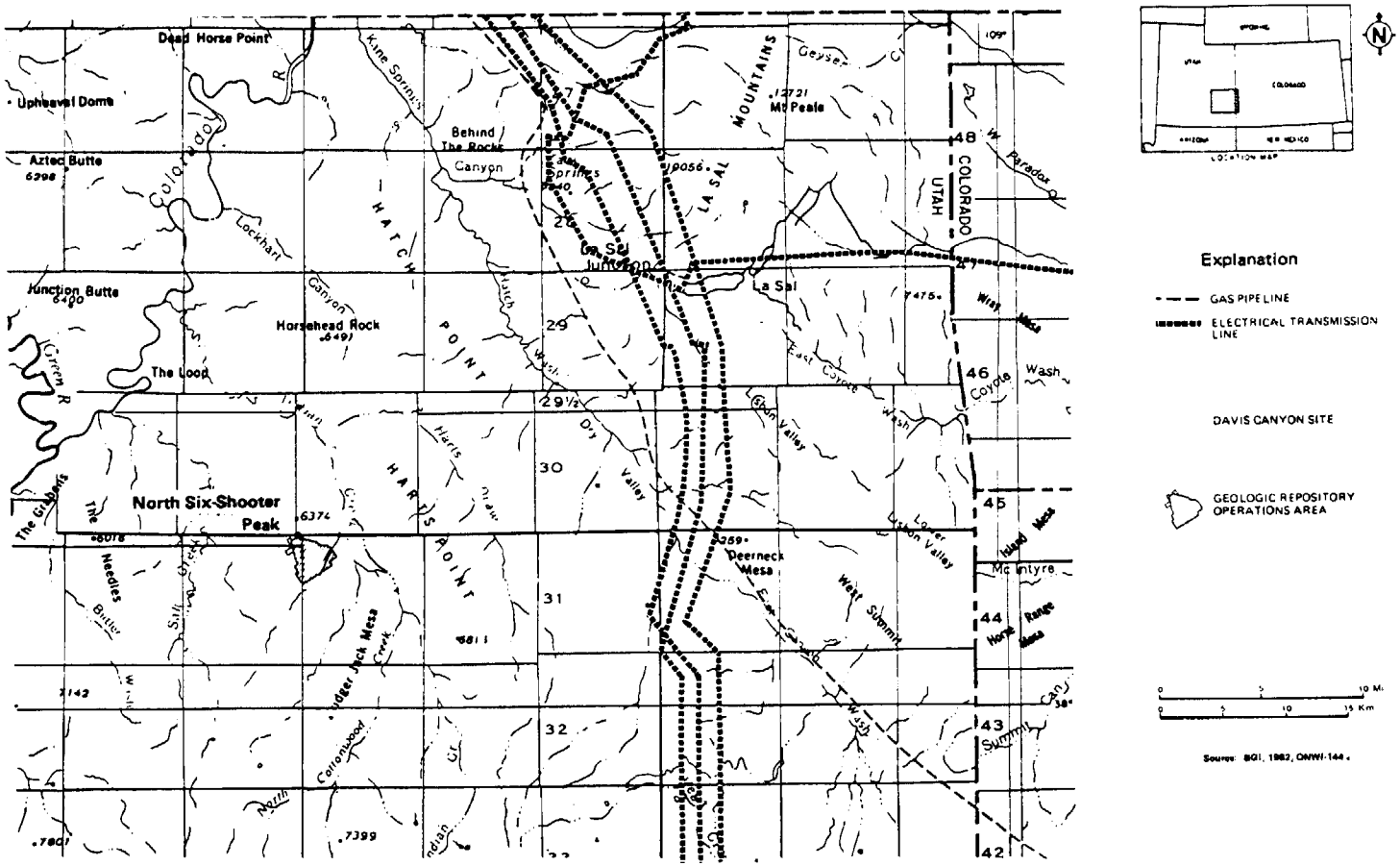
Area Airports

Figure 3-79

Table 3-37. Description of Airports in Paradox Basin Area

Name of Airport	Walker Field	Cortez-Montezuma	Canyonland Field	San Juan County	Blanding Municipal	Bluff
Location	4 miles northeast of Grand Junction, CO	3 miles southwest of Cortez, CO	17 miles northwest of Moab, Utah	4 miles north of Monticello, Utah	3 miles south of Blanding, Utah	5 miles south of Bluff, Utah
Elevation (feet)	4,858	5,914	4,574	6,996	5,865	4,476
Runways (feet)	1-10,500 x 150 1-5,366 x 100	1-7,200 x 100	1-6,900 x 150	1-4,800 x 75	1-6,000 x 75	1-4,000 x 50
Runway Surface	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt	Dirt
Lights	Beacon, runway	Beacon, runway	Beacon, runway	Beacon, runway	Beacon, runway	None
Hours Attended	24	Daylight	Daylight	24	24	None
Services:						
Fuel service	Yes	Yes	Yes	Yes	Yes	No
Repair	Major	Yes	Yes	No	Yes	No
Storage	Hangars, tiedowns	Hangars, tiedowns	Tiedowns	Tiedowns	Hangars, tiedowns	Tiedowns
Charter	Yes	Yes	Yes	Yes	Yes	No
Flight instruction	Yes	Yes	Yes	Yes	Yes	No
Plane rental	Yes	Yes	Yes	Yes	Yes	No

Source: Utah Department of Transportation, 1980.



Utilities

Figure 3-80

lines at Deerneck Mesa. Parallel to this line is a 10-inch pipeline owned by MAPCO. The Davis Canyon site has no telephone service, but a microwave repeater station is available for radio communication.

3.6 SOCIOECONOMIC CONDITIONS

The Davis Canyon site is located in northwestern San Juan County in southeastern Utah, close to Colorado, New Mexico, and Arizona. San Juan and Grand Counties, Utah, are considered to comprise the socioeconomic study area. The socioeconomic study area is defined as the approximate region within which in-migrating workers would be willing to commute on a daily basis to the site. This section summarizes significant socioeconomic characteristics of these counties, including descriptions of the demography, economy, services and facilities, and government and fiscal arrangements. Within these counties, socioeconomic baseline characteristics focus on three communities: Moab in Grand County, and Monticello and Blanding in San Juan County (Figure 3-1). These communities are the major population centers located in the vicinity. Other small communities are also located in these counties; data for these areas are presented as available and applicable. Unless otherwise noted, the following information on socioeconomic conditions is from BGI (1984, ONWI-471).

3.6.1 Population Density and Distribution

This section presents a description of population characteristics, population projections, and density within cities and towns surrounding the Davis Canyon site.

3.6.1.1 Population Density

Figure 3-81 presents the population distribution used for the radiological analysis. This demographic discussion of the site is formatted to conform with meteorological data, which aids in the radiological assessment. Specifically, the area within a 80-kilometer (50-mile) radius of the site is divided into (1) 16 compass sectors; and (2) 0 to 10, 10 to 20, 20 to 30, 30 to 40, and 40 to 50 mile annuli. This circular grid is then superimposed on a map of the area to calculate the population in each grid segment.

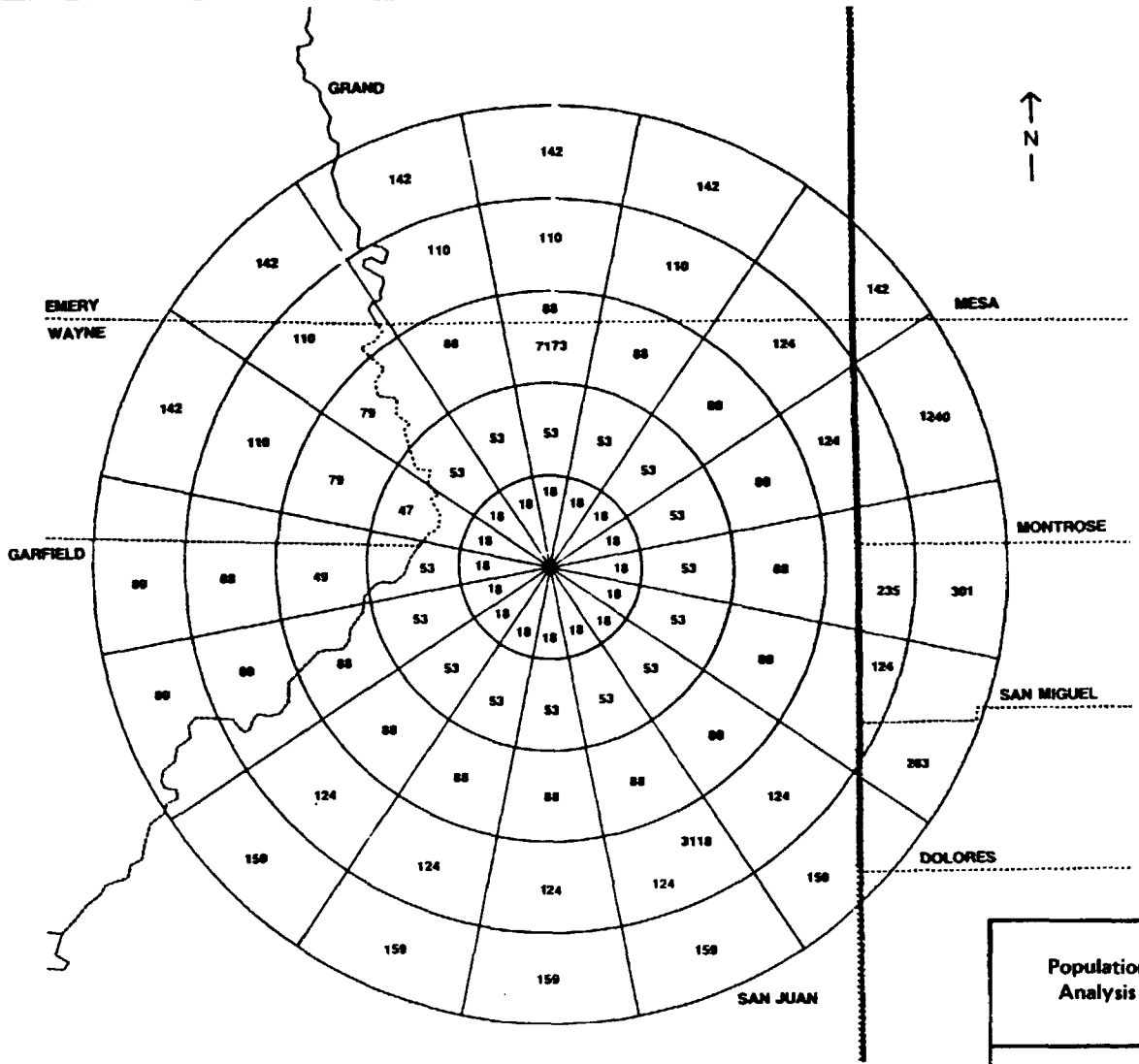
The population values within each segment of the poplation diagram are calculated by the following method: (1) subtracting the contributions of population centers from the total county population to establish a rural population; (2) dividing this rural population value by the county area to get a rural population density; (3) multiplying this rural density by the area represented by the segment; and (4) recording this value, along with the population center values for the centers which occur inside the segment, on the diagram.

Table 3-38 shows the number of persons per square mile for Grand and San Juan Counties, Moab, Monticello, Blanding, and the State of Utah. Density of study area counties is considerably lower than the State average, reflecting the rural nature of this area. Most of the population of both counties is centered in the cities and towns.

The population density in the immediate vicinity of the site is low. The nearest residences to the site are: (1) the Dugout Ranch, located 9.5 kilometers (6 miles) away; (2) a private resort, which is 9.6 kilometers (6 miles) away; and (3) the National Park Service ranger residences, which are located 10.6 kilometers (6.6 miles) away.

3.6.1.2 Population Distribution

The population of Grand County increased approximately 5 percent between 1960 and 1970, and 23 percent between 1970 and 1980. In Grand County, the urban population increased approximately 2 percent between 1960 and 1970 and 11 percent between 1970 and 1980. Urban populations are defined as incorporated areas with 2,500 or more persons. This growth in urban population is reflected in the growth in Moab, the only urban community in Grand County.



Population Distribution for Radiological Analysis for Davis Canyon Study Area

Figure 3-81

Table 3-38. Persons per Square Mile, Grand and San Juan Counties

Jurisdiction	Land Area (square miles)	Persons Per Square Mile (1980)
Grand County	3,689.00	2.2
San Juan County	7,725.00	1.6
Moab	3.01	1,771.8
Monticello	2.7	714
Blanding	1.58	1,973.4
Utah	82,073.00	17.8

Source: BGI, 1984, ONWI-471.

The population of San Juan County increased approximately 6 percent between 1960 and 1970, and nearly 28 percent between 1970 and 1980. All of San Juan County was classified rural in 1960 and 1970 because communities did not meet the 2,500 urban population criterion. However, urban population in San Juan County in 1980 represented 25 percent of the total County population (3,118 persons). This urban population results from the growth in Blanding between 1970 and 1980.

The Utah Population Estimates Committee (Barber et al., 1985) prepared 1984 estimates of the population in Utah counties. The methodology used to estimate county population included Latter Day Saints Church membership, school enrollment, and Federal tax return net exemption data. Using this method, Grand County had a 1984 population estimate of 7,600 and San Juan was estimated to have 12,600 people. Between 1980 and 1984 Grand County lost approximately 640 inhabitants while San Juan County gained 350 residents. The primary reason for the recent decline in population growth for both of these counties (San Juan actually lost about 300 residents between 1983 and 1984) has been the recent decline in the uranium mining industry (Prall and Teuscher, 1984).

3.6.1.3 Population Projections

The State of Utah's Office of Planning and Budget (1985) has prepared long-term baseline population projections using the Utah Process Economic and Demographic (UPED) model. The State's projections for Grand and San Juan Counties included the years 1990, 2000, and 2010. These projections were used to prepare Table 3-39. Some of the major underlying assumptions that were used by the State of Utah include the following:

- No future synthetic fuels or nuclear waste repository development for southeastern Utah
- Constant age-specific fertility rates (3.14 average births per woman throughout her childbearing years)
- Constant age-specific mortality rates
- Employment-related migration concentrated in early adult ages
- Constant age-sex specific household formation probabilities
- Increasing labor force participation rates, trending toward increasing national projections.

3.6.1.4 Population Characteristics and Temporary Population

Both Grand and San Juan Counties are rural areas with small towns distributed along the highways. The 1980 populations of the study area counties and incorporated communities are shown in Table 3-40. The unincorporated community of Spanish Valley is adjacent to Moab. Its 1980 population was 1,840 persons. La Sal, an unincorporated community in Grand County, had about 100 persons. Table 3-41 presents the age, race, and gender distribution of the study area counties. The male to female ratio for the study area averaged 1.005, while the State's average was 0.984.

Indian reservations within the study area consist of portions of the Ute Indian tribe of the Uintah and Ouray reservation in the northeastern portion of Grand County and part of the Navajo Indian tribal lands in southern San Juan County. A portion of the Ute Indian reservation within Grand County (485,640 hectares [1,200,000 acres]) is part of the Hill Creek Extension Area. The entire reservation is reserved for tribal members only; only fishing and other recreational activities are allowed, and no surface roads or settlements exist in the Hill Creek extension (Bureau of Indian Affairs, 1980, p. 4).

Table 3-39. Population Projections: Counties and Incorporated Communities

Location	1980 Actual	1984 Estimate	1997[b] Projection	2006[b] Projection
Grand County	8,241	7,600	8,575	9,520
Moab	7,173[a]	6,620	7,464	8,290
San Juan County	12,253	12,600	15,455	16,880
Monticello	1,929	1,980	2,433	2,660
Blanding	3,118	3,210	3,933	4,300

(a) Moab population count includes Spanish Valley.
(b) Interpolated from state of Utah decennial estimates.
(c) Incorporated communities were allocated 1997 and 2006 populations based upon their 1980 share.

Sources: Prall and Teuscher, 1984; BGI, 1984, ONWI-471.

Table 3-40. Populations of Study Area Counties and Incorporated Communities

City/County	1980 Population	% Change from 1970
Grand County	8,241	+23
Moab	5,333	+11
San Juan County	12,253	+28
Monticello	1,929	+35
Blanding	3,118	+39

Source: BGI, 1984, ONWI-471.

Table 3-41. 1980 Population Characteristics, Davis Canyon Area

	Total		White		Spanish Origin[a]		American Indian[b]	
	Male	Female	Male	Female	Male	Female	Male	Female
Grand County								
Total Persons	4,131	4,110	3,993	3,973	177	176	--	--
Under 5 years	505	477	485	450	31	35		
5-14	718	760	684	728	35	37		
15-19	359	378	347	364	21	21		
20-24	404	380	382	365	28	19		
25-64	1,887	1,829	1,840	1,783	57	59		
65 and older	258	286	255	283	5	5		
San Juan County								
Total Persons	6,147	6,106	3,272	3,153	215	218	2,760	2,839
Under 5 years	947	917	542	485	40	53	399	408
5-14	1,595	1,456	700	647	52	51	870	785
15-19	686	662	295	279	21	22	377	373
20-24	480	515	256	270	17	12	220	236
25-64	2,132	2,236	1,286	1,252	79	70	794	941
65 and older	307	320	193	220	6	10	111	96

(a) Persons of Spanish Origin may be of any race.
(b) Only listed for counties with 400 or more of the specified group.

Source: Bureau of the Census, 1982a.

In 1980, 5,599 American Indians lived in San Juan County. Of these persons, 4,539 lived on the Navajo Indian reservation in San Juan County. American Indians accounted for 46 percent of the San Juan County inhabitants. In Grand County, less than 4 percent of the population were nonwhite, and American Indians accounted for only 2 percent of the total county population. The Native American population of Moab in 1980 was 2 percent of the city's total. Monticello's American Indian population was about 4 percent of its total population. Blanding had a substantial American Indian population with Native Americans representing 17 percent of its total (Bureau of the Census, 1982a).

The temporary population within the study area includes visitors to Lake Powell, Arches National Park, Canyonlands National Park, Natural Bridges National Monument, Edge of the Cedars State Park, Monument Valley, and other recreation areas in Grand and San Juan Counties. According to the Institute of Outdoor Recreation and Tourism at Utah State University, approximately 352,000 out-of-state tourists (Hunt and Cadez, 1981a) and 215,000 in-state recreationists (Hunt and Cadez, 1981b) visited attractions in the region during 1981. This excludes recreation visits by persons living in the two counties.

3.6.2 Economic Conditions

Moab, Blanding, and Monticello are intermediate market centers. Moab, the principal community of Grand County, is connected to the Grand Junction, Colorado, market. The Monticello and Blanding area of San Juan County deals economically with Cortez, Colorado (Prall and Teuscher, 1984). This means that the businesses and people of Grand and San Juan Counties go to Grand Junction or Cortez to purchase some of the goods and services they require.

The following economic information focuses on the economies of Grand and San Juan Counties, because these counties contain the area where potential project-related in-migration would be located. This information includes data on employment, income levels, economic trends, and tourism.

3.6.2.1 Employment by Sector

Mining, trade and government have been the major employers in Grand and San Juan Counties (Table 3-42). Mining has played an important role throughout the last decade, averaging about one-third of nonagricultural employment in San Juan and Grand Counties. In recent years mining and construction employment has declined significantly. At the same time, the government sector has increased.

The average male labor force participation rate is 79 percent in the study area, while the average female labor force participation rate is 43 percent (Bureau of the Census, 1983, pp. Utah 13-17).

3.6.2.2 Unemployment

Until recently, San Juan County has historically had a higher rate of unemployment than Grand County (see Table 3-42). This was probably attributable in part to the higher unemployment rate among the large Native American population in San Juan County. According to statistics provided by the Tribal Office Centers in Shiprock, New Mexico, and Yuba City, Arizona, the unofficial rate of unemployment among the Navajo population was 35 to 50 percent in 1980 (Bureau of Indian Affairs, 1980).

The unemployment rate has increased dramatically in the study area since 1980, with Grand County having nearly twice the State average. The primary reason for the higher rates of unemployment for both Grand and San Juan Counties has been the decreasing demand for uranium (see Table 3-43). For example, a large mill in Moab, which employed over 500 people in 1980, recently suspended its mining and milling operations.

Table 3-42. Economic Characteristics of Grand and San Juan Counties, 1970-1984

	Grand County				San Juan County			
	1970	1980	1983	1984	1970	1980	1983	1984
Labor Force	2,680	4,010	3,630	3,170	3,020	4,170	4,020	4,070
Employed	2,550	3,730	2,970	2,660	2,690	3,910	3,490	3,630
Unemployed	130	280	660	510	330	260	530	440
Unemployment Rate	4.85	6.90	18.00	16.00	10.93	6.30	13.10	10.70
Total Nonagricultural	2,170	3,270	2,370	2,266	1,780	3,330	2,920	2,990
Employment by Sector[a]								
Manufacturing	80	70	40	60	NA	180	130	150
Mining	500	740	470	380	370	1,200	590	500
Construction	160	350	90	70	NA	160	210	180
Transportation and Public Utilities	190	250	180	180	120	160	190	110
Wholesale and Retail Trade	400	810	660	620	280	380	390	420
Finance, Insurance, and Real Estate	50	90	80	80	NA	30	40	40
Service	340	400	360	370	190	360	390	570
Government	440	580	490	510	560	870	980	1020
Per Capita Income	3,145	8,543	7,937	NA	1,878	4,849	5,271	NA

(a) Totals may not add due to rounding.

Source: Utah Department of Employment Security, 1985.

The unemployment rate has dropped slightly since 1983. However, this reflects the considerable out-migration which has occurred in the study area (Barber et al., 1985).

3.6.2.3 Per Capita Income Trends

In 1980, Grand County's per capita income was considerably higher than the State's average of $7,600 and San Juan's per capita income was considerably lower. By 1983, Grand County's per capita income had dropped well below the State average of $9,210 (Utah Department of Employment Security, 1985). The noticeable drop in per capita income for Grand County was caused mainly by the decrease in mining employment. This has resulted in increased unemployment and underemployment when some workers replaced higher paying mining jobs with lower paying jobs.

The continued lower per capita income trends in San Juan County are in part due to Native American population unemployment rates. While recent oil drilling and exploration activities around Aneth in southeastern San Juan County have helped Navajos gain some unexpected income, it has not eased their economic plight (Weber State College, 1981).

3.6.2.4 Tourism

An indicator of the contribution of tourism to local government revenues in the socio-economic study area is the transient room tax. This is entirely a local revenue tax which funds the Grand and San Juan County Travel Councils. Approximately $79,000 was generated in transient room taxes in 1982 in Grand County, with over 71 percent generated during the April to September "tourist season" (Table 3-44). In 1982, San Juan County collected approximately $19,000 in transient room taxes with 72 percent generated between April and September.

A more important indicator is the level of gross sales and employment attributed to tourism. They can illustrate the relative importance of tourism in the two-county economy.

In 1981, the Institute of Outdoor Recreation and Tourism surveyed tourists and other travelers passing through the Canyonlands Travel Region (Grand and San Juan Counties). The Institute's analysis of the information appears in several reports prepared for the Utah Department of Community and Economic Development, Division of Travel Development. Utah Tourism Motor Vehicle Travel (Hunt and Cadez, 1981a), Utah Resident Recreation Travel (Hunt and Cadez, 1981b), and computer printouts by the Canyonlands Travel Region of the data represent the most comprehensive evaluation of tourism expenditures currently available. Because 1980-81 is the base year of their study, expenditures provided are in 1981 dollars.

Visitor-use information for Canyonlands National Park is provided by a National Park Service (NPS) survey completed in 1978 (Davidson-Peterson and PBQ&D, 1978). It is the most complete report on the districts within the park.

An analysis of findings on the Canyonlands Travel Region and Canyonlands National Park reveals the following:

Visitation

1. A 1979 survey (Heritage Conservation and Recreation Service, 1979) indicated that 75 percent of the Canyonlands National Park visitors were nonresidents of Utah.

2. In 1981, 42,100 persons visited the Needles District and 40,485 visited the Island-in-the-Sky District (NPS, 1981b). (For percentages of visitors to selected points of interest in the Needles District see Figure 3-82; for the Island-in-the-Sky District see Figure 3-83.)

Table 3-43. Unemployment Rate Estimates in Uranium Industry in Grand and San Juan Counties (based on monthly claims)

Location	Unemployment Rates (%)			
	March 1981	March 1982	March 1983	May 1983
Grand County	8	29	41	39
San Juan County	3	9	32	35

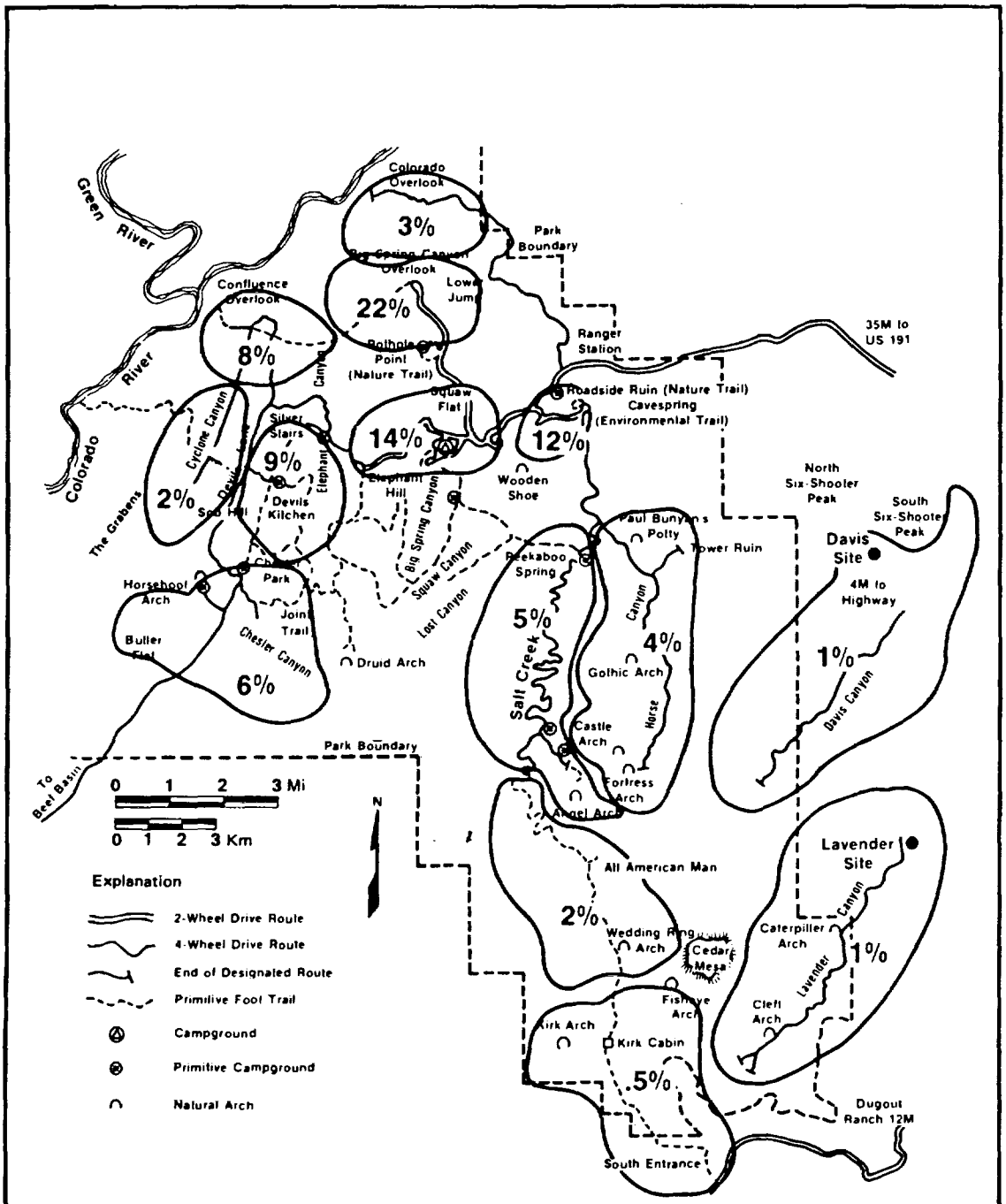
Source: Rimmasch, 1984.

Table 3-44. Transient Room Tax, Grand and San Juan Counties

Location	Transient Room Tax by Quarter (dollars)					
	1Q82	2Q82	3Q82	4Q82	1982 Totals	1Q83
Grand County	9,931	27,259	28,875	12,745	78,810	7,527
San Juan County	1,999	5,994	7,481	3,295	18,770	2,134

Note: Quarters comprise the following months:
First: January through March
Second: April through June
Third: July through September
Fourth: October through December.

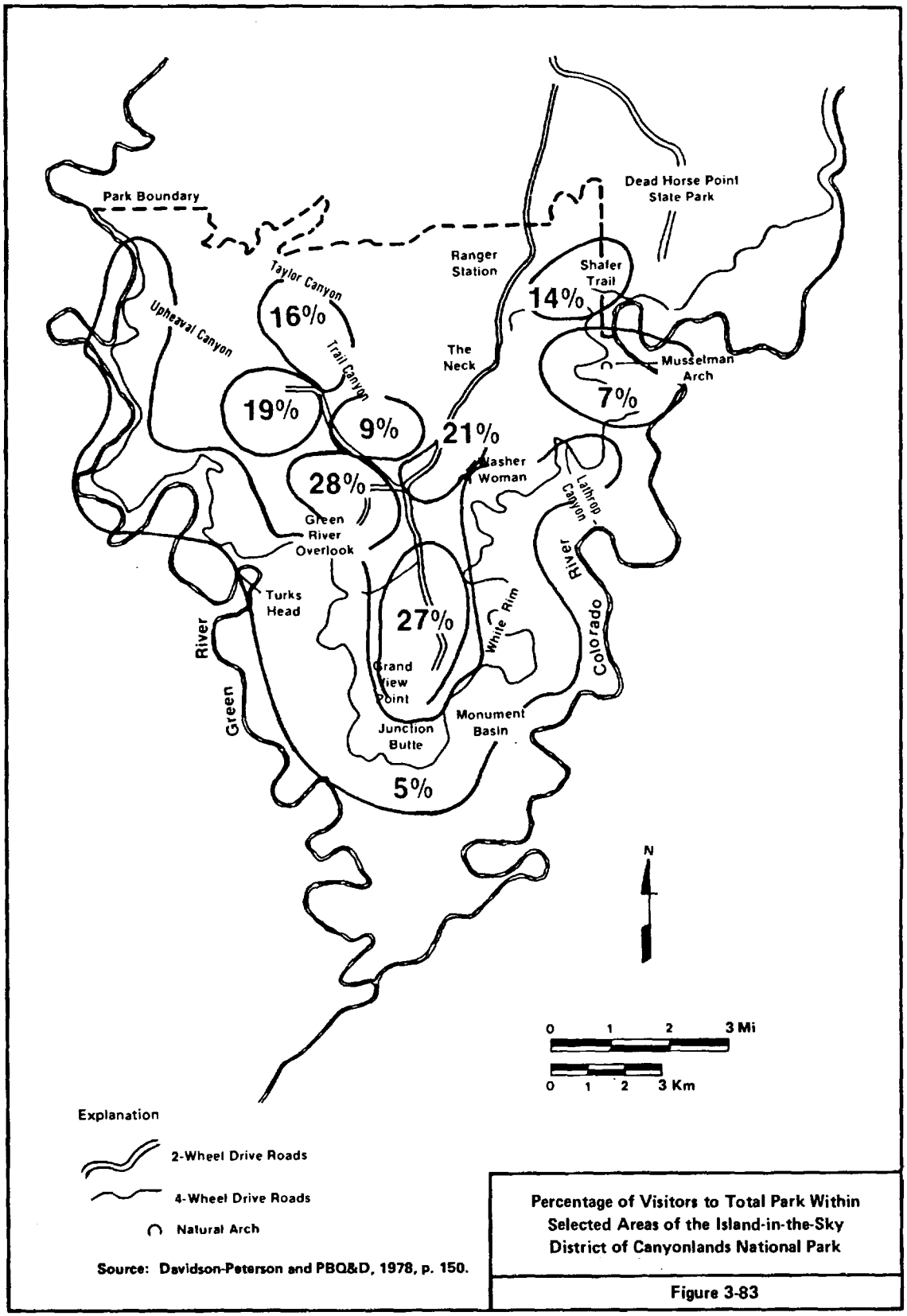
Source: BGI, 1984, ONWI-471.



Percentage of Visitors to Total Park Within Selected Areas of the Needles District of Canyonlands National Park

Source: Davidson-Peterson and PBQ&D, 1978, pp. 221, 227, 228.

Figure 3-82



Source: Davidson-Peterson and PBQ&D, 1978, p. 150.

Percentage of Visitors to Total Park Within Selected Areas of the Island-in-the-Sky District of Canyonlands National Park

Figure 3-83

3. Of the visitors to the Needles District, 40 percent were primarily drawn to the region to see Canyonlands National Park, whereas 27 percent of the Island-in-the-Sky visitors had Canyonlands National Park as their primary destination (Davidson-Peterson and PBQ&D, 1978, p. 189).

4. In 1981, 28,000 visitors coming to the Canyonlands Travel Region to see tourist sights were attracted to the area primarily to see Canyonlands National Park.

5. Getting away from people is a major in-park activity for visitors to the Needles and the Island-in-the-Sky Districts of Canyonlands National Park (Davidson-Peterson and PBQ&D, 1978, p. 207).

6. Of the commercial trips that enter Cataract Canyon 82 percent Launch on the Colorado River at Potash or Moab (NPS, 1981a).

7. In 1980, there were 5,500 passengers on commercial river trips. Of the commercial passengers 80 percent were on motorized rather than oar-powered trips (NPS, 1981a).

Expenditures

1. Each nonresident tourist visiting the region's attractions spent an average of $33.95 in the local economy per visit. This was considerably higher than the average expenditure for a nonresident tourist who was traversing the region ($0.69). The percentage of expenditures for nonresident tourists included: 25.4 percent for food items, 22.5 percent for lodging, 32.5 percent for transportation, and 19.6 percent for other (retail, entertainment, and services).

2. Each Utah resident recreationist spent approximately $10.80 in the local economy per visit to the region. The percentage of expenditures for Utah residents touring the region included: 24.8 percent for food, 6.7 percent for lodging, 28.3 percent for transportation, and 40.2 percent for other retail purchases.

3. Full-time NPS employees at Canyonlands National Park earned an average annual salary of $20,000 (Parry, 1984). There were 23 full-time employees and 14 seasonal employees (Wylie, 1984). Assuming seasonal employees earned half the salary of full-time employees, total wages for Canyonlands employees were $600,000 (1984 dollars).

4. The gross-sales-to-employment ratio was equal to $18,000 for one employee when all the sectors of the local economy were considered. The gross-sales-to-employee ratio for the retail and service sectors of Grand and San Juan Counties was $35,000 spent for one employee (BGI, 1984, ONWI-471).

5. The 1981 local gross taxable sales in the retail and service sectors for Grand and San Juan Counties totaled $57,186,000 while the gross taxable sales from all sectors totaled $124,452,000.

6. Total tourist expenditures in the Canyonlands Travel Region from resident and nonresident sources was $16,609,800 (Hunt and Cadez, 1981a, b). These direct expenditures represent approximately 30 percent of the local gross taxable sales in the retail and service sectors of the two-county economy, and 13 percent of gross sales from all sectors.

7. River trip user expenses vary in accordance with the length of the trip. If an average of $400 (1981 dollars) per passenger per 5-day trip is assumed, the expenditures attributed to trips which originated with Moab river-running firms would be about $1,804,000. However, not all of the commercial launches from

Moab enter Canyonlands National Park. Strait (1985) suggests that the commercial white water trips through Cataract Canyon at the park averaged $1,022,390 annually for the past 7 years.

Based on resident and nonresident per capita expenditures and the number of resident and nonresident tourists who came to the region primarily to see the Needles and Island-in-the-Sky Districts of the park, the expenditures total $845,000. Using primary destination as the basis for determining economic impact avoids double-counting persons who came to the region primarily to see Arches National Park or other area attractions. The proportion of the $845,000 spent by Needles District visitors was about 60 percent or $507,000. When the expenditures of Colorado River visitors who launched from the Moab area are included, the total expenditures would be approximately $2,650,000 (1981 dollars).

The potential expenditures by Canyonlands National Park employees would be less than the projected wages of $600,000 because some of these wages would be used for savings and some would be used for purchases outside the region. (The $600,000 would also be lowered if it were changed to 1981 dollars.) Even if all of these wages were converted to local purchases, both Canyonlands National Park employee expenditures and tourist expenditures together would represent only about 3 percent of the gross taxable sales from all sectors of the local economy. Direct tourist expenditures for Canyonlands National Park and the river-running industry in Moab would account for 16 percent of the direct tourist expenditures in the two-county region.

Employment

1. During 1980, employment for Grand and San Juan Counties totaled 6,955 jobs (BGI, 1984, ONWI-471).

2. During 1981 seasonal employment in Grand and San Juan Counties for food stores, eating and drinking establishments, hotels and motels, gasoline service stations, amusements, and retail stores totaled 250 jobs (Utah Department of Employment Security, 1984).

3. The total of indirect employment multipliers for retail trade in Utah was 0.6. For hotels it was 0.5, and for amusements it was 0.8 (Bradley and Fjeldsted, 1975). For example, each new directly induced job in the hotel industry also is indirectly responsible for 0.5 additional job in the local economy.

4. The total person-years of employment equated with direct expenditures would be equal to total tourism expenditures divided by the employment-to-sales ratio for the retail and service sectors. This is equal to 475 person-years ($16,609,800 divided by $35,000 per employee). When this is converted to full-time and seasonal employment, it is responsible for the equivalent of 300 full-time and 250 seasonal workers. (This assumes that all seasonal jobs are a direct result of tourism expenditures.)

5. Tourism employment also is created by the State and Federal governments, which employ persons to develop, manage, and maintain area tourist attractions. Government employees serving the recreational areas within Grand and San Juan Counties numbered approximately 100 full-time and 50 seasonal personnel. This includes employees of the National Park Service, National Forest Service, State parks, and Bureau of Land Management (Spahr, 1984; Jensen, 1984; Bistryski, 1984; Minor, 1984; Wylie, 1984).

In terms of direct employment based on tourist expenditures, when the gross retail and service sector sales to employment ratio is used, 76 person-years of employment results. This is equivalent to about 48 full-time and 40 seasonal employees. Tourism also has indirect employment effects on the local economy as the persons directly employed and the businesses in which they are employed purchase goods and services at other local businesses. The largest retail-sector indirect employment multiplier was 0.8 for amusement establishments. If this

multiplier is assumed for tourism, an additional 38 full-time and 32 seasonal employees would result. NPS employees working at Canyonlands National Park included 23 full-time and 14 seasonal. Since their consumption would not be confined to the retail and service sectors of the local economy, the employment to gross sales ratio for all sectors could be used to compute the magnitude of the indirect employment created by their local purchases. This calculation results in 33 person-years of employment.

For the year 1981, the estimated total person-years of direct and indirect employment resulting from Canyonlands National Park visitors and river-runners from Moab would have been about 200. This is equal to about 3 percent of the 1981 Grand and San Juan County employment.

The preceding analyses are based upon secondary data sources. While there is some uncertainty, it can be inferred that the results show the approximate economic importance of the park and its associated activities within the total Canyonlands Travel Region.

According to Hunt and Cadez (1981a), the level of tourist expenditures dropped considerably between 1978 and 1981. In fact, the Canyonlands Travel Region was the only one of the nine state-designated travel regions where absolute decreases in tourist expenditures occurred. During that same period, the local economy's gross taxable sales increased. Although tourism expenditures decreased during those years in which the Institute of Outdoor Recreation and Tourism surveyed the region, the general trend in visitation at Canyonlands National Park was increasing (Table 3-45).

When the average growth rate in the local economy during that period was adjusted for inflation, it equaled 7.3 percent. The growth rate for the same period for levels of visitation in Canyonlands National Park was 5.3 percent.

By 1983, however, the decline in the mining industry in Grand and San Juan Counties increased the relative importance of tourism expenditures in the local economy. The total gross sales dropped to $111,671,000 (1983 dollars) in 1983 (Brinkerhoff, 1984) from the $124,452,000 recorded in 1981. If the level of visitation to the Canyonlands Travel Region is assumed to be fairly constant (see Table 3-45), the relative importance of direct tourism expenditures in the local economy would have increased from 13 percent of the total gross sales from all sectors in 1981 to 18 percent in 1983.

The amount spent locally in 1983 by Canyonlands National Park visitors and river-runners launching near Moab would have been $3,242,000 (1983 dollars). This would represent a change from 2.1 percent of the total gross taxable sales in 1981 to 2.9 percent in 1983. By taking into account the decline in local mining industry, it is possible to suggest that the relative importance of tourism in the local economy has changed since 1981. The gross retail and service sector sales totaled $60,542,000 in 1983 (Utah State Tax Commission, 1984). After the decline in the mining industry, expenditures by Moab river-runners and Canyonlands National Park visitors in 1983 would have represented about 5.4 percent of the retail and service sector gross taxable sales in Grand and San Juan Counties. In 1981 their expenditures would have represented 4.6 percent of those sales.

However, even if mining continues to be depressed, there is no indication that the other sectors of the local economy will not readjust from the loss of mining expenditures and continue to grow. Because the historic growth rate in the local economy between 1978 and 1981 matched the growth rate in visitation for Canyonlands National Park, it is assumed that these visitors and the river-runners would continue to account for 2.9 percent of the sales from all sectors and 5.4 percent of the retail and service sales into the future. This would be the case unless the mining industry were to reestablish itself.

Increasing park visitation at Canyonlands National Park could result in employment opportunities for seasonal and NPS personnel in the park. There are about 4,000 visitors for each full-time employee and it is assumed that each new increment of 4,000 visitors will result in another NPS employee.

Table 3-45. Visits to Canyonlands and Arches National Parks and Natural Bridges National Monument, 1978 to 1983

Year	Canyonlands	Arches	Natural Bridges	Total
1978	86,307 (17.9)	326,948 (67.7)	69,941 (14.4)	483,196 (100.0)
1979	75,133 (17.7)	269,840 (63.5)	79,814 (18.8)	424,787 (100.0)
1980	56,965 (13.8)	290,519 (70.6)	63,988 (15.6)	411,472 (100.0)
1981	90,920 (19.0)	326,508 (68.3)	60,681 (12.7)	478,109 (100.0)
1982	98,310 (19.9)	339,415 (68.6)	56,833 (11.5)	494,558 (100.0)
1983	101,779 (22.8)	287,875 (64.5)	56,329 (12.6)	445,983 (100.0)

Note: Numbers in parentheses represent percentages of the total.

Source: BGI, 1984, ONWI-471.

3.6.3 Community Services

An assessment of the quantity and quality of community services appears in this section. The quality of local services in the two-county study area is addressed by examining how the local residents view the availability and quality of the services they need and use.

Residents of Grand and San Juan Counties and the communities of Moab, Blanding, Monticello, Spanish Valley and La Sal rated each of their local services as being "excellent," "good," and "poor" in the Executive Summary of the Community Attitude Survey (Southeastern Utah Association of Local Governments, 1980). The services which were rated as being poor in Moab, Spanish Valley and Grand County included: (1) public housing development, (2) available shopping, (3) airport facilities, (4) animal control, and (5) public transportation. Residents of Spanish Valley also thought that the quality of streets, education, and the availability of doctors were poor. Moab residents identified the condition of sidewalks, curbs, and gutters as also being poor. The services which were rated as being poor in San Juan County, La Sal, Blanding and Monticello included: (1) availability of housing, (2) public housing, (3) animal control, (4) public transportation, (5) sidewalks and curbs, and (6) recreational facilities. County residents also felt that the availability of shopping facilities, television programs, trade and craftsperson services, and the quality of street and road maintenance and street lighting were poor. Residents of Monticello thought that the availability of trade and craftsperson services, shopping facilities, television programs, and the quality of street and road maintenance and street lighting were poor. Residents of La Sal felt there were many services which were of poor quality. They identified the availability of physicians and medical personnel, dental personnel, trade and craftsperson services, education, banking services, and television programs as being a problem. They also felt that the quality of parks, social services, community planning, water and sewer systems, airport facilities, fire protection, medical and mental health services was poor.

Despite these problems, the area as a whole was basically satisfied with the quality of banking services, law enforcement, fire protection, traffic control, postal service, sewer systems, housing, overall sanitation conditions, water systems, parking facilities, social services, education, and the environment. They also thought that the availability of education and library services was good.

Specific information on the use and capacities of housing, education, health services, recreation, protective services, water supply and treatment, sewage treatment and waste disposal, and community transportation and utilities are provided next. This more quantitative analysis affirms many of the inadequacies and adequacies perceived by the local populace.

3.6.3.1 Housing

Single family dwellings represent the highest percentage of units in study area counties and communities (Table 3-46). However, mobile homes also make up a large part of the dwelling units, particularly in Grand County (32 percent in 1980). Of the San Juan County communities, Blanding has the highest percentage of mobile home units (16 percent in 1980).

Owner-occupied units were more characteristic of Grand and San Juan Counties in 1970 and 1980 than were rental housing units. In 1980, 71 percent of all units in Grand County were owner occupied, and 21 percent were renter occupied. In San Juan County in 1980, 66 percent were owner occupied and 22 percent were renter occupied.

Based on the statistics used in Table 3-46, Moab had approximately 300 vacant housing units available in 1984 (including units for rent or sale, and mobile home spaces). Monticello had an estimated total of 50 mobile home spaces and available housing units for rent or sale, while Blanding had over 60.

In 1980, Moab had 491 hotel or motel rooms, Monticello had 93, and Blanding had 110. The occupancy rate for rooms in Moab during the summer of 1979 was 97 percent, but was only 38 percent during the winter. No occupancy rates were available for Monticello and Blanding;

Table 3-46. Number of Housing Units in Grand and San Juan Counties, 1980

Housing Type	Grand	San Juan	Moab	Monticello	Blanding
1980 Year Round Housing	3003	3409	1986	635	834
Single family	1712	2511	1157	492	601
Multifamily	329	284	276	42	75
Mobile home	962	614	533	101	158
1980 Available Vacant Units[a]	118	152	69	26	35
For sale	43	57	21	10	12
For rent	75	95	48	16	23
1980 Mobile Home Spaces Available	120	20	67[b]	4[b]	5[b]
Additional Available Housing Units and Mobile Home Spaces[c]	270	100	178	19	24
Total Available Housing Units and Mobile Home Spaces (1984)	508	272	314	49	64
Motel Rooms	691	239	491	93	110
Summer vacancy[d]	35	12	25	5	6
Winter vacancy[e]	415	143	295	55	66

(a) Does not include units boarded up, held for occasional use, or those which are rented or sold but not yet occupied.
(b) Estimated, based on county percentage.
(c) Estimated, based on median persons per unit and State of Utah 1984 out-migration estimates for Grand and San Juan Counties.
(d) Assume 95-percent occupancy in summer.
(e) Assume 40-percent occupancy in winter.

Sources: BGI, 1984, ONWI-471
Prall and Teuscher, 1985
Bureau of the Census, 1982b.

however, the data in Table 3-44 on transient room taxes suggest that they are less than 50 percent occupied during the winter season.

3.6.3.2 Education

All schools in the Grand County School District are located in Moab. In addition to elementary and secondary schools, an area vocational center is located there. Grand County had 1,199 elementary school students and 792 secondary students in the 1981 school year. In 1984 it was estimated that Grand County had the capacity to accommodate 125 additional high school students, and over 425 elementary school students (grades one through eight). Postsecondary education is provided by the Southeastern Utah Center for Continuing Education (Utah State University). A 4-year college program with one quarter residence at Logan is offered (Utah Industrial Development Information System, 1980).

In the San Juan County School District, elementary, secondary, and vocational schools are located in Blanding. In addition, an elementary and a secondary school are located at Monticello, and three elementary schools and one secondary school are located in communities on or adjacent to the Navajo Reservation. Another elementary school is located at La Sal. The Zenos L. Black Career Education Center at Blanding serves vocational educational needs of local secondary and postsecondary students.

San Juan County had 2,130 elementary school students and 990 secondary students in the 1984 school year. Enrollment at the schools in San Juan County (except Monticello High School) has been at or near capacity. Monticello High School was at less than 80 percent of its capacity as recently as 1982. No new facilities are planned for Monticello or Blanding. Table 3-47 provides enrollment capacity and student-to-teacher ratios for the study area.

3.6.3.3 Health Services

The Allen Memorial Hospital in Moab serves Grand County and parts of surrounding communities, including some parts of San Juan County. The hospital is a 38-bed acute care facility with the only emergency room in Grand County. The hospital maintains a four-vehicle ambulance service. Hospital utilization currently averages less than 25 percent of capacity. Excess physician office space currently exists.

The San Juan County hospital in Monticello has 36 beds, provides the only emergency facilities in the County, and manages a five-vehicle ambulance service. Blanding has one doctor and a nursing home. A 26-bed hospital is located on the Navajo Indian Reservation at Monument Valley, Arizona.

The number of physicians and service to population ratios for Grand and San Juan Counties appear in Table 3-48. A physician-to-population ratio of 1.0 per 1,000 people is considered adequate for a semirural area by the National Center for Health Statistics (1983). Based on this criterion, neither Grand nor San Juan County has enough physicians available.

The Four Corners Regional Commission (1978) reported that southeastern Utah had a difficult time recruiting primary care doctors to serve the region. They also noted that there was an insufficient number of registered nurses in the region. It was also noted that for some medical needs residents go outside the study area for treatment.

3.6.3.4 Recreation

Recreational facilities available in Moab, Monticello, and Blanding are presented in Table 3-49. All three cities have municipal parks and facilities for tennis, baseball, swimming, and golf. Moab has two parks run by the Lion's Club and Monticello has a county fairgrounds. Blanding, Moab, and Monticello also have public libraries. There are also commercial operators who provide skiing, hunting, rafting, and other activities in the region. In addition to the municipal facilities, a number of Federal and State parks in the study area offer sightseeing, camping, picnicking, hiking, and water-sport opportunities for residents and tourists. Section 3.4.1.3.2 provides further information on these activities.

Table 3-47. Enrollment, Capacity, and Student-Teacher Ratio for Socioeconomic Study Area Schools (1984-1985 School Year)

	Grand County (Moab)	San Juan County
Elementary Enrollment (excess capacity)	1,200 (+425)	2,130 (NA)
Elementary Student/ Teacher Ratios	23:1	21:1
Secondary Enrollment (excess capacity)	430 (+125)	990 (NA)
Secondary Student/ Teacher Ratio	19:1	16:1

Note: NA = Not available.

Source: BGI, 1984, ONWI-471; Utah Department of Employment Security, 1985.

Table 3-48. Health Services

	Grand County (Moab)	San Juan County (Monticello)
Hospital Beds	38	36
(excess capacity)	(20)	(25)
Number of Physicians	4	4
(physicians per 1000 population)	0.48	0.31

Sources: BGI, 1984, ONWI-471; Prall and Teuscher, 1984.

Table 3-49. Community Recreational Facilities

City	Tennis Courts	Swimming Pools	Baseball Diamonds	Golf Courses	Other
Moab	6	1	4	1 (9-hole)	Rodeo arena 2 city parks
Monticello	4	1	3	1 (9-hole)	Ski area at Blue Mountain adjacent to Monticello, county fairgrounds
Blanding	4	1	3	1 (3-hole)	Indoor roller skating rink; 4 basketball courts; 3 picnic areas

Source: BGI, 1984, ONWI-471.

3.6.3.5 Protective Services

Grand County police services include the County Sheriff's Department and the Moab Municipal Police Department. The sheriff's department covers all of Grand County and Moab upon request. Back-up services are provided by the Moab municipal police or neighboring county sheriff's offices. San Juan County protective services are provided by the County Sheriff's Department and municipal police in Blanding and Monticello. The National Park Service also provides protective services within units of the National Park System in these counties. Table 3-50 presents the 1980 service-to-population ratios in Grand and San Juan Counties for the number of officers per 1,000 people. In 1980, the national average of police officers per 1,000 people was two (FBI, 1984). None of the study area cities or counties met this standard in 1980. Although the area population has decreased, it is doubtful that any of the communities would have met the national average by 1984. The fact that there is a considerable transient (tourist and other) population should also be noted when assessing police coverage.

Fire services for Grand County are provided by the Moab Fire Protection District and the Castle Valley Fire Protection District. The Moab district services an area of 62 square kilometers (24 square miles) and includes the City of Moab; the Castle Valley district encompasses 109 square kilometers (42 square miles). Areas in Grand County that are not served by either of these two fire districts are served by the State Forestry and Fire Control or trained volunteers. The Moab Fire Protection District provides fewer firefighters per 1,000 dwelling units than does San Juan County or the cities of Monticello and Blanding. The district is given a protection class rating of 5 by the Insurance Service Office, on a scale of 1 to 10 (high to low). The Moab Fire Protection District has facilities adequate to service 3,000 or 4,000 more people. A new 946-liter (250-gallon) mini-pumper has been purchased to replace the one currently in service.

The public land agencies (Bureau of Land Management, U.S. Forest Service, Utah Division of Lands and Forestry, and the National Park Service) handle wildfire control on their own lands. Cooperative agreements among all these agencies provide mutual aid and assistance for wildfire control in Southeast Utah.

The county fire department serves all of San Juan County except for the cities of Monticello and Blanding, which have their own fire departments. All fire department personnel in San Juan County are volunteers who receive training through the State of Utah. The San Juan County Fire Department has plans for building new housing for existing equipment, and a new county fire station. Monticello and Blanding were each given a fire protection class rating of 7 by the Insurance Service Board. Table 3-50 presents the 1980 service-to-population ratios for the numbers of firefighters per 1,000 population in the study area. The fire protection class is probably a better indicator of the quality of fire protection services in the study area, since it incorporates the adequacy of equipment, personnel, and facilities. The fire personnel ratios unfairly compare full-time to volunteer firefighters.

3.6.3.6 Water Supply and Treatment

Table 3-51 summarizes present water supply systems for study area cities. Moab city water comes from wells operated by the Grand County Conservancy District. Moab's well water does not require treatment (Utah Bureau of Public Water Supplies, 1981).

The San Juan Water Conservancy District provides water services to Monticello and Blanding from surface springs on Blue Mountain (Ball et al., 1981). Monticello's water treatment plant has a capacity of 4.73 million liters (1.25 million gallons) per day; 1980 peak use was approximately 3.6 million liters (0.95 million gallons) per day (Ball et al., 1981). Blanding's water is obtained from surface water and one well. The majority of the water (7.2 million liters [1.9 million gallons] per day) comes from two creeks just north of Blanding. The water well (#2; 900,925 liters [238,000 gallons] per day) is used only in emergencies; a second well (#1; 427,750 liters [113,000 gallons] per day) is not used at present because of a sanding problem.

Table 3-50. Protective Services, 1980

Jurisdiction	Police Officers		Firefighters	
	Number	Per 1,000 Population	Number	Per 1,000 Dwelling Units
Grand County	6	0.73	(a)	(a)
Moab	9	1.69	40-45[a]	13.3-15.0[a]
San Juan County	7	0.97[b]	74[b][c]	38.0
Monticello	3	1.56	20	34.5
Blanding	3	0.96	25	30.0

(a) Moab Fire Protection District includes Grand County.
(b) Excluding Monticello and Blanding.
(c) All volunteers.

Source: BGI, 1984, ONWI-471.

Table 3-51. Municipal Water Supply

City	Agency	Supply Capacity (million gal/day)	Calculated Demand (million gal/day)	Storage Capacity (million gal)
Moab	Grand County Water Conservancy District	3.56	4.2	3.00
Monticello	San Juan County Water Conservancy District	1.27	0.95	1.25
Blanding	San Juan County Water Conservancy District	2.28	1.76	1.11

Source: BGI, 1984, ONWI-471.

The Spanish Valley Water and Sewer Improvement District serves a populated unincorporated area located outside Moab city limits. This district and the City of Moab have made arrangements to provide water and wastewater treatment services jointly. By 1985 Moab will purchase water from the George White Well #4 in Spanish Valley, so the total water supply will be approximately 15.2 million liters (4.02 million gallons) per day.

In Monticello, temporary shortages are expected to be eliminated within the next 5 years following construction of the Monticello reservoir, which will have a total capacity of 4,315 million liters (1,140 million gallons). The reservoir will supply Monticello with a potable water source of 1,847 million liters (488 million gallons); the remaining 2,464 million liters (651 million gallons) will be used for irrigation.

Development of a separate irrigation system that will bypass the existing treatment plant is expected to reduce Monticello's 1980 peak use of approximately 3.63 million liters (0.96 million gallons) per day of potable water to approximately 2.50 million liters (0.66 million gallons) per day. When a water line is installed from the Monticello Reservoir to the Monticello water treatment plant, Monticello's water distribution system will be sufficient to serve 6,000 people. Additional households can be served with normal private subdivision expansion of the existing water delivery system.

Blanding has also upgraded its water system to keep pace with expected growth. A new well has been added and the storage reservoir has been enlarged. These expansions are expected to provide for a population of 6,000. Enlargement of Blanding's existing treatment plant will expand the total capacity from 6.32 to 9.08 million liters (1.67 to 2.4 million gallons) per day (Nielson, 1984).

3.6.3.7 Sewage Treatment and Solid Waste Disposal

Present and planned wastewater system capacities are listed in Table 3-52. Moab utilizes a trickling filter plant for wastewater treatment and is currently planning to expand its wastewater treatment plant to serve Spanish Valley residents.

In 1982 a sewer lagoon system sufficient to process waste for a population of 3,000 was completed for the City of Monticello. There is room to expand this system to process waste for a population of 5,000 (Terry, 1984).

Blanding completed construction of a new wastewater lagoon treatment system in 1983. The system has the capacity to process waste for 4,720 persons. It is expected to be adequate for the next 20 years (Nielson, 1984).

Solid waste disposal sites are available to a limited extent within the study area. Moab has two 16-hectare (40-acre) solid waste landfill tracts, each with a 5-year life (Martin, 1983). Monticello is presently utilizing 8 hectares (20 acres) of land that could serve the city for the next 20 years (Terry, 1984). Solid waste is disposed of at a 4-hectare (10-acre) site in Blanding; no landfill site exists, but the city may eventually be required to develop one (Nielson, 1984).

3.6.3.8 Community Transportation and Utilities

The Four Corners Regional Commission (1978) noted that there is a problem maintaining the streets and roads in the study area. A second problem has been provisions for public mass transit. The lack of city or county-wide transit systems has created problems for certain groups such as the elderly. However, social service agencies in the area have acquired some buses to provide services to their clients. Additional data on road, rail, and air transportation are presented in Section 3.5.

Moab is served by Utah Gas Service and Utah Power and Light, and Monticello is served by Utah Gas Service and Empire Electric Co. of Cortez, Colorado. Blanding has no natural gas service and is served by Utah Power and Light.

Table 3-52. Community Wastewater System Capacities, Present and Planned

City	1980 Population	Collection System Capacity		Treatment System Capacity	
		Present	Planned	Present	Planned
Moab	5,333	Adequate	Some repair and replacement of sewer lines	1,400 connections; capacity for 300 additional connections; 1 million gal/day	Additional 1,300 connections; 1.3 million gal/day
Monticello	1,929	Adequate	Minimal amount of trunk sewer lines needed for expansion	Sufficient for 3,000 people	5,000 people
Blanding	3,118	(a)	(a)	4,720 people; 0.47 million gal/day	

(a) Data not available.

Source: BGI, 1984, ONWI-471.

3.6.4 Social Conditions

This section presents information on recent social history of the area, life-style differences, attitudes toward growth, attitudes toward the project, a discussion of available social services, and indicators of social problems. Information on local heritage is available in Section 3.4.6.

3.6.4.1 Social History and Life-style Differences

Early in this century, Grand and San Juan Counties were agrarian in nature. The predominant cultural influence on white settlement was the Mormon Church (Peterson, 1975) which colonized the area. The Native Americans living in the region tolerated the limited white presence, although there was considerable tension. Peterson (1975, p. 59) wrote that the Indians accepted the Mormons paternalistic overtures and took advantage of trade opportunities, but "this arrangement led to increasing control of the country and its resources [for the Mormons]." By 1895 the American Indian presence was limited to the Navajo Reservation established south of the San Juan River, while small bands of Utes and Paiutes remained near Blanding.

Besides the Mormon settlers, the other major early influence of the region's culture was the introduction of livestock which brought cowboys and cattle ranchers to the area. This precipitated several confrontations over the rights to grazing land. Government intervention and regulation eventually served to eliminate these earlier conflicts (Peterson, 1975, pp. 104-106).

In 1952, the uranium boom drew many new in-migrants to the area. The establishment of the National Parks and other recreational opportunities in the study area also initiated the development of the tourist industry. This attracted some artisans to the area.

These past social and economic forces which shaped the early development of Grand and San Juan Counties also affect the current sociocultural landscape. For example, the historic relegation of the Native Americans to southern San Juan County accounts for the fact that Grand County has so few American Indians. The early Mormon settlers which established the communities of Grand and San Juan Counties resulted in the dominance of the Mormon culture in the region today (Weber State College, 1981). However, the uranium boom brought many individuals with diverse backgrounds to the region. As a result, many other religious denominations are now present in both counties. For example, Moab has more denominations per capita than any other city in Utah (City of Moab, 1985).

Any discussion of life-style differences in the region runs the risk of unfairly stereotyping the residents. However, some generalizations can be made to express societal tendencies. For example, it can be said that ranching in isolated areas has tended to produce self-reliant life-styles. The same can be stated for the Navajo and Ute cultures which are based on different languages, religions, and values (Burnett, 1980; Feinberg, 1978) than exist for the white inhabitants of Grand and San Juan Counties.

Life-style differences are also indicated by the socioeconmic status of the different societal groups. For example, higher rates of unemployment and lower wage levels have contributed to the continued lower socioeconomic status of the Native Americans living in Moab, Monticello, Blanding, and on the Navajo reservation (Weber State College, 1981). Increasing unemployment among the mining population has also adversely affected the socioeconomic status of miners.

3.6.4.2 Attitudes Toward Growth and the Project

The Southeastern Utah Association of Local Governments (1980) conducted an attitude study in which local residents were asked whether they strongly agreed, agreed, disagreed, or strongly disagreed with the statement "continued growth is generally beneficial to our community." Residents of La Sal, Monticello, Blanding, and the rest of San Juan County, and Moab, Spanish Valley, and the rest of Grand County generally agreed with the statement. They

strongly disagreed with the statement that "I am willing to allow the air and water quality in my community to be adversely affected in order to bring in industrial activities." Growth at the expense of public health and safety was not acceptable.

The attitudes of local residents toward the proposed activities of the nuclear waste project have been favorable. For example, a 1984 survey in Monticello showed that 63 percent were in favor of testing by the Department of Energy (DOE) for a nuclear waste site. A nuclear repository at Gibson Dome was favored by 61 percent (San Juan Record, 1984). The results of a ballot issue in Grand County showed that, by a margin of 2 to 1, the local residents favored continuing DOE studies that could lead to development of a respository (Schmitz, 1983). A State of Utah visitor survey was conducted by the NPS. The surveys of visitors to Arches National Park, Natural Bridges, Canyonlands National Park, and at local NPS offices demonstrate that there was strong opposition to locating a high-level nuclear waste repository near Canyonlands National Park (Schmitz, 1983).

All of these polls indicate there is a potential for social polarization with respect to the project issue. There are people who strongly feel they would be adversely affected and there are people who just as strongly believe that they would benefit. Such strongly held, contrasting beliefs may result in group conflict.

3.6.4.3 Social Services

The Grand County Social Services Department operates an office in Moab. Two types of services are provided: family services, including aid to the elderly, foster care, and aid to battered spouses; and assistance payments, such as food stamps, and medical and financial aid.

Other agencies in Grand County also provide social services to specialized groups, including: (1) the Grand County Senior Citizens program, which provides socialization, recreation, nutrition, and county alternatives to institutionalization; (2) Moab Handicapped, Inc., a private nonprofit agency that provides socialization and recreation services for the developmentally disabled and mentally retarded; and (3) the Grand County Indigent Program, which provides emergency aid to needy county residents.

The San Juan County Social Services office has a staff of 45. Full-time offices are located in Monticello and Blanding; part-time staffing is provided in Bluff and Montezuma Creek. Services include programs for mental health, alcohol and drugs, aging, and nutrition, as well as assistance payments and family services.

In addition to the Social Services Office, the Utah Development Council has, since 1968, provided a service delivery system to improve the health, education, and economic potential of the Utah Navajo in San Juan County.

There were 596 people receiving financial aid in Grand County in June, 1982, or a total of 293 cases; 240 cases were receiving food stamps only, and 53 cases were receiving medical, financial, and other assistance.

The San Juan County Social Services Office provides financial, medical, and food stamp assistance to 823 cases per month. Mental health services are available and can handle between 170 and 190 cases per year. Children, youth, and family services (such as protective service intervention, adoptions, day care, foster care, nutrition service, financial-employment-educational counseling and guidance services) are provided to 580 cases per month. The larger number of cases in San Juan County as compared to Grand County may be a reflection of higher unemployment, larger population and lower per capita income. The number of cases for both counties may be affected by the seasonal nature of employment opportunities provided by the tourist industry.

The adequacy of social services has been assessed for Grand, Carbon, and Emery Counties for the Utah Energy Office (Weaver et al., 1982b). This analysis suggested that, in 1982, Four Corners Community Mental Health Center, Alcoholism Treatment Center, Planned Parenthood

Association of Utah, the Southeastern Utah Health District, Utah Social Services, and Juvenile Courts were below the recommended adequacy standards for service workers per 1000 population.

3.6.4.4 Social Problems

There are many different kinds of indicators that characterize the social problems of an area. The Four Corners Regional Commission (1978) suggests that instability in the social environment is created when large numbers of people must out-migrate. Grand County and San Juan County are both experiencing considerable out-migration. The decline of an area's major industry can also put a strain on social services, especially when a growing percentage of the local residents are unemployed. This, too, has occurred in the study area.

Another indicator of social problems is the uniform crime rate. Moab, for example, experienced a jump from 46.23 crimes per 1,000 population in 1983 to 54.20 per 1,000 in 1984. This increase resulted primarily from increases in assaults and thefts (City of Moab, 1985). There were no cases of homicide, rape, or arson. In general, the historic trend for serious crime in Grand County has been similar to the State's while San Juan's has been lower.

Poverty among the elderly, alcohol and drug abuse, and the shortage of physicians were seen as continuing problems by the Four Corners Regional Commission (1978). Moab and Monticello have experienced some social problems associated with the decline of the uranium mining industry. At present, local governments and community organizations are working hard to improve the quality of life (City of Moab, 1985).

3.6.5 Fiscal Conditions and Government Structure

This section describes the governmental structure of study area cities. Data on the extent and source of local revenues and expenditures presented in this section indicate the extent to which local communities can meet current as well as future project-related service demands.

3.6.5.1 Fiscal Conditions

Property taxes are a major source of income for Grand and San Juan Counties and the cities in these counties (Claus and Adkison, 1983; Smuin, Rich & Co., 1983, p. 23). These jurisdictions also receive a large portion of their revenue from intergovernmental transfers, including Federal payments provided to the county in lieu of taxes on federally owned, tax-exempt lands. In addition, a portion of the fuel taxes and vehicle registration fees collected by the State are allocated to local governments for county and city road construction and maintenance. Specific revenue sources for Moab, Blanding, and Monticello, and for Grand and San Juan Counties appear in Table 3-53.

Public health and safety and roadway expenditures, in addition to general government outlays, constituted the largest classes of expenditures in all the jurisdictions. These data are presented in Table 3-53.

The Southeastern Utah Association of Local Governments (1980) noted that there were numerous constraints which had limited the effectiveness of Southeastern Utah financial resources in mitigating problems. The report cited the following problems:

1. Grand and San Juan County have a large number of mobile homes. Because mobile homes have a lower assessed valuation, they return less tax revenue than permanent dwellings. This smaller tax revenue yield is multiplied by the fact that a mobile home will depreciate in value and return progressively less tax revenue, while a permanent family dwelling will appreciate in value and return more tax revenue.

Table 3-53. Fiscal Structure of Study Area Counties and Cities, 1982

	Grand County	San Juan County	Moab	Blanding	Monticello
Revenues ($)					
Taxes	703,693	2,531,851	709,968	289,311	217,704
Licenses and permits	7,610	6,115	187,803	7,135	4,649
Intergovernmental revenues	806,466	1,925,269	232,976	124,192	23,296
Charges for services	177,457	224,079	241,708	45,195	--
Fines and forfeitures	145,753	127,125	32,436	13,104	48,981
Miscellaneous	303,782	728,193	175,788	79,526	14,809
Total	$2,144,761	$5,542,632	$1,580,679	$558,463	$309,439
Expenditures ($)					
General government	467,415	1,332,113	268,133	49,791	89,632
Public safety and health	616,980	685,862	471,234	123,407	105,376
Highways and public improvements	789,188	2,187,923	460,042	58,610	54,560
Parks and recreation	40,514	184,114	116,747	5,124	14,820
Debt services	--	--	49,040	45,972	--
Miscellaneous	37,542	40,887	223,167	94,427	--
Intergovernmental expenditures	211,847	--	--	--	--
Total	$2,163,486	$4,430,899	$1,588,363	$377,355	$264,388
Balance ($)	-18,728	1,111,733	-7,684	181,129	45,051

Source: BGI, 1984, ONWI-471, pp. 104-106.

2. The Utah State Constitution prohibits the sharing of funds across political jurisdictions. For example, this has prevented the State from distributing their portion of Federal mineral land leasing fees and similar revenues to impacted counties or cities.

3. There has been an insufficient base for generating taxes. For example the recent decline in the mining industry in Grand County has reduced property and severence tax revenues.

4. There are limitations on local bonded indebtedness which legally prevent jurisdictions from exceeding established ceilings. While the different jurisdictions in Grand and San Juan Counties do not appear to have reached the level of their bonded indebtedness, several have outstanding bonds.

In addition to these constraints, the Southeastern Utah Association of Local Governments (1980) estimated that infrastructure costs for each new resident would be about $500 per year. They use this estimate to project the additional public expenditures required to finance front-end projects.

3.6.5.2 Government Structure

Monticello is the county seat of San Juan County, and Moab is the county seat of Grand County. The elected officials of each county are three commissioners, a clerk, sheriff, attorney, treasurer, assessor, recorder, auditor, and surveyor. Continuity of the county government is provided in the staggered terms of office of the commissioners. The other officials are elected every 4 years in partisan elections.

Monticello, Blanding, and Moab each have a mayor and five councilpersons. Monticello and Blanding also have a city manager. Special-purpose districts in the study area include water, fire-protection, cemetery, and mosquito-abatement districts. San Juan and Grand Counties each have county-wide school districts.

3.7 CHAPTER 3 REFERENCES

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The DOE would also acquire the necessary interest in or authorization to use lands outside the site that would be used to perform geologic or environmental studies.

The description of the proposed activities is divided into three subsections:

- Geotechnical Field Studies: Geologic research activities
- Exploratory Shaft Facility: Land acquisition, construction, and subsurface testing activities
- Other Activities: Environmental and socioeconomic activities.

4.1.1 Geotechnical Field Studies

The geotechnical characterization program has been designed to provide the data required to support engineering design and performance assessment. The program of geotechnical field studies, as presently envisioned, includes exploratory boreholes, hydrologic testing and monitoring, geophysical explorations, surface and subsurface testing and monitoring, and field mapping. In situ testing within the exploratory shafts and associated underground openings is also a part of the geotechnical and engineering field program. Table 4-1 lists the proposed field activities to be performed during site characterization and the principal sections of the NWPA (10 CFR Part 960) to which they are related. These activities would begin approximately 13 months prior to shaft site preparation activities.

The proposed geotechnical field activities are described in this section. The locations of the proposed sites for the activities have been selected on the basis of engineering layouts and other technical, environmental, and access considerations. These locations are based upon the DOE's understanding of the technical needs of the program. Final locations may be modified based on updated data and revised interpretations.

Table 4-2 summarizes the estimated requirements for each of the geotechnical field activities identified, including scope, quantity planned, land use, work force, equipment needs, and duration. Figure 4-1 provides an indication of the expected sequence and phasing of field activities. Figure 4-2 illustrates current planned borehole locations at the Davis Canyon site, Figure 4-3 shows activity locations in the candidate area.

4.1.1.1 Basic Geotechnical and Hydrologic Studies

A number of drilling sites are planned in the area surrounding the engineering design boreholes (EDBHs) to provide data to address licensing requirements. The geotechnical and hydrologic studies include 62 deep and shallow boreholes in addition to about 450 shallow foundation borings and 136 to 281 monitoring wells. The data acquired from these boreholes would be used to do the following:

- Evaluate the hydrogeologic conditions
- Evaluate geologic structure
- Characterize existing fractures and the potential for subsurface fracturing
- Characterize hydrochemical and geochemical parameters necessary to evaluate location compatibility for waste isolation (e.g., ground-water circulation patterns, chemical stability of host rock, pathways and residence times for radionuclide migration)
- Characterize mineral resource potential
- Help predict natural and engineered changes in the hydrogeologic and geochemical regime

Table 4-1. Geotechnical Field Activities to be Performed During Site Characterization, Davis Canyon

Activity Name	Activity Discussion
10 CFR 960.4 - Postclosure Guidelines[a]	
Geohydrology (960.4-2-1)	
Aquifer Hydro-Nests	4.1.1.1.4
Deep Aquifer Hydro-Nests	4.1.1.1.5
Geologic/Hydrologic Boreholes	4.1.1.1.7
Geochemistry (960.4-2-2)	
Shallow Aquifer Hydro-Nests	4.1.1.1.4
Deep Aquifer Hydro-Nests	4.1.1.1.5
Rock Characteristics (960.4-2-3)	
Geologic Mapping	4.1.1.3
Stratigraphic Boreholes	4.1.1.1.2
Indian Creek Syncline and Cross-Canyon Boreholes	4.1.1.1.10
Tectonics (960.4-2-7)	
Microseismic Network	4.1.1.2.3
Seismic Reflection and Refraction Lines	4.1.1.2.1
3-D Seismic Survey	4.1.1.2.2
Potential Field Surveys	4.1.1.2.4
Shay Graben Trench	4.1.1.1.8
10 CFR 960.5 - Preclosure Guidelines	
Surface Characteristics (960.5-2-8)	
Access Route Topographic Mapping	4.1.1.4
Rock Characteristics (960.5-2-9)	
Engineering Design Borehole (EDBH)	4.1.1.1.1
Early Foundation Design Boreholes	4.1.1.1.6
Repository and Surface Facilities and Access Foundation Borings	4.1.1.1.6
Hydrology (960.5-2-10)	
Exploratory Shaft Facilities Monitoring Wells, Repository and Surface Facilities Monitoring Wells and Shaft Monitoring Wells.	4.1.1.1.3

(a) Dissolution (960.4-2-6) is not listed as a separate topic, but the required activities will be performed under the geohydrology and geochemistry topics.

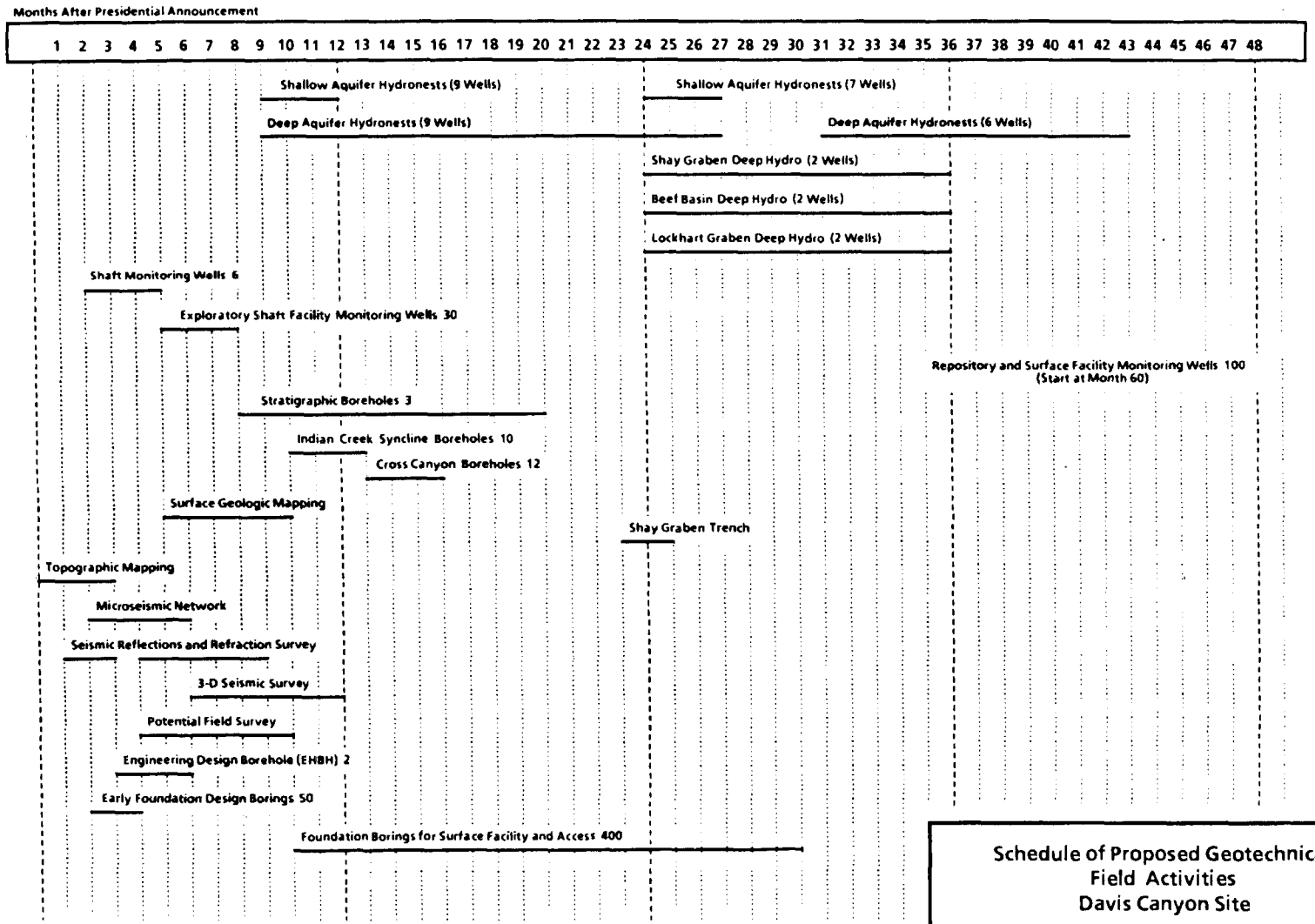
Table 4-2. Summary of Geotechnical Field Activity Requirements, Davis Canyon

Activity	Scope	Quantity per Site	Total Number of Boreholes	Land Use: Number of Sites	Land Use: Requirements per Site[a]	Work Force per Site	Major Equipment per Site	Duration of Activity	Duration at Each Site
Shallow Aquifer Hydro-Nests	Drilling, coring, logging, testing, and monitoring	3 and 1 wells	16	6	4-10 acres	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	6 months	1 month
Deep Aquifer Hydro-Nests	Drilling, some coring, logging, testing, and monitoring	3 wells	15	5	12 acres	27	1 platform drill rig, auxiliary equipment, 8-10 light vehicles	30 months	6 months
Shay Graben Deep Hydro	Drilling, coring, logging, and testing	1 well	2	2	4 acres	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	12 months	6 months
Beef Basin Deep Hydro	Drilling, some coring, logging, casing, and testing	1 well	2	2	4 acres	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	12 months	6 months
Lockhart Basin Deep Hydro	Drilling, selective coring, logging, casing, and testing	1 well	2	2	4 acres	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	12 months	6 months
Shaft Monitoring Wells	Drilling, selective coring, logging, testing, and monitoring	3 wells	6	2	None, on land cleared for EDBH	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	3 months	3 months
Exploratory Shaft Facilities Monitoring Wells	Drilling, casing, logging, testing, and monitoring	1 well	30	30	None, on land cleared for shaft facilities	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	3 months	3 days
Repository and Surface Facilities Monitoring Wells	Drilling, casing, logging, testing, and monitoring	1 well	100	100	None, on land cleared for other facilities	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	9-20 months	2 days
Stratigraphic Boreholes	Coring, logging, mini-hydrofracture test for stress fields	1 borehole	3	3	4 acres	27	1 large truck-mounted drill rig, auxiliary equipment, 8-10 light vehicles	12 months	4 months
Indian Creek Syncline Boreholes	Coring, logging, and structural analysis	1 borehole	10	10	0.1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	3 months	2 weeks
Cross Canyon Boreholes	Coring, logging, and structural analysis	1 borehole	12	12	0.1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	3 months	2 weeks
Surface Geologic Mapping	Minor hand digging	196 square miles[b]	--	--	Access only	4	2 light vehicles	4-5 months	--
Topographic Mapping	Surveying of access routes	--	--	35-75	Access only	8	2 light vehicles	3 months	--
Borehole Search and Characterization	Possible reentry and plugging of found holes	1	0+	0+	Access only or 0.10+ acre	15	1 light vehicle, drilling equipment as required	1-6 months	1-6 months
Shay Graben Trench	Trenching, sampling, and description	--	--	1	0.69 acre	6	1 backhoe, 2-4 light vehicles	2 months	2 months
Microseismic Monitoring Network	Install stations and maintain	1 station	--	27 (10 new)	0.01 acre	4	1-2 light vehicles	4 months	Intermittent

Table 4-2. Summary of Geotechnical Field Activity Requirements, Davis Canyon (Page 2 of 2)

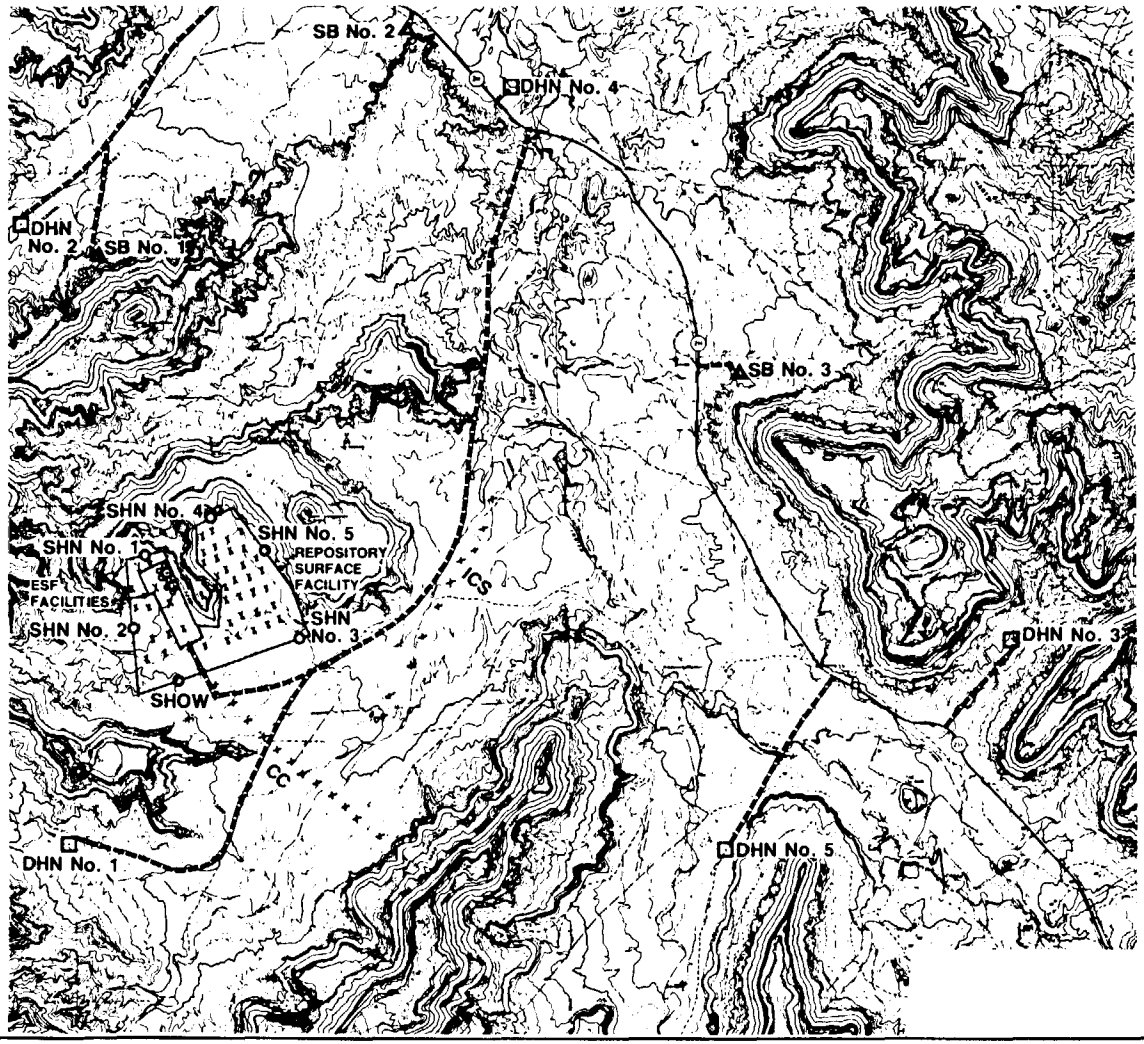
Activity	Scope	Quantity per Site	Total Number of Boreholes	Land Use: Number of Sites	Land Use: Requirements per Site[a]	Work Force per Site	Major Equipment per Site	Duration of Activity	Duration at Each Site
Seismic Reflection Lines	Surface surveys using heavy impact or shallow charge	112 line-miles[c]	--	--	Access only along roadways (136 acres)	25	7 heavy vehicles, 5 light vehicles, seismic equipment.	6 months	--
3-D Seismic Reflection Survey	Detailed seismic reflection survey over site area	10 square miles[b]	--	--	Roadway clearing (250 acres)	15	7 heavy vehicles, 5 light vehicles, seismic equipment	6 months	--
Seismic Refraction Lines	Detailed near-shaft and shallow subsurface profiling	2 line-miles[c]	--	--	Access only by trucks	4	2 light trucks	2 months	--
Potential Field Survey	Over site gravity, magnetic, electric potential field survey	--	--	(?)	Access only on foot	3	2 light vehicles	6 months	--
Engineering Design Borehole (EDBH)	Drilling, coring, and logging	1 borehole	2	2	10 acres	27	1 platform drill rig, auxiliary equipment, 8-10 light vehicles	3 months	3 months
Early Foundation Design Borings	Drilling, sampling, coring, and logging	1 borehole	50	50	0.1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	2 months	1 day
Foundation Borings for Surface Facilities and Access	Drilling, sampling, coring, logging, and test pits	1 borehole	400	400	0.1 acre	6	1 small truck-mounted drill rig, auxiliary equipment, 2 light vehicles	20 months (parttime)	1 day

(a) One acre = 0.405 hectare.
(b) One square mile = 2.590 square kilometers.
(c) One mile = 1.609 kilometers.



Schedule of Proposed Geotechnical Field Activities
Davis Canyon Site

Figure 4-1



Explanation

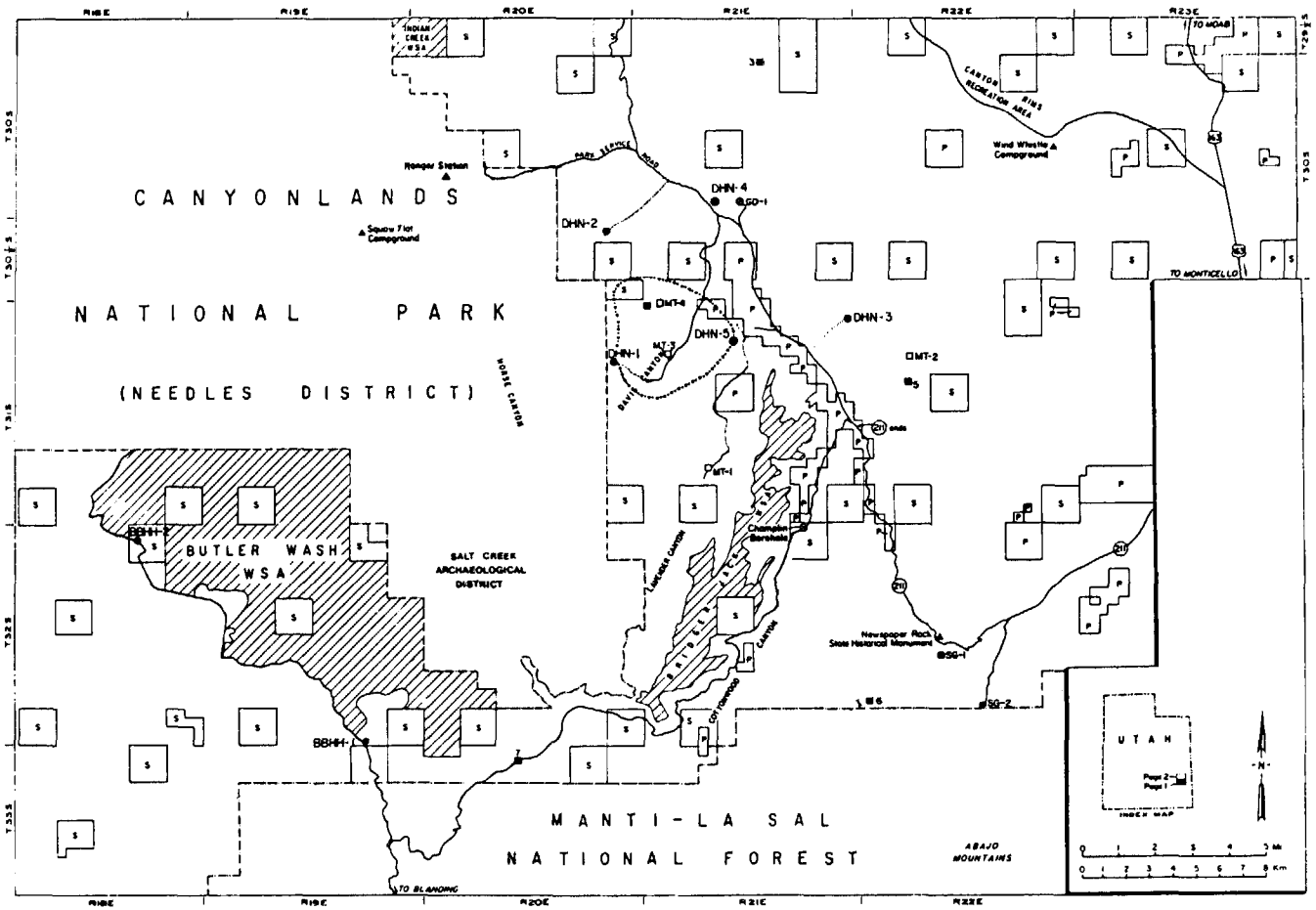
- Engineering Design Boreholes (2)
- Shaft Monitoring Wells (6)
- Foundation Borings
- SB Stratigraphic Boreholes (3)
- SHN Shallow Hydrologic Nests (5)
- SHOW Shallow Hydrologic Observation Well (1)
- DHN Deep Hydrologic Nests (5)
- ICS Indian Creek Syncline Borings (10)
- CC Cross Canyon Borings (12)
- Access Route

Feet 0 2000 4000
Meters 0 600 900
Scale

Proposed Location of Drilling Activities, Davis Canyon Site

Figure 4-2

A larger reproduction of this figure appears at the back of this volume.

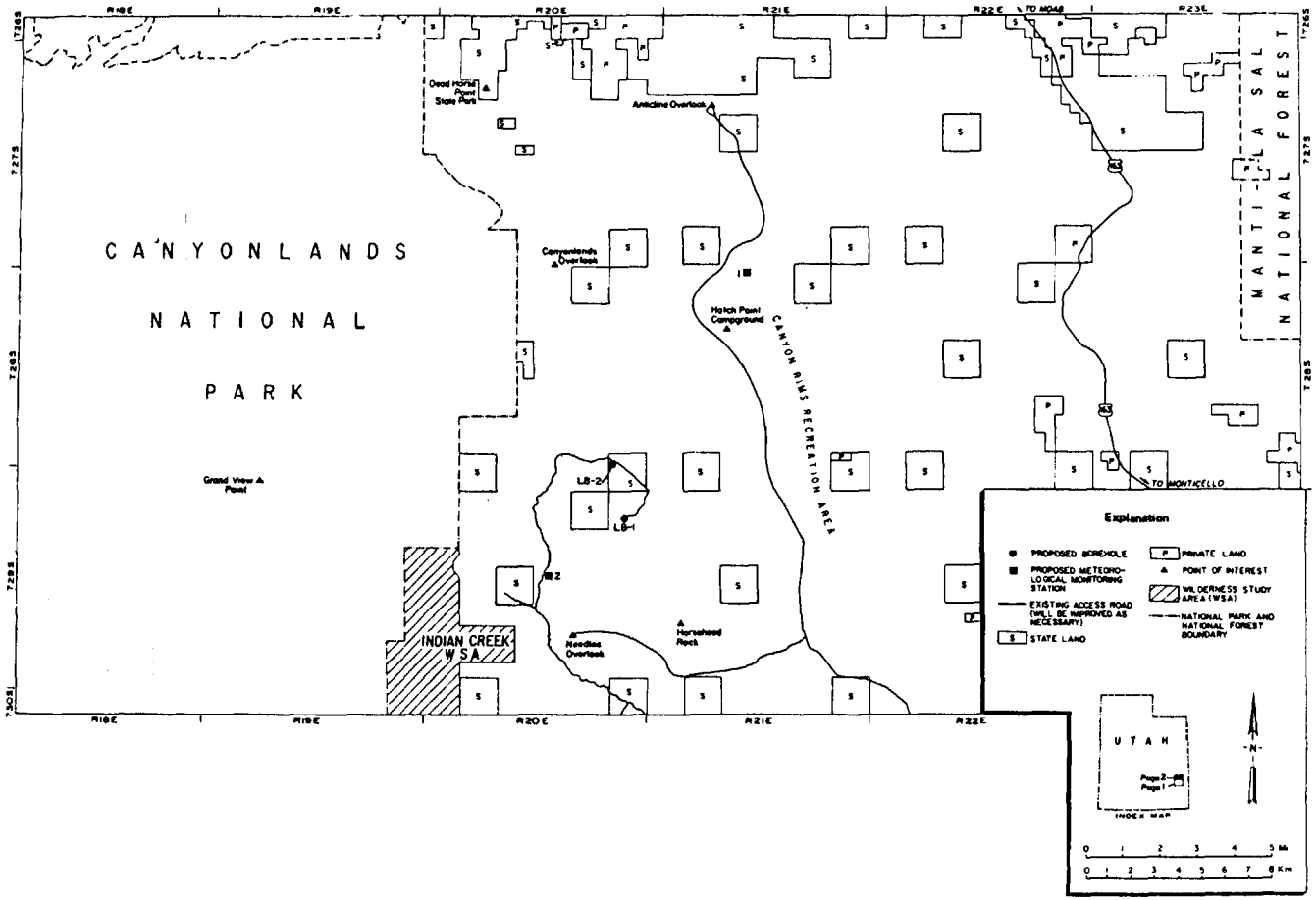


Proposed Field Activities in the Davis Canyon Candidate Area

Page 1 of 2

Figure 4-3

A larger reproduction of this figure appears at the back of this volume.



Page 2 of 2

Proposed Field Activities in the Davis Canyon Candidate Area

Figure 4-3

A larger reproduction of this figure appears at the back of this volume.

- Provide data on water quality and the water-yielding capacity of geologic formations at various depths

- Evaluate the configuration of stratigraphic units around the repository site.

Hydrologic testing and sampling would be both short-term (during drilling and immediately upon completion of a hole) and long-term. Specific conditions would determine the types of tests and instruments to be used. Test and sample intervals would be based on project needs and on results of drilling and logging. Hydrologic monitoring would be continuous and sampling would be periodic (approximately quarterly for at least 1 year), after drilling and completion of the boreholes.

Erosion will be minimized for all surface disturbances with terracing, sediment ponds, and fabric sediment fences. All potentially damaging fluids such as brines will be transported off site for disposal under environmentally controlled conditions.

4.1.1.1.1 Engineering Design Boreholes (EDBHs). Two engineering design boreholes (EDBHs) are proposed for Davis Canyon to obtain data and samples for the determination of the geotechnical characteristics of the stratigraphic sections to be penetrated by the exploratory shafts. Other objectives include the following:

- Confirm the depth to and thickness of the potential repository layer at the Davis Canyon site

- Help assess existing subsurface fracturing and geologic structure

- Provide data on geophysical characteristics which can be used for stratigraphic correlation and rock properties correlations

- Obtain feasibility and design data for the exploratory shaft and underground facilities

- Characterize hydrologic, geochemical, and mineralogical parameters necessary to evaluate the site

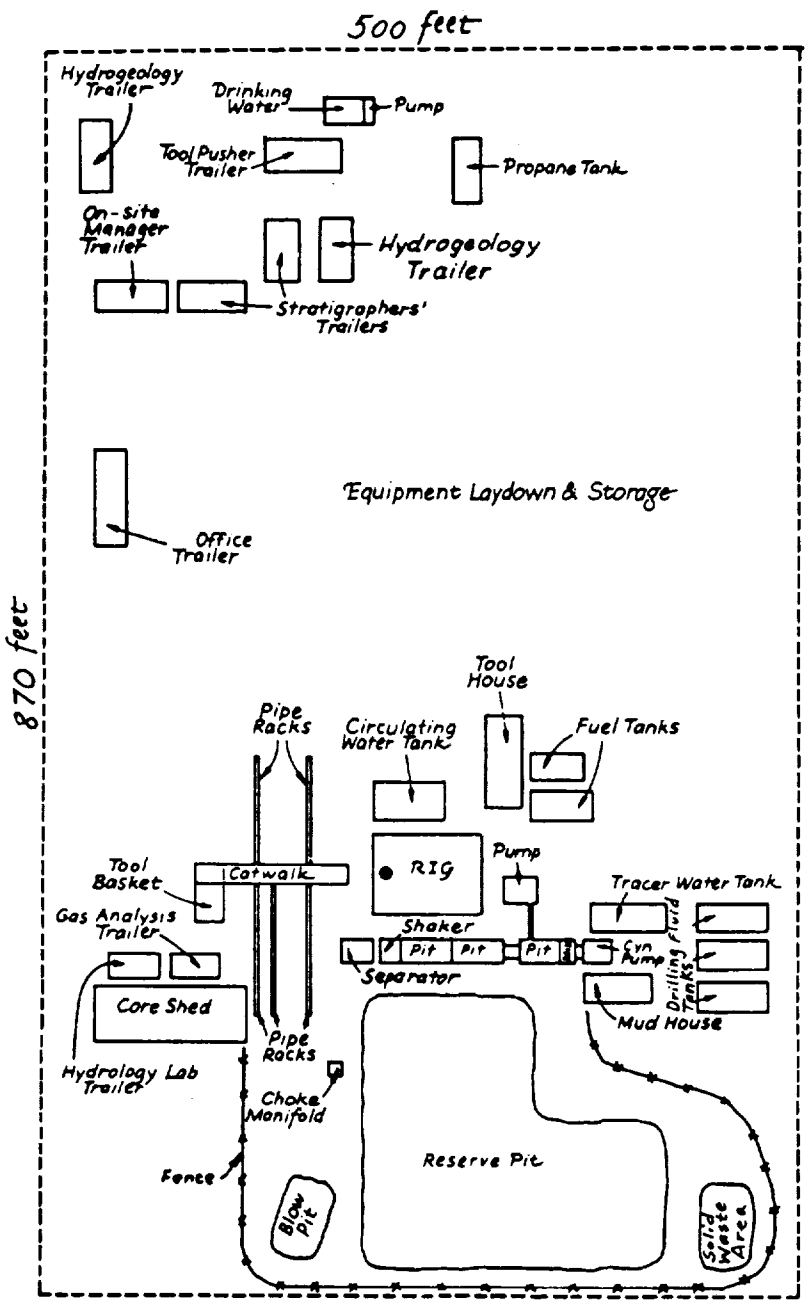
- Characterize the mineral resource potential of the site.

Activity Description. The boreholes would be continuously cored (outside hole diameter would be between 15.2 and 16.5 centimeters [6 and 6.5 inches]) to a total depth of approximately 976 meters (3,200 feet), recovering a 10.2-centimeter (4-inch) diameter core. The core would be moved to the core-handling shed, geologically described, photographed, and packaged for shipment.

The drilling and coring would require 4 hectares (10 acres) for each drill site. This drill site would be somewhat larger than the standard oil and gas exploration field site because of increased space requirements for equipment and personnel. Major facilities at each drill site, shown on Figure 4-4, would include the following:

- Drilling rig and auxiliary equipment
  - Platform drilling rig with a 40-meter (130-foot) mast - using diesel engines to power the drawworks, the drilling fluid circulation pumps, and the electrical generator. Total drilling configuration is operated on 597 kilowatts (800 horsepower)
  - Drill pipe, drilling and coring tools, and clean-out equipment

- Mud storage tanks or pits - Three 15,898-liter (4,200-gallon) tanks or pits



Note: Drawing Not to Scale

Explanation

- Approximate Borehole Location

Typical Drill Site Layout

Figure 4-4

- Solid waste storage area - One waste container or pit
- Equipment laydown storage areas
- Core-handling shed - A 5 by 18-meter (15 by 60-foot) portable building
- Supervisory quarters, offices, and laboratory space - Up to nine trailers
- Blowout preventers
  - One annular-type blowout preventer
  - One ram-type blowout preventer
  - One rotating head
- Fluid storage tanks - Three 79,480-liter (21,000-gallon) storage tanks
- Casing.

Location and Access. An EDBH will be located at the center of each of the two exploratory shaft sites, 1,200 meters (4,000 feet) southwest of South Six-Shooter Peak in the northeast quarter of Section 1, T31S, R20E (Figure 4-2). Access road and pad preparation are the initial activities. Access would be from the north off the paved National Park Service (NPS) extension of Utah State Highway 211 (Utah 211), a distance of approximately 7.7 kilometers (4.8 miles) and will follow an existing jeep trail.

The existing jeep trail closely parallels the Davis Canyon drainage, and for about 1.6 kilometers (1 mile) is actually in the ephemeral stream bed. Where the jeep trail is in the stream bed, the planned access road will be placed on the bench of the stream, so that normal rainfall runoff will not interfere with access.

The planned access road is 7.3 meters (24 feet) in width (two 3.7-meter [12-foot] lanes), with 1.2-meter (4-foot) wide rounded shoulders on each side, and will be constructed of asphalt on a suitable base. Although a road design has not been completed, it is likely that there may be places where the jeep trail is in the stream bed and the stream bench is not wide enough. This may require stream bed modification and the installation of rip rap or culverts at these places.

No changes are expected to Utah 211 that would require additional culverts, bridges, or other stream bed modifications.

Activity Requirements. The 4-hectare (10-acre) drill site would be cleared, and the uprooted vegetal matter would be windrowed on one side of the site. Topsoil would be windrowed separately.

The cleared area would be leveled to accommodate the storage of drill pipe, supplies, support equipment, the erection of the drill rig, and the construction of a reserve mud pit. Excavated soil from the reserve mud pit and blow pit would be stockpiled and seeded in place. The reserve pit (892 square meters [9,600 square feet]) would be fenced on three sides with four strands of barbed wire. The entire site would be fenced to prevent entry of humans, livestock, and wildlife into potentially hazardous areas.

Equipment used for road and pad construction would consist of 1 or 2 bulldozers, 1 road grader, 1 water truck, and 1 backhoe. Estimated vehicular requirements for EDBH activities are presented in Table 4-2.

The proposed drilling operation is to take place on a round-the-clock basis. The EDBH drill sites would be actively drilled for approximately 90 days. Additional time may be used for testing.

Fresh water would be required at the EDBH drill site for uses such as construction, maintenance, improvements of the drill pad, dust suppression on the access road, cooling of engines on drilling auxiliary equipment, base for drilling fluids; and for drinking and sanitary purposes. Water would be purchased from a local water hauling company.

It is estimated that 8,300 liters (2,200 gallons) of fresh water per day (4 truckloads per week) would be sufficient for dust suppression. The water-based drilling and auxiliary system would require approximately 111,279 liters (29,400 gallons) per day (7 truckloads every day). A maximum of 3,975 liters (1,050 gallons) per day of potable water (1 truckload every 4 days) would be needed. Portable sanitary units and septic tanks would be placed at the site. The collected wastes would be transported to an approved offsite disposal area. Covered containers to store rubbish would prevent wind-blown litter. All waste materials (e.g., drilling mud and cuttings) would be hauled to approved disposal sites (Section 4.1.2).

A 24-hour drilling operation typically requires 2 to 3 drilling crews of 9 persons each. Approximately 12 technical and supervisory personnel would be on site each operating day (total maximum work force at any one time is 15). During normal operations 8 to 10 persons would be on site.

Geophysical Logging. Downhole geophysical logging would be performed in the EDBH. Logging involves lowering special measuring tools into the borehole and recording data as the tool is withdrawn. General procedures and equipment for the various logging techniques are quite similar with regard to environmental assessment. Some tools contain radioactive isotopes; these are used in accordance with well established industry and NRC standards. The logging is conducted using a specially equipped truck that can be brought to the site on existing roads.

4.1.1.1.2 Stratigraphic Boreholes Activity Description. Three stratigraphic boreholes would be drilled, continuously cored, and geophysically logged in the same manner as the EDBHs. The total depth of each would be approximately 976 meters (3,200 feet). The purposes of the holes are similar to those of the EDBH; they would provide data for repository layout and design and additional information to assess subsurface geology. Two of these holes will be selected for mini-hydrofracturing tests.

To conduct the hydrofracturing tests, zones in the borehole 3 to 4.5 meters (10 to 15 feet) long will be isolated by using inflatable packers. Fracturing will be accomplished by slowly increasing pressure in the test zone by a pump on the surface. The trailer-mounted pump will be powered by a small diesel or gas engine. Fractures created by this process are estimated to extend 3 to 15 meters (10 to 50 feet) from the borehole. Only a small volume of fluid is needed for this type of test.

Location and Access. Locations of stratigraphic boreholes are shown on Figure 4-2.

Drill site SB-1 is located in Corral Pocket 0.6 kilometer (0.4 mile) northwest of North Six-Shooter Peak in Section 25, T30S, R20E. SB-1 can be accessed from the paved NPS extension of Utah 211, approximately 2.9 kilometers (1.8 miles) southwest on a new access road.

Drill site SB-2 is located 4.5 kilometers (2.8 miles) north of North Six-Shooter Peak along the paved NPS extension of Utah 211 on the southwest side of the road in Section 20, T30S, R21E. SB-2 can be accessed from Utah 211, approximately 0.3 kilometer (0.2 mile) south on a new access road.

Drill site SB-3 is east of the mouth of Davis Canyon approximately 4.3 kilometers (2.7 miles) east-northeast of South Six-Shooter Peak in Section 34, T30S, R21E. SB-3 can be accessed from the paved NPS extension of Utah 211, approximately 0.6 kilometer (0.4 mile) east on a new access road.

Activity Requirements. Hole layout, land requirements, equipment, labor requirements (27), completion time for each drillhole, and drilling techniques are essentially the same as for the EDBH except that the total drilling configuration (drawworks, circulating pumps, electrical generator) is operated on 672 kilowatts (900 horsepower). Improved and new access roads would be 6 meters (20 feet) wide and top crowned, with culverts installed, as necessary. Gravel would be applied to maintain stable access.

4.1.1.1.3 Exploratory Shaft Facilities Monitoring Wells, Repository and Surface Facilities Monitoring Wells, and Shaft Monitoring Wells - Activity Description. Six shaft monitoring wells would be drilled near the exploratory shaft locations to monitor the effect of shaft construction on the upper aquifers. These wells will penetrate approximately two thirds of the Honaker Trail Formation (base of the upper hydrostratigraphic unit) with a total depth of between 610 and 762 meters (2,000 and 2,500 feet).

Exploratory shaft facilities monitoring wells will be drilled at approximately 30 sites early during site characterization. These holes will be used to establish baseline hydrologic and geochemical conditions and to measure the depth to ground water. Periodic monitoring will be conducted to detect any effects from shaft sinking and EDBH drilling. Depths and locations will be based upon final plans and experience gained from shaft monitoring wells.

Repository and surface facilities monitoring wells will be installed at approximately 100 locations in order to establish baseline conditions and record any construction-induced changes. Locations will be determined based upon adequate coverage of final surface facilities designs. Hole depths will be based upon data developed in earlier shaft monitoring wells and shaft facilities monitoring wells.

Location/Access. The aforementioned wells will be located 61 to 91 meters (200 to 300 feet) from the exploratory shafts (Figure 4-2). No additional site preparation or new access would be required beyond that necessary for exploratory shaft facility construction.

Activity Requirements. Space and personnel requirements for these monitoring wells would be similar to the EDBH. However, less time would be required for mobilization and fewer personnel would be on site during installation. The following equipment (or its design equivalent) is proposed for the six-borehole shaft monitoring program:

- Drilling rig and auxilliary equipment - A large truck-mounted drilling rig with a 30-meter (97-foot) mast using diesel engines to power the drawworks, the drilling fluid circulation pumps, and the electrical generator. Total drilling configuration is operated on 672 kilowatts (900 horsepower).

- Mud tanks or pits - A minimum of two 75-barrel (11,923 liter [3,150 gallon]) steel tanks or pits constructed for drilling fluid circulation

- Solid waste storage area - One waste container

- Equipment laydown and storage areas

- Supervisory quarters, offices, and lab space - Up to nine trailers

- Blowout preventers
  - One annular type blowout preventer
  - One ram-type blowout preventer
  - One hydraulically operated preventer control unit
  - One rotating head

- Fluid storage tanks - Two 500-barrel (79,485 liter [21,000 gallon]) steel tanks.

4.1.1.1.4 Shallow Aquifer Hydro-Nests - Activity Description. Six drill sites around the reference repository would investigate the effects, if any, of shaft construction on the upper hydrostratigraphic unit. Five of the six sites would contain three wells drilled into the upper unit. The sixth site would be a single well installation. The total number of wells is 16. The maximum depth of these wells is 762 meters (2,500 feet). All wells would be cored and sampled through each of the zones selected for hydraulic tests. Selected wells would be converted to long-term monitoring wells when tests are completed. All wells would be geophysically logged.

Three-well hydraulic interference tests would be conducted using these boreholes. These tests would consist of production or injection of fluid into one well while monitoring well pressures (water levels) and, in some cases, selected chemical parameters in the other wells. In general, a single test would last approximately one week.

Location and Access. All six shallow aquifer hydro-nest drill sites are located within the boundaries of the controlled area in a side canyon off of Davis Canyon (Figure 4-2). The 6 drillsites are within approximately 1.6 kilometers (1 mile) of the exploratory shaft facility (ESF). Three are in Section 6, T31S, R21E, and 3 are in Section 1, T31S, R20E.

Access to three of the shallow aquifer hydro-nest drill sites will be by the same routes used for the exploratory shaft. Approximately 2.4 kilometers (1.5 miles) of new access road will be needed to reach the other three holes.

Activity Requirements. Each test drill site would require a total of about 1.6 to 4 hectares (4 to 10 acres). A single large truck-mounted drill rig would be used to drill all three holes on a drill site. The drill pad area would be cleared and leveled to accommodate storage of drill pipe and supplies, erection of the drill rig, and construction of mud pits. Drilling techniques and water uses and requirements would be as described for an EDBH except that the total drilling configuration is operated on 672 kilowatts (900 horsepower).

A 24-hour drilling operation would be conducted. Hence, personnel requirements would be the same as for an EDBH.

Improved and new access roads would be 6 meters (20 feet) wide and top crowned, with culverts installed as necessary. Gravel would be applied as required to maintain stable access.

4.1.1.1.5 Deep Aquifer Hydro-Nests Activity - Description. Hydrologic data are needed to confirm and precisely define the hydrologic regime of the lower hydrostratigraphic unit (LHU) that includes the Pinkerton Trail, Molas, and Leadville Formations. Generally, the holes will either penetrate 152 meters (500 feet) into the Leadville limestone, or to its base, whichever is encountered first. The base of the Leadville limestone, within the area of investigation, is between 1,524 and 1,829 meters (5,000 and 6,000 feet) deep. At each of the five drilling sites, three wells would be drilled into the LHU (Figures 4-2 and 4-3). The deepest well at each site would be selectively cored. The remaining wells would be cored and sampled through those test zones selected for hydraulic tests. Hydrologic testing, which will be conducted as holes are bored, may lead to identification of zones for interference testing. Three-well hydraulic interference tests would be conducted as described in Section 4.1.1.1.4. Drilling and testing of each hole would occur over a period of approximately 6 months. When testing is complete, selected wells would be used for long-term monitoring. All wells would be geophysically logged. Brines produced by drilling and testing will be trucked to disposal wells.

Location and Access. Location of the five deep-aquifer hydro-nest drill sites are shown on Figure 4-2. Drill site DHN-1 is located in Davis Canyon approximately 4 kilometers (2.5 miles) southwest of South Six-Shooter Peak in Section 12, T31S, R20E. DHN-1 can be accessed from the north, off the paved NPS extension of Utah 211, along the road to the exploratory shaft facility and an additional 3.0 kilometers (1.8 miles) along a new access road.

Drill site DHN-2 is located in Corral Pocket approximately 1.6 kilometers (1 mile) northwest of North Six-Shooter Peak in Section 25, T30S, R20E. DHN-2 can be accessed from the north, off the paved NPS extension of Utah 211, 3.4 kilometers (2.1 miles) southwest on a new access road.

Drill site DHN-3 is located approximately 7.2 kilometers (4.5 miles) east of South Six-Shooter Peak in Section 1, T31S, R21E. DHN-3 can be accessed from the paved NPS extension of Utah 211, approximately 2.4 kilometers (1.5 miles) northeast on a new access road.

Drill site DHN-4 is located near the paved NPS extension of Utah 211, 4.6 kilometers (2.9 miles) north-northeast of South Six-Shooter Peak in Section 28, T30S, R21E. DHN-4 can be accessed approximately 0.3 kilometer (0.2 mile) northeast on a new access road.

Drill site DHN-5 is located just inside of Lavender Canyon in Section 10, T31S, R21E. It can be accessed from the paved NPS extension of Utah 211, approximately 1.6 kilometers (1 mile) southwest on a new access road.

Activity Requirements. The three boreholes drilled at each test site would require a total of about 4.9 hectares (12.0 acres). A single drill rig would be used to drill all three holes on a pad. The pad area would be cleared and leveled to accommodate storage of drill pipe and supplies, erection of the drill rig, and construction of mud pits. Drilling techniques and water uses and requirements would be the same as for an EDBH. Drilling equipment is described as follows:

- Drilling rig and auxiliary equipment - Platform drilling rig with a 40-meter (130-foot) mast using diesel engines to power the drawworks, the drilling fluid circulation pumps, and the electrical generator. Total drilling configuration is operated on 597 kilowatts (800 horsepower).
  - Drill pipe, drilling and coring tools, and ancillary equipment

- Mud tanks or pits - A minimum of three 100-barrel (15,898 liters [4,200 gallons]) to a maximum of six 200-barrel (31,796 liters [8,400 gallons]) steel tanks or pits

- Solid waste storage area - One waste container

- Equipment laydown and storage areas

- Core handling shed - A 5-by-18-meter (15-by-60-foot) portable building

- Supervisory quarters, offices, and lab space - Up to nine trailers

- Blowout preventers
  - One annular-type blowout preventer
  - One ram-type blowout preventer
  - One rotating head

- Fluid storage tanks - Three 500-barrel (79,485 liters [21,000 gallons]) steel tanks

- Casing.

A 24-hour drilling operation would be conducted; hence, personnel requirements for each hole would be the same as for a single EDBH (27).

Improved and new access roads would be 6 meters (20 feet) wide and top crowned, with culverts installed as necessary. Gravel would be applied as required to maintain stable access.

4.1.1.1.6 Early Foundation Design Borings, Repository, Surface Facilities, and Access Route Foundation Borings - Activity Description. Numerous foundation borings would be drilled in the areas of the site surface facilities, the exploratory shaft facility, and along the various access routes to the site. The purpose of these borings is to secure information about the near-surface soil and rock. At the site, the information would be used for siting the structure, designing the foundation, estimating earthwork, and evaluating onsite materials for use in construction. Investigations for similar purposes would be conducted over the transportation access routes and utility corridors concurrent with geotechnical activities at the site. In addition, information would be obtained on the surficial and shallow subsurface geology.

Typical shallow-depth geotechnical exploration would be conducted using small, truck-mounted rotary drill rigs. It will be necessary to drive the rigs off-road to sample most of the planned locations (Section 4.2.1). Subsurface characteristics would be determined from test borings drilled and sampled for examination and laboratory testing of soil and rock. Some borings may be geophysically logged. Depending on the boring location and the soil conditions, a truck-mounted auger with a split-spoon sampler, or a continuous-flight solid auger with a California spoon, or a Shelby tube sampler would be used. If drilling extends into bedrock, a rotary rock bit or diamond-core rotary bit would be used to advance the boring.

Foundation borings would be drilled at the location of the surface facilities in Davis Canyon. Thirty to 50 borings would be completed prior to the start of exploratory shaft facility construction. Borings would be used in locating and designing access routes for vehicular and railroad transport, and for water and utility lines. Boreholes along these routes would be at 0.4-kilometer (0.25-mile) intervals; additional borings would be made at water pump stations, along the tunnel alignments, and at tunnel portals. An estimated 400 boreholes are planned for surface facilities and access.

At the site, it is estimated that the borings would be drilled to a depth of 15 meters (50 feet). Borings along access routes would be drilled to similar depths; however, borings along tunnel alignments would be approximately 304 meters (1,000 feet) deep.

Location and Access. The locations of borings at the site would be determined later, on the basis of what type and layout of engineered structure is being considered. Access to site foundation boring locations would be similar to that described for the EDBH.

The locations and access for borings along the access routes would be determined when final selection of the routes is made.

Activity Requirements. Each foundation boring would require a total of 0.04 hectare (0.10 acre). However, many of these holes will be drilled in areas which would already be disturbed for other engineered facilities. All of these borings would be drilled with a small truck-mounted rotary drill rig. The work crew of such a rig consists of a three-person drilling crew and a supervisor. No new or improved roads are expected to be required to conduct foundation boring.

4.1.1.1.7 Geologic and Hydrologic Boreholes - Activity Description. Six geologic and hydrologic borings are planned outside the site (Figure 4-3). These borings are needed to adequately characterize the regional geology and hydrology, particularly to investigate dissolution at Lockhart Basin (two boreholes) and possible dissolution features at Shay Graben (two boreholes). Two hydrologic and geologic boreholes would also be located in Beef Basin. The finished diameter of all these holes would range from 10 to 23 centimeters (4 to 9 inches). The boreholes would be drilled and selectively cored to a depth of approximately 152 meters (500 feet) into, or at the base of, the Leadville limestone. Estimated depths of these holes are as follows:

- LB-1 to 1,676 meters (5,500 feet)
- LB-2 to 1,585 meters (5,200 feet)
- SG-1 to 1,981 meters (6,500 feet)

- SG-2 to 2,164 meters (7,100 feet)
- BBHH-1 to 1,372 meters (4,500 feet)
- BBHH-2 to 1,158 meters (3,800 feet).

A number of hydrogeologic tests are also planned for each of the hydrologic and geologic borings, both within the potential repository stratum, and at other depths in the boring. This testing consists of lowering an inflatable packer to isolate a test zone and performing injection and pumping tests and water sampling for detailed geochemical and isotopic analyses.

After completion of drilling and testing in each borehole, casing and selective completion tools would be installed to allow future monitoring of the water-producing zones and to protect any freshwater aquifers from contamination. Long-term hydrologic testing, sampling, and water-level monitoring would be a continuing effort on a quarterly schedule.

Location and Access. Locations of the hydrologic and geologic boreholes are shown on Figure 4-3. At Lockhart Basin, drill site LB-1 is located 4.8 kilometers (3 miles) northeast of Horsehead Rock in Section 1, T29S, R20E. LB-1 can be accessed to the north following an existing unpaved road 22 kilometers (13.5 miles) off Utah 211, then south approximately 2.8 kilometers (1.75 miles). Site LB-2 is located 6.4 kilometers (4 miles) northwest of Horsehead Rock in State-owned Section 36, T28S, R20E. LB-2 can be accessed to the north following an existing unpaved road 22 kilometers (13.5 miles) to the site.

Drill site SG-1 in the Shay Graben is located 0.8 kilometer (0.5 mile) south of Utah 211 in Section 21, T32S, R22E. SG-1 can be accessed from the north off Utah 211, 0.4 kilometer (0.25 mile) south on an existing unpaved road from the Kelly Ranch. The other Shay Graben drill site (SG-2) is located approximately 4.0 kilometers (2.5 miles) south of Utah 211 in Section 27, T32S, R22E, and can be accessed from the north off Utah 211 along an existing road.

Beef Basin hole BBHH-1 is located 10 kilometers (6 miles) west of Cathedral Butte in Section 35, T32S, R19E. BBHH-1 can be accessed from an existing unpaved road extending northward 68 kilometers (42 miles) from Utah State Highway 95 (Utah 95). Approximately 5.3 kilometers (3.3 miles) of road would require some improvement. Borehole BBHH-2 is located in Section 2, T32S, R18E. BBHH-2 also can be accessed northward along the existing unpaved road for approximately 82 kilometers (51 miles). Approximately 16.4 kilometers (10.2 miles) of road beyond the BBHH-1 site would require improvement.

Activity Requirements. The total land area required for the drill pad of each hydrologic/geologic borehole would be about 1.6 hectares (4.0 acres). The pad area would be cleared and leveled to accommodate storage of drill pipe and supplies, erection of the drill rig, and construction of mud pits. Drilling techniques and equipment, and water uses and requirements would be similar in type and amount to the lower hydrostratigraphic unit test wells.

A 24-hour drilling operation would be conducted, so personnel requirements would be the same as for the EDBH.

Improved and new access roads would be 6 meters (20 feet) wide and top-crowned, with culverts installed as necessary. Gravel would be applied as required to maintain stable access.

4.1.1.1.8 Shay Graben Trench - Activity Description. The near-surface geologic investigations would include excavating a trench across the south fault of Shay Graben to provide data on the timing and amount of Quaternary displacement on that structure. Exposures created by the excavations may also provide data on the nature of depositional and erosional events that have occurred along the structures during Quaternary time and would provide fresh (unweathered) material for sampling.

Location and Access. The trench at Shay Graben is planned to be located approximately 3 kilometers (2 miles) north-northwest of the peak of Shay Mountain in Section 25, T32S, R21E (Figure 4-3). Access to the trench site follows existing roads or trails. Limited off-highway vehicle travel (less than 0.4 kilometer [0.25 mile]) would be required to reach the trench site. No road construction or upgrading would be required for this activity.

The backhoe trench across Shay Graben would be approximately 1 meter wide at its total depth (with 1:1 side slopes) by 90 meters long and up to 8 meters deep (50 by 300 by 25 feet). With fencing and windrowing of excavated soil, the trench would require an area of 30 by 90 meters (100 by 300 feet) or 0.28 hectare (0.69 acre).

Activity Requirements. The trench would remain open for about 4 weeks and would require approximately 10 days for excavation and fencing; 6 days for examination, description, and sampling, and 2 days for backfilling and fence removal.

The work force requirements would consist of 6 persons during excavation activities at the trench and 3 persons per trench during postexcavation activities (i.e., examination, description, and sampling). Vehicles required for this proposed work force would be 2 or 3 per day.

4.1.1.1.9 Borehole Search and Characterization. A search will be conducted for unrecorded wells within the site vicinity. Those that could have potential impact on the stability of the repository may need to be reentered for testing and evaluation. No such boreholes are thought to exist at the site. Search techniques may include reviewing State and local drilling records, reviewing historical newspaper accounts and aerial photographs, conducting door-to-door surveys, contacting various historical societies, and possibly walking portions of the site with hand-held metal detectors. If an abandoned well is discovered, it may be necessary to excavate the well bore to gain additional information about hole conditions. Remedial work, characterization, or borehole plugging may require disturbance of a few acres over a period of up to 6 months.

4.1.1.1.10 Indian Creek Syncline and Cross Canyon Boreholes. Ten boreholes will be drilled in Davis Canyon, roughly parallel to the creek bed which runs the length of the canyon; these are referenced as Indian Creek syncline boreholes on Table 4-2 and Figure 4-2. Twelve boreholes will be drilled across Davis Canyon from the exploratory shaft facility (ESF); these are referenced as Cross Canyon boreholes on Table 4-2 and Figure 4-2. These holes may be drilled for a small-diameter core to a depth of about 152 meters (500 feet) for the purpose of investigating potential local fracture systems and establishing detailed local structural control. Only one light drill rig and two light support vehicles will be required. No drilling brines will be used and a mud pit may not be necessary. Little if any land clearing will be necessary for access.

4.1.1.2 Geophysical Studies

Two types of seismic reflection surveys would be performed. Single seismic lines across key areas would be used to investigate subsurface geologic features of the site and its vicinity, and a 3-D seismic survey would focus on the subsurface of the Davis Canyon site.

4.1.1.2.1 Seismic Reflection and Refraction Lines Activity Description. Seismic reflection and refraction survey activities in the Davis Canyon site are proposed to provide additional data on the depth and lateral extent of the repository salt layer and to help define subsurface structures. Seismic reflection profiling involves inducing an elastic pulse near the ground surface and using geophones to detect the resulting motion of the ground at various points. The elastic pulse (or wave) may be generated by automated truck-mounted vibrating equipment or a high-energy source. Lines of geophones are strung out along survey routes and connected to a recording truck.

Location and Access. Approximately 180 kilometers (112 miles) of seismic reflection surveys are proposed in the site area. Seismic line layout would parallel existing roads on Federal, State, and private land. High resolution seismic reflection lines will be located on the site near the EDBH boreholes.

Four short refraction surveys, each about 0.8 kilometer (0.5 mile) long, will be run in the vicinity of the ESF to determine shallow seismic velocities. These surveys will use hand-portable equipment, two light trucks, and a crew of four persons. Disturbances will be limited to walking and driving along the lines. The seismic energy source will be a weight drop, blasting cap, or rifle bullet impact.

Activity Requirements. The average rate at which surveys can be done for reflection is 5 to 8 kilometers (3 to 5 miles) per day, but mobilization time between survey lines must be included. Because no instruments would be installed, there would be no land requirements other than for access. For the refraction survey, about 0.8 kilometer (0.5 mile) can be profiled each day.

4.1.1.2.2 3-D Seismic Survey Activity Description. The activity for conducting the 3-D seismic survey is essentially the same as for single seismic lines except that the close spacing of a grid of stations allows three-dimensional interpretation.

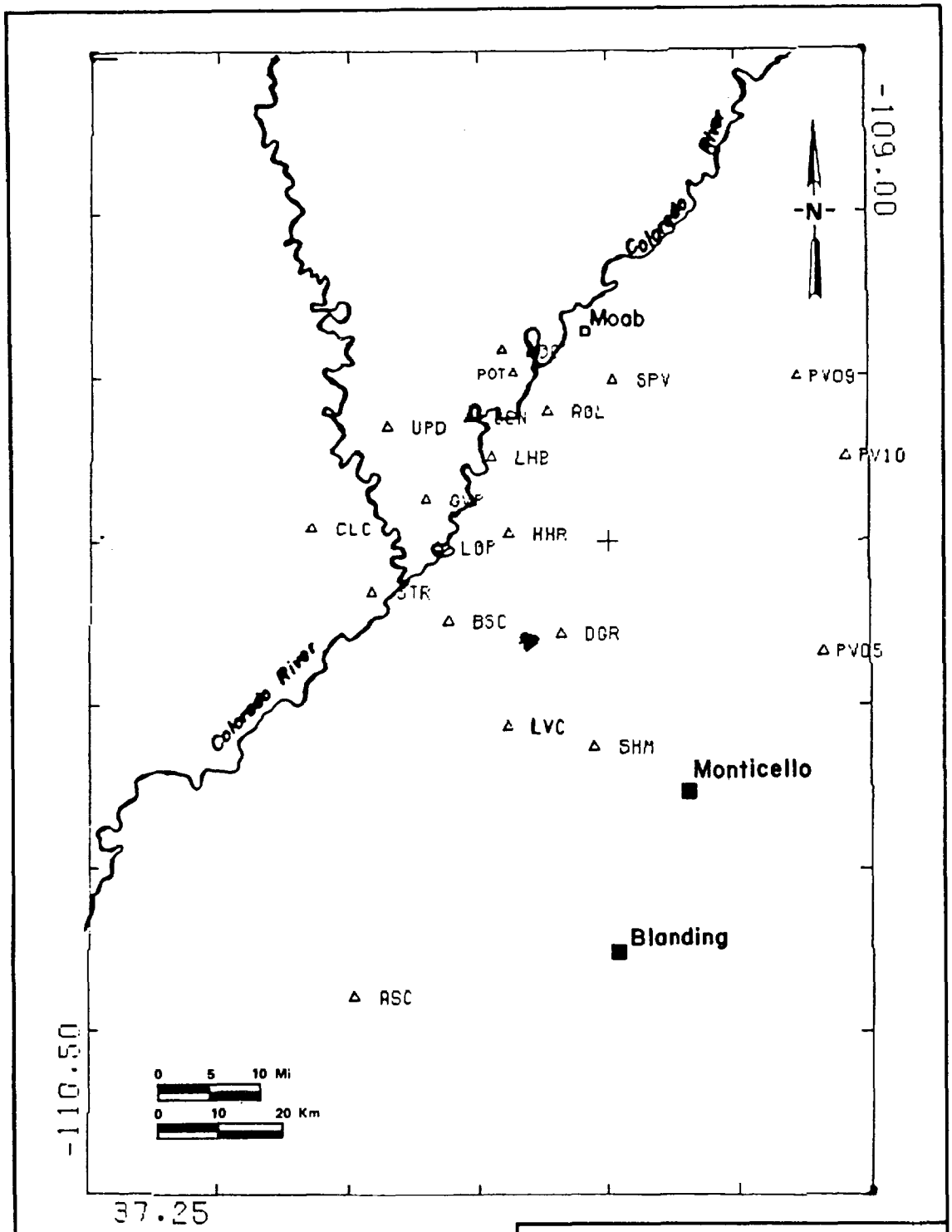
Location and Access. A 25.9-square-kilometer (10-square-mile) grid of seismic reflection lines is planned over the underground facilities. This grid would be laid out with lines spaced 22 to 47 meters (75 to 150 feet) apart and about 4 kilometers (2.5 miles) long.

Activity Requirements. Vehicles needed to conduct the survey include three or four heavy trucks, two or three vibrator trucks, a recording truck, and three or four trucks for geophones, auxiliary equipment, and crew. Seismic lines must be cleared and surveyed by a two-person crew walking the lines. Geophones are laid out and retrieved in groups. The energy source would be either truck-mounted vibrators or dynamite. For explosives, shallow (approximately 7.6-meter [25-foot] deep) drill holes would be loaded with a 0.5- to 2.3-kilogram (1- to 5-pound) charge.

4.1.1.2.3 Microseismic Network Activity Description. A microseismic network has been installed during screening studies to monitor microearthquake activity in the vicinity. The network currently has 17 permanent seismograph stations sited as shown in Figure 4-5. These stations have been detecting low-level seismic activity in the region. Data from the network are analyzed to determine the locations and characteristics of the microearthquakes observed. The microearthquakes would be evaluated to assess their possible relation to faults and to help characterize the current tectonic environment around the site.

Location and Access. Approximately 10 additional stations would be installed during site characterization to improve the areal coverage of the network and provide more detailed coverage near the site. Locations for the additional stations have not been selected but they would be determined according to the field conditions encountered.

Activity Requirements. Each seismograph station consists of a partially buried 208-liter (55-gallon) drum containing battery-powered electronic instruments, a seismometer placed about 0.3 meter (1 foot) into the ground, and an antenna 2 to 3 meters (6 to 10 feet) high for a low-powered directional radio transmitter. The radio signals are transmitted to an office facility in Moab where the seismic data are recorded. Some radio links require repeater stations similar to the seismograph stations, but without a seismometer. Each station requires 1 or 2 days for installation and maintenance visits for a few hours every 4 to 6 months. Access to station sites is by existing roads and trails, or by helicopter.



Explanation

△ Existing seismographic station

Geologic Repository Operations Area

Seismographic Stations in the Paradox Basin Microseismic Network

Figure 4-5

4.1.1.2.4 Potential Field Survey. Detailed gravity and magnetic surveys would be performed over approximately 26 square kilometers (10 square miles) in the vicinity of the site. These surveys involve taking measurements with a hand-carried instruments (gravimeter and magnetometer) on a surveyed grid. Vehicles would stay on existing roads and trails, with a two-person gravity crew and a two-person survey crew working on foot. Each reading takes 2 to 5 minutes. Helicopter access may be required to reach points inaccessible by foot. Hole-to-hole resistivity and seismic surveys may be run to investigate stratigraphy and potential discontinuities. A hole-to-surface borehole resistivity study would be conducted in an engineering design borehole (EDBH). This would require a truck-mounted winch and power source (generator) at the borehole. The measurements would be made by two or three people walking a grid about the borehole approximately 1.6 kilometer by 1.6 kilometer (1 mile by 1 mile) with lines 76 to 152 meters (250 to 500 feet) apart. These lines would need to be surveyed but probably not completely cleared of vegetation. A two-person survey crew would walk the lines, placing two copper electrodes into the ground every 30 to 61 meters (100 to 200 feet), obtaining a measurement, then removing the stakes and proceeding to the next station.

4.1.1.3 Geologic Mapping

Activity Description. Detailed geologic mapping would be completed over the site. This would include detailed mapping of Quaternary deposits, bedrock geology, fractures, and mines and prospects.

Quaternary site mapping would provide data on the type, thickness, and distribution of unconsolidated Quaternary deposits in the site area. Data would be collected for age dating and possibly for determining the engineering properties of the surficial deposits. Examination of these deposits would provide information on the effects of geomorphic processes that have been occurring at the site during the past 10,000 years. The magnitude and frequency of paleoflood events, cyclic patterns of alluviation, and gullying of fine-grained fill during Holocene time are of particular interest for projecting future flood events and for determining the local effects of paleoclimatic changes.

Areas of bedrock outcrop would be distinguished from soil- or talus-covered areas so that reviewers can easily determine the data base for the map and, therefore, its accuracy. Emphasis would be placed on tracing marker beds and formation contacts to help define the geologic structure. Survey control may be established on key marker beds or formation contacts so that accurate structure contour maps can be developed. Mines, prospects, and borehole locations would also be mapped in detail.

The characteristics of joints and fractures in the immediate and general site area would be investigated using both aerial photographs and ground-based mapping. The results of borehole and core logging would also be utilized in this characterization. Joints would be mapped and characterized as to length, strike, dip, formations affected, whether or not they cross formation contacts, and their potential as pathways for ground-water movement.

Location and Access. The bedrock geologic mapping activity provides for the production and documentation of a detailed geologic map of the 508-square-kilometer (196-square-mile) area centered on the proposed site. The geology would be mapped on 1:12,000-scale topographic maps.

Geologic mapping would be conducted on foot by geologists and surveyors systematically mapping across the area. Vehicular traffic would be confined to existing roads and trails.

4.1.1.4 Access Route Topographic Mapping

Topographic maps, at a scale suitable for the design of access and utility routes, would be developed for portions of the routes which would be evaluated. The site area has already been mapped. Light vehicles, survey crews on foot, and aircraft are used for topographic mapping.

4.1.1.5 Pre-Waste-Emplacement Geochemical Conditions

Rock and fluid samples would be collected from boreholes for chemical, petrographic, mineralogical, and isotopic analyses to provide information on baseline radioactivity, which is necessary for design and testing of waste package components, analyses of waste package performance, evaluation of potential radionuclide release rates, and determining the compatibility of various construction materials with the subsurface environment.

4.1.2 Exploratory Shaft Facility (ESF)

The exploratory shaft facility (ESF) is to be constructed to gain access to the potential repository salt horizon and to perform in situ tests for site characterization (PB/PB-KBB, 1985; 1986). The facility will consist of two shafts; a production shaft and a service shaft. The service shaft is required for personnel safety (Section 4.3.2) and ventilation. Both shafts will be constructed by conventional shaft sinking techniques and will have a finished diameter of 3.6 meters (12 feet). The underground excavation totals approximately 1,652 linear meters (5,420 linear feet) to support testing. The remainder of this section is based on a preliminary-level design that reflects compliance with "gassy" mine regulations (30 CFR Part 57). ESF design elements are conservative in nature and will be finalized upon completion of engineering boreholes described in the previous section.

The ESF site would occupy approximately 24 hectares (59 acres) in Davis Canyon, San Juan County, Utah (Figure 4-6). Access to the ESF site would be from the nearest two-lane, hard-surface road (Utah 211). The access road would be approximately 8.2 kilometers (5.1 miles) in length, requiring an area of 14.2 hectares (35 acres) considering the entire 18.3-meter (60-foot)-wide right-of-way.

The ESF site (Figure 4-7) will be arranged to accommodate the following:

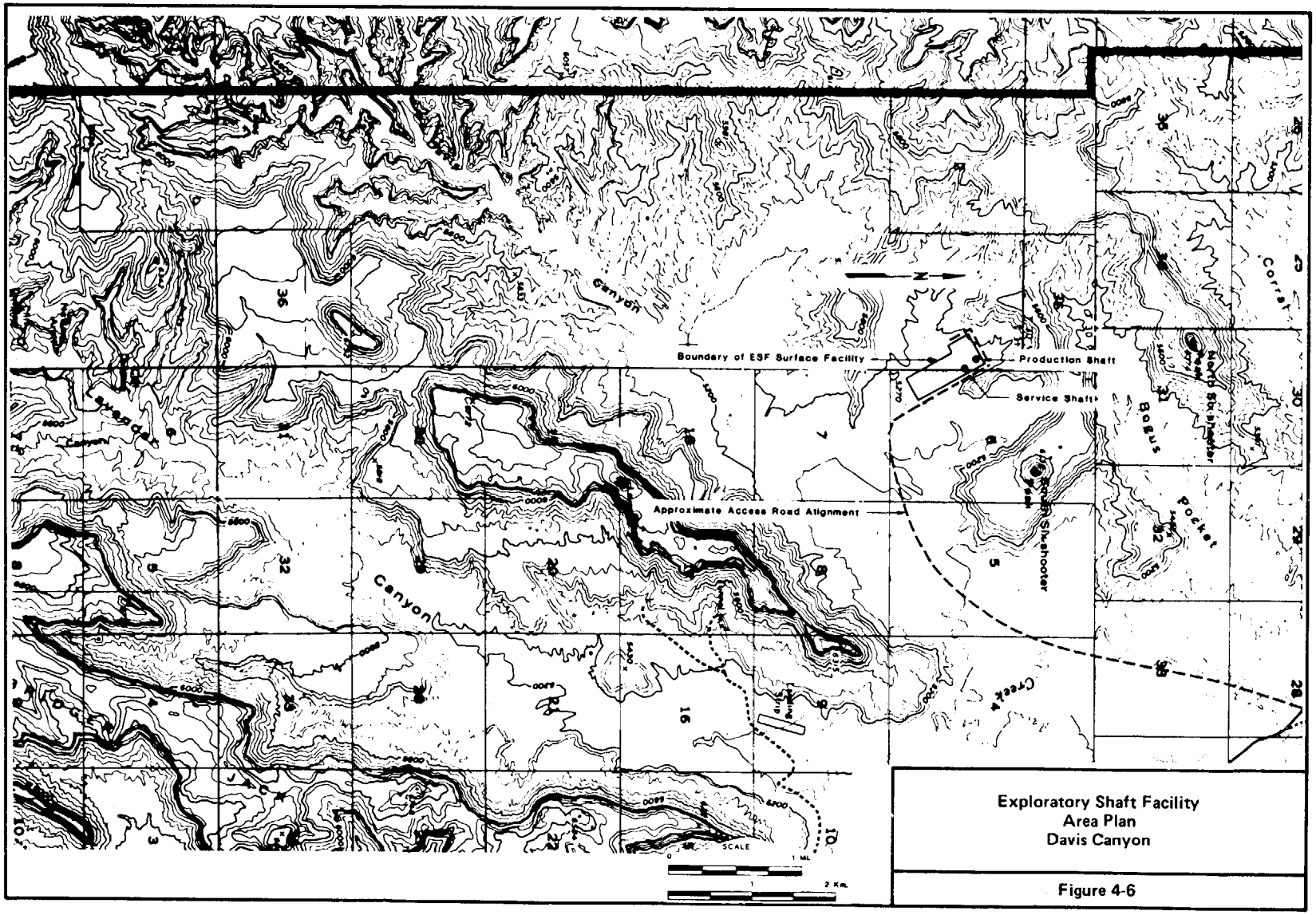
- Simultaneous construction of two shafts
- Functional arrangement to support construction
- Consolidation of all excavated wastes into one area for ease of handling, maintenance, and control of salt-contaminated material.

The site is comprised of construction areas for contractor equipment and materials, storage piles which accommodate stockpiled materials obtained during shaft and subsurface construction, an evaporation and retention pond, and a sediment pond. The site arrangement also provides for administrative facilities which include office facilities, laboratory facilities, a security building, utilities, and parking.

A perimeter roadway provides security control and emergency access to the entire site. A 2.1 meter (7-foot)-high chain link security fence will be constructed along the outside perimeter.

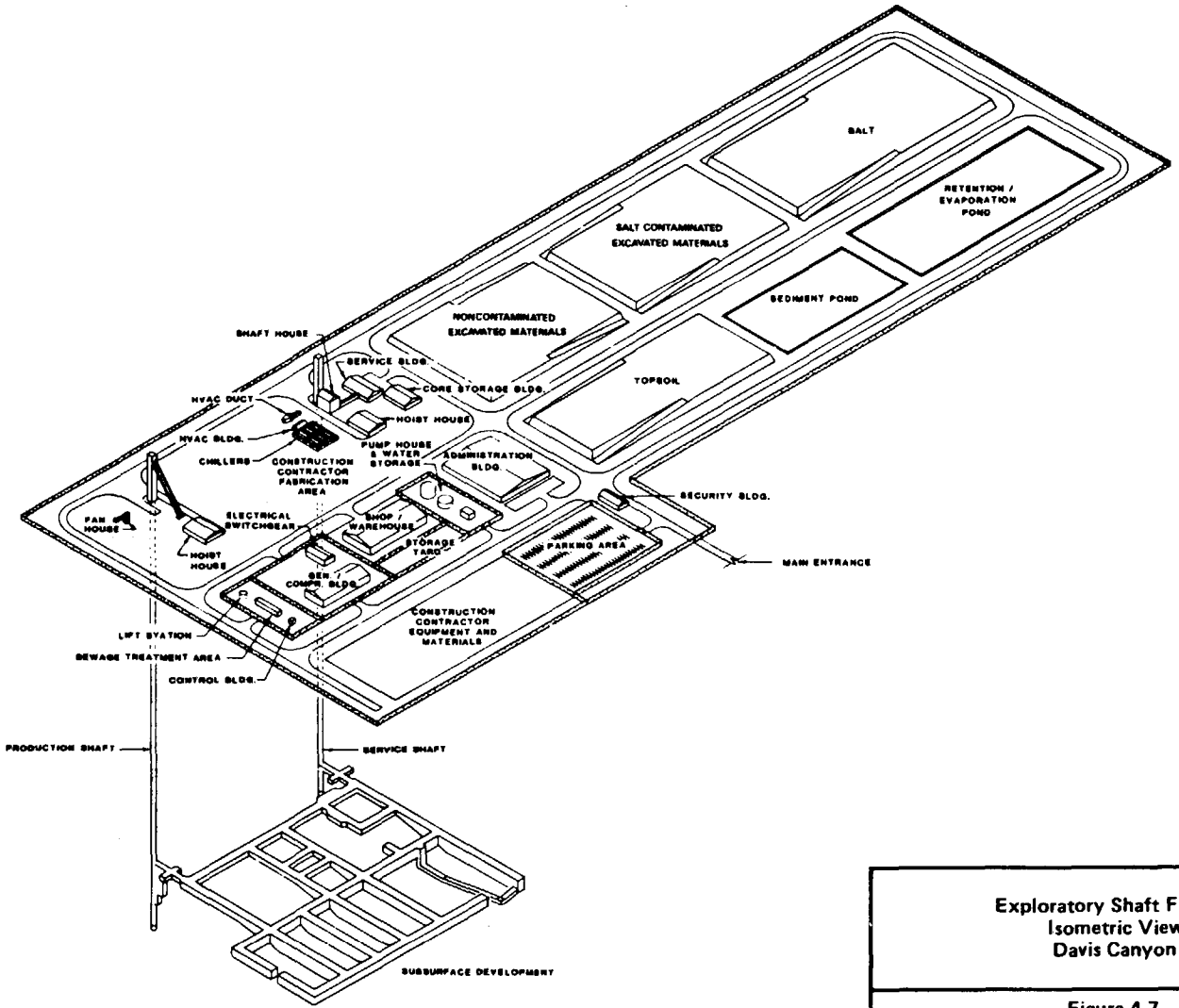
The ESF site arrangement has been designed in accordance with the following guidelines:

- Fit the natural contour of the land as closely as possible and practical and minimize erosion and sedimentation within and around the site
- Minimize clearing and disturbance
- Restrict grading to requirements for structures and facilities, roadways, parking areas, utilities, drainage ditches, and surface stormwater runoff control.



Exploratory Shaft Facility
Area Plan
Davis Canyon

Figure 4-6



Exploratory Shaft Facility
Isometric View
Davis Canyon

Figure 4-7

4.1.2.1 Land Requirements

The amount of land required for the Davis Canyon facility site and parking lot in the Paradox Basin is as summarized below:

- Site: 24 hectares (59 acres)
- Access road and right-of-way: 14.2 hectares (35 acres).

These amounts are for the finished site. Additional land may be required based on site-specific orientation and ownership boundary locations. The access roadway would start from the nearest two-lane, hard-surface public roadway (National Park Service extension of Utah 211) and extend approximately 8.2 kilometers (5.1 miles) to the site entrance.

The Davis Canyon site in the Paradox Basin is located primarily on public land managed by the U.S. Department of the Interior, Bureau of Land Management (BLM) and on some land owned by the State. The DOE will obtain the needed access by entering into a cooperative agreement with the BLM and by purchasing any State-owned land. Boundary surveys and establishment of construction survey monuments would be a part of the activities leading to the above agreement.

4.1.2.2 Construction

The ESF construction stages are (1) site preparation, (2) shaft and surface facility construction, (3) shaft outfitting, and (4) underground excavation. Shafts will be constructed by conventional drill-and-blast shaft-sinking techniques. A summary of the ESF project characteristics is provided in Table 4-3.

Underground excavation would be accomplished in two stages: initial underground excavation and expanded underground excavation. Initial underground excavation would occur before outfitting the shafts.

The initial excavation stage will include enough drift to support equipment setup and the additional underground excavation required to connect the two shafts. Once the connection is made between the shafts, the underground ventilation circuit is established, and both shafts become available for evacuation should an emergency arise. The remaining excavation for testing is then completed.

The estimated schedule for construction and testing activities is summarized in Figure 4-8. The estimated average number of personnel at the site during each construction and testing phase is listed in Table 4-4.

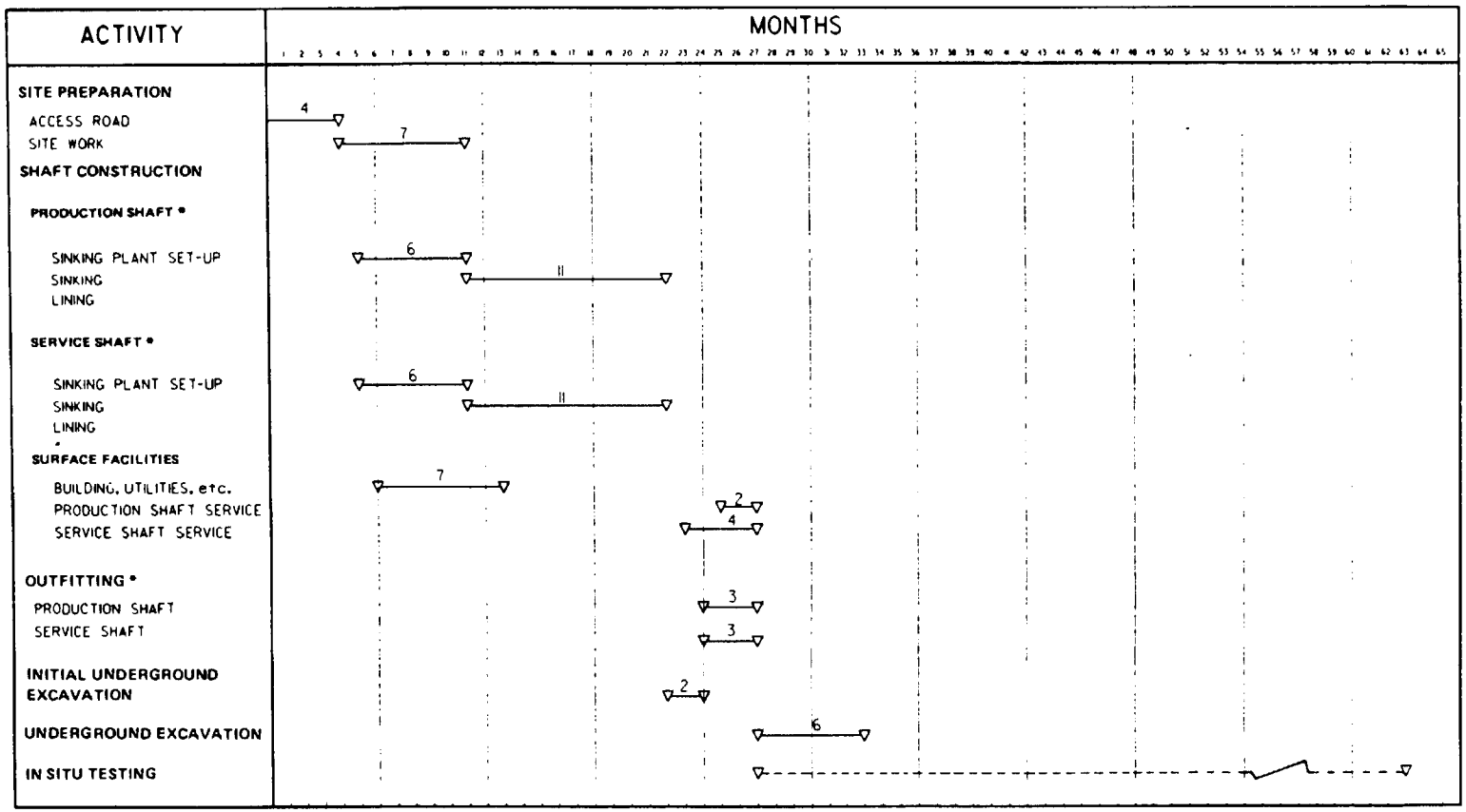
The phasing of construction activities determines those periods when the impact of site operations may be the greatest. Table 4-5 identifies 12 periods defined by different sets of concurrent construction activities during construction and testing operations. By reference to ensuing equipment usage tables, Table 4-5 lists the peak cumulative horsepower usage by period. From this, two conservative cases have been identified which have been used as a basis for the air quality input analysis presented in Section 4.2.1.3.

4.1.2.2.1 Site Preparation. Construction activity is initiated by first accomplishing construction surveys and establishing field monuments. Equipment for construction for the access road and for ESF site preparation is shown in Table 4-6. Estimated resources consumed during site preparation, and during the ensuing phases of ESF construction, testing and final disposition are shown in Table 4-7.

Table 4-3. Exploratory Shaft Project Characteristics, Two 12-Foot Conventionally Mined Shafts

Construction Detail	Approximate Quantitative Description[a]
Surface area for exploratory shaft activities	59 acres
Conventionally mined shafts:	
Finished diameter	12 feet
Lining depth	2,830 feet
Finished shaft depth	
Production shaft	3,044 feet
Service shaft	2,965 feet
Depth to shaft stations	2,930 feet
Horizontal workings at base of shafts	5,420 feet
Initial excavation and connection drift between shafts	825 feet
Expanded excavation	4,595 feet
Access road (length)	5.1 miles
Access road (width)	24 feet, 4-foot shoulders
Access road right-of-way (width)	60 feet
Highest structure (headframe)	125 feet
Electric power source	4 - 2,400-kW generators
Emergency power	3 - 800-kW generators
Capacity of excavated material storage pile areas	
- Noncontaminated	69,000 cu yd
- Contaminated	75,000 cu yd
Capacity of salt storage pile area	135,000 cu yd
Material excavated	226,000 cu yd
- Noncontaminated	56,000 cu yd
- Contaminated	61,000 cu yd
- Salt	109,000 cu yd
Maximum height of salt and other spoil piles	30 feet
Capacity of evaporation and retention ponds	4.5 million gallons
Capacity of sediment pond	2.1 million gallons
Surface facilities	
- Prefabricated building units	70,000 sq ft (total)
Foundations	Concrete slabs for prefabricated building units, concrete footings for shaft collar and shaft hoisting equipment
Total freshwater demand	276 acre-feet (90 million gallons)

(a) Based upon preliminary design information. Site-specific data used for final design may change these parameters.



*Should a full liner be necessary, an additional 11 months shaft construction and outfitting will be required for each shaft.
Source: PB/PB-KBB, 1985; 1986; McIntosh, 1986.

Exploratory Shaft Facility Construction/Testing Sechedule Davis Canyon

Figure 4-8

Table 4-4. Estimated Personnel Requirements by ESF Phase, Davis Canyon

Exploratory Shaft Facility Phase	Number of Personnel (average)[a]
Site preparation	130
Shaft and surface facility construction and outfitting	295
Initial underground excavation	245
Expanded underground excavation	280
Testing	290
Final disposition	100

(a) Includes contractor and noncontractor personnel.

Table 4-5. Concurrent Construction Activities, Davis Canyon ESF Site

Period	Month	Tables Used	Peak Cumulative HP
1	1-4	Access Road (4-6)	4,475
2	5	Site Work (4-6)	4,925
3	6	Site Work (4-6) Sinking Plant Set Up for Production Shaft (4-10) Sinking Plant Set-up for Service Shaft (4-10)	7,405
4	7-11	Site Work (4-6) Sinking Plant Set Up for Production Shaft (4-10) Sinking Plant Set-up for Service Shaft (4-10) Surface Facility Construction (4-10)	12,464
5	12, 13	Shaft Sinking for Production Shaft (4-10) Shaft Sinking for Service Shaft (4-10) Surface Facilities (4-10)	14,499
6	14-22	Shaft Sinking for Production Shaft (4-10) Shaft Sinking for Service Shaft (4-10)	9,440
7	23	Initial Underground Excavation (4-11)	8,570
8	24	Service Facilities for Service Shaft (4-10) Initial Underground Excavation (4-11)	9,849
9	25	Service Facilities for Service Shaft (4-10) Outfitting Production Shaft (4-12) Outfitting Service Shaft (4-12)	9,309

Table 4-5. Concurrent Construction Activities, Davis Canyon ESF Site
(Page 2 of 2)

Period	Month	Tables Used	Peak Cumulative HP
10	26, 27	Service Facilities for Production Shaft (4-10) Service Facilities for Service Shaft (4-10) Outfitting Production Shaft (4-12) Outfitting Service Shaft (4-12)	10,331
11	28-33	Underground Excavation (4-13) Testing (4-15)	13,455
12	34, 63	Testing (4-15)	8,100

Table 4-6. Equipment for Construction of Access Road and Site Preparation

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Site Preparation				
Access road (4 months)	1	Excavator	195	195
	3	Dozers	300	900
	1	Grader	180	180
	6	Trucks	250	1,500
	2	Vibratory compactors	210	420
	1	Wheel loader	270	270
	2	Pavers	145	290
	1	Water truck	250	250
	1	Oiler	200	200
	2	Pickup trucks	135	270
				4,475
Site Work (7 months)	2	Dozers	300	600
	1	Scraper	450	450
	1	Grader	180	180
	8	Trucks	250	2,000
	1	Vibratory compactor	210	210
	1	Excavator	195	195
	1	Wheel loader	270	270
	2	Compressors	150	300
	1	Water truck	250	250
	1	Oiler	200	200
	2	Pickup trucks	135	270
				4,925

Table 4-7. Estimated Resources Consumed During Exploratory Shaft Facility Activities, Davis Canyon

Resource, Unit	Site Prep. (11 mo)	Shaft & Surface Facility Const. (39 mo)	Initial Underground Excavation (2 mo)	Shaft Outfitting (13 mo)	Underground Excavation (6 mo)	Testing (36 mo)	Final Disposition (33 mo)	Total Consumption (mo)
Diesel fuel, 1,000 gal (mobile)	190	250	14	23	65	49	280	871
Propane fuel, 1,000,000 scf (generators)	--	580	24	41	54	593	127	1,418
Water, 1,000 gal	1,900	15,000	860	2,000	1,100	16,000	53,000	89,860
Concrete, 1,000 cu yd	--	34	--	--	--	--	1	35
Plastic liner, 1,000 sq yd	240	--	--	--	--	--	--	240
Steel, tons	--	6,000	19	670	35	--	--	6,724
Blasting powder, 1,000 lb	66	260	13	--	--	--	--	339
Resin, 1,000 lb	--	160	14	1	56	--	--	231
Polyurethane, 1,000 gal	--	3	--	--	--	--	--	3
Fertilizer, tons	--	--	--	--	--	--	4	4
Seed, 1,000 lb	--	--	--	--	--	--	3	3
Gravel, 1,000 cu yd	35	--	--	--	--	--	--	35
Asphalt and Bitumen, tons	20,000	6,000	--	--	--	--	--	26,000
Polymer Sealant, 100 gal	-	-	-	-	-	-	32	32

ESF site construction is initiated by the development of an 8.2-kilometer (5.1-mile) access roadway. Opening of an access route to the site would begin as soon as possible so that site preparation and sinking plant setup can proceed quickly. The new roadway construction will be designed to minimize erosion and siltation by the use of temporary sediment basins, jute mesh, or straw bales, according to the construction procedures being employed at the project. The amount of excavation and embankment will be minimized by a road profile which is flattened and liberally rounded to blend with the existing topography as much as possible and still be consistent with the roadway design class. Several access corridors to the site have undergone a preliminary feasibility analysis. The preliminary alignment selected extends from Utah 211 to the site along the northwestern bank of the Davis Canyon Tributary. This alignment requires only one stream bed crossing and avoids major drainage improvements and structures which may be required for the repository but not for the ESF site.

The roadway design will minimize environmental impacts, present an acceptable appearance, and minimize the removal of vegetation or alterations of other natural features as much as practicable. Natural land drainage patterns will be studied to ensure that the roadway complements them. Drainage ditches and culverts will be constructed where necessary. Geometric elements of the access road will be arranged for safe and efficient traffic operations. Where the roadway crosses an established flood plain, the flood plain characteristics and flow elevations will be determined and a compatible design constructed.

The access road will be designed as an all-weather road with a 7.3-meter (24-foot) width consisting of two 3.7-meter (12-foot) lanes and 1.2-meter (4-foot) rounded shoulders on each side. This roadway accommodates two-way traffic at a 50-mile-per-hour design speed. The roadway will have a flexible base constructed of an acceptable material which is used locally for road construction and has demonstrated its performance in strength and serviceability. The subgrade will be constructed of a suitable material to provide a uniform, continuous, and permanent base support. The road will be surfaced and paved with asphalt.

The roadway design will conform to applicable State and local requirements and environmental standards. Intersection of the access road and Utah 211 will comply with the applicable State, Federal, and local alignment and sign regulations.

Table 4-8 gives the design criteria for the access roadway.

Site preparation consists of limited clearing and grading. Due to the anticipated homogeneity of soil from surface to bedrock and the scarcity of vegetation at the ESF site, the need for a clearing operation would be minimal. Excavated material would be used as embankment or stockpiled. Rocky materials, including loose rocks occasionally dislodged from surrounding slopes, would be removed and stockpiled separately.

Due to the scarcity of woody vegetation at the site, the need for clearing will be minimal. Of the 24 hectares (59 acres) comprising the ESF site, 21.4 hectares (53 acres) will be disturbed during construction. Prior to grading, about 15 centimeters (6 inches) of topsoil and overburden will be removed and stockpiled. Rocky materials, if any, will be removed and stockpiled separately within the same area.

Earthwork would be required to excavate the evaporation/retention and sediment detention ponds. Earthwork would also be required around the shaft houses and service buildings to provide positive runoff control away from the shafts. Terracing of steep slopes near parking facilities would also be required to achieve acceptable grades. Suitable excavated materials will be used for the construction of site roads, fill areas, and dikes; other excavated materials would be stockpiled.

Site roads would be 6 meters (20 feet) wide and have 1.2-meter (4-feet) rounded shoulders. The site roads will be constructed of a compacted aggregate flexible base and a stabilized subgrade. The access roads will be constructed with a base of compacted aggregate overlain with asphalt. Interior site roads would be crowned. The perimeter site road would be sloped to drain toward the site to contain all surface runoff. Road culverts would be constructed with corrugated metal pipe and compacted backfill.

Table 4-8. Access Roadway Design Criteria

Design speed	50 mph
Operating speed	35-45 mph
Horizontal curvature	7 degrees
Minimum radius	800 feet
Minimum stopping sight distance	350 feet
Lane width	12 feet
Loading	HS-20
Maximum grade	
Preference	6 percent
Maximum	10 percent

Average daily automobile traffic would increase from baseline levels to include approximately 120 round trips to the site by passenger vehicles per day during the site preparation stage. Truck traffic is expected to increase from baseline levels to include approximately 490 round trips to the site per month, assuming no construction camp. The estimated vehicular traffic during the ESF construction, testing, and final disposition periods is given in Table 4-9.

4.1.2.2.2 Shaft and Surface Facility Construction - Purpose of Shafts. The purpose of the exploratory shafts is to gain access to the potential repository horizon and perform in situ tests for site characterization. These shafts will also be used to circulate fresh air to the underground operations and contain conveyances for material or personnel handling requirements.

From the surface to its final depth, a shaft passes through many different rock types. Whereas strong rocks may not require any external support, unconsolidated material or weakly cemented rocks may require some form of support to keep the shaft open. The rocks may either be completely dry, partially saturated, or when below the water table, saturated. Therefore, in addition to supporting the rocks, water must be controlled to permit safe underground operations. This is especially critical in water-soluble evaporites such as rock salt and potash. The support of rocks and control of water is the function of the shaft lining and of the seals that are constructed at strategic locations.

Conventionally mined shafts have been constructed to depths exceeding 3,045 meters (10,000 feet). Shaft depths of 915 meters (3,000 feet) are not unusual for North American and European mining operations.

A circular cross-sectional shape is most prevalent in modern shafts. The circular shape is the most stable configuration to resist lithostatic and hydrostatic pressures acting against the shaft lining. For ventilation purposes also, a circular shaft is more efficient than other shapes since it offers the least resistance to the ventilating air current.

Shaft Sinking Methods, Ground and Water Control. The drill and blast method of shaft sinking employs the basic cycle of drilling, blasting, and removing muck from the shaft. A preliminary ground support system follows a few feet behind the advancing shaft bottom. A number of holes are drilled in the shaft bottom, loaded with an explosive, and blasted. The blasted material (muck) is hoisted to the surface in the muck buckets. For efficiency of operations and schedule, at least two buckets are usually used for muck removal. Once the excavated material has been removed to the surface, the cycle is repeated. Figure 4-9 is a schematic showing the drill and blast method of shaft sinking. A preliminary lining is installed in the shaft as the sinking progresses to protect the workers in the shaft from rock falls. Information obtained from the engineering design boreholes is used to determine the extent and method of ground-water control in the shaft during sinking.

The ground support system required to support the preliminary lining, and if necessary the final shaft lining, will be designed for the anticipated mechanical behavior of the shaft walls.

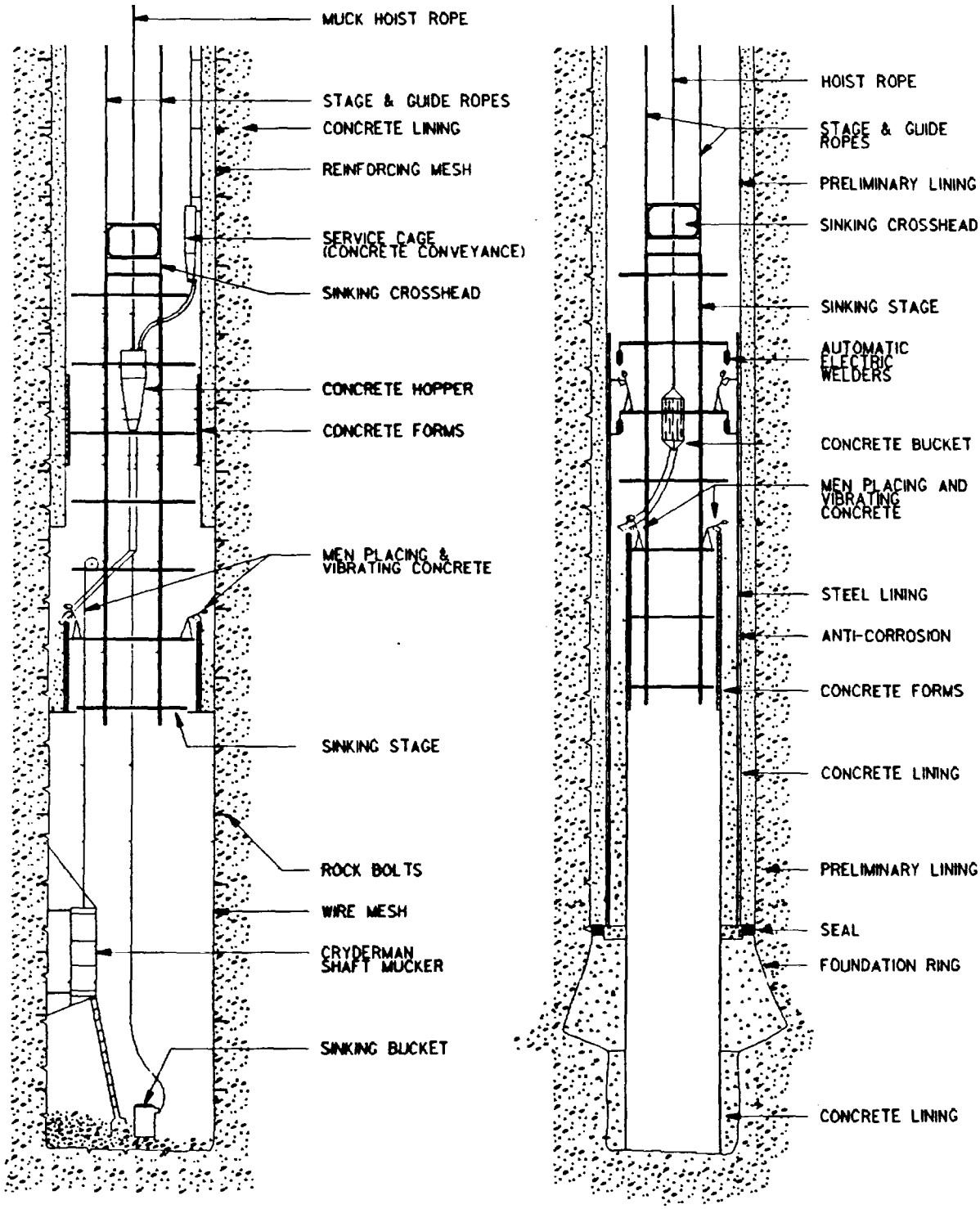
Preliminary Lining. The type of preliminary support can vary from rock bolts and wire mesh in competent rock to consolidation by grouting or freezing in water-bearing soils. A single ground control system is seldom sufficient for shafts except for shallow near-surface openings. The initial ground support for deep shafts is generally augmented by lining the shaft walls with monolithic concrete or precast concrete blocks grouted in place.

Table 4-9. Estimated Vehicular Traffic During ESF Construction and Testing, Davis Canyon (Without Base Camp)

Phase[a]	Daily Automobile Round Trips[b]	Monthly Truck Round Trips
Site preparation	120	490
Shaft and surface facility construction	270	220
Initial underground excavation	220	115
Shaft outfitting	270	40
Underground excavation	250	55
Testing	260	120
Final disposition	90	550

(a) Phases are as shown in the schedule appearing in Figure 4-8. When schedule phases overlap, truck traffic is additive; passenger vehicle traffic is not.

(b) Based on Table 4-4 and 1.1 persons per vehicle.



Exploratory Shaft Facility
Drill and Blast
Method of Shaft Sinking
Davis Canyon

Figure 4-9

The ground support system used during excavation is dependent upon the stability of the free-standing, unsupported shaft walls. This unsupported height, which provides some flexibility in how soon the preliminary lining is installed after excavation, is a function of the time-dependent behavior of the materials being excavated. Zones of structural weaknesses, joints, and fracture patterns may require ground support systems. These systems may include steel ribs, liner plates, shotcrete, etc., and may be combined for specific intervals of shaft walls or sections of excavation. Soils or rocks too weak to support themselves long enough to place ground support systems may require pretreatment, carried out prior to reaching the weak strata. Pretreatment may consist of stabilization by grouting, dewatering, or freezing the strata. In order to be cost- and time-efficient, this pretreatment frequently must be carried out from the surface. Where the average particle size of rocks is large (greater than 5 millimeters [0.02 inch]) and the water volumes are not excessive, grouting or dewatering can be used for water control, ground stabilization, or both. However, in unconsolidated rocks of small particle size, the most frequent water control measure is freezing. The stratigraphy of the Davis Canyon site will not require freezing technology.

Water control in shaft construction is a two-phase approach: the first phase deals with the control of water during shaft sinking, and the second phase is based on the criteria of permissible flows in the shaft after it has been constructed. Water control systems employed in shaft construction are, therefore, based on the ultimate dryness criteria for the completed shaft. While the ultimate dryness is part of the design of the final shaft lining, the methods used during shaft construction can be different. Strata producing minor water inflows usually do not require any action to control water. The minor flows are either excavated with the rock and hoisted to the surface or collected by water rings, drained to a sump, and then pumped or bailed to the surface.

Grouting with cement slurries, resins, or gels by pressure injection has been used successfully to control water flows in shafts. Joints and fractures in the impermeable rocks are usually more easily sealed by grouting than are sections of permeable rocks or soils. Some rocks with very fine cracks, and most soils, do not readily lend themselves to the control of water flows by grouting. In addition to grouting, water is sometimes controlled by pumping around the prospective shaft area from wells on the surface.

Shaft linings may consist of rock bolts and wire mesh, brickwork, precast concrete blocks, monolithic concrete, cast iron with concrete, single and double shells of steel with concrete, and combinations of steel profiles with concrete.

The shaft lining may be bonded to the strata by grouting or it may be separated from the strata by annulus filled with a viscous material such as bitumen. The structural stability of a free-standing shaft lining in a bituminous envelope is carried by a substantial foundation. This design isolates the shaft liner from the stresses of mining and tectonic activities, and the bitumen acts as a continuous waterproof seal.

Final Lining. A final shaft lining constructed with monolithic concrete is the standard lining where water-tightness is not required. It may be combined with compressible material placed between it and the shaft wall in plastic zones. This material will deform with the creeping strata and thus result in a reduction of strata pressure on the concrete lining. The concrete lining may be installed in dry or water-bearing strata.

Seal System. In salt and potash mining operations, it is necessary to prevent the movement of water along the liner-host rock interface in order to ensure that progressive dissolution of salt behind the lining does not occur. A seal is also required to isolate various aquifers, thus preventing cross contamination.

A "seal system" consists of the shaft lining, which prevents the movement of water in a horizontal direction, and a shaft seal between the liner and the host rock to prevent water movement in a vertical direction. The "seal system" thus consists of the host rock in which the seal is placed, the seal material itself, and the shaft lining. The placement of the seal in impervious rock below an aquifer and above the salt bed is critical since a seal is only as effective as the rock in which it is placed.

Three types of seals are in common usage. The traditional sealing method used with cast iron tubbing, commonly used to line water-bearing rock in early mining practice, employs a wedge ring set between the tubbing rings. This wedge ring has a greater horizontal depth than the tubbing rings above and below. The space between the wedge ring and the shaft walls is sealed by hammering in precisely cut wooden wedges, or "pikotage," until the space is so tightly packed that even a tapered steel needle cannot be driven in. The wood expands on contact with water, and the seal is further tightened. The material cost for this type of seal is low, but the labor cost and installation time are high.

For complete effectiveness, chemical seals are used in modern practice, especially in salt and potash mines. These chemical seals use a polymeric sealing compound called Chemical Seal Ring (CSR). CSR, mixed with gravel, is placed as a pumpable slurry which is pliable enough to penetrate the cracks. It expands considerably on contact with water, further tightening the seal. After emplacement, the slurry hardens to form an insoluble plastic solid. Allowance is made in the design to pressurize this seal for greater effectiveness. A schematic design for such a seal system is shown in Figure 4-10.

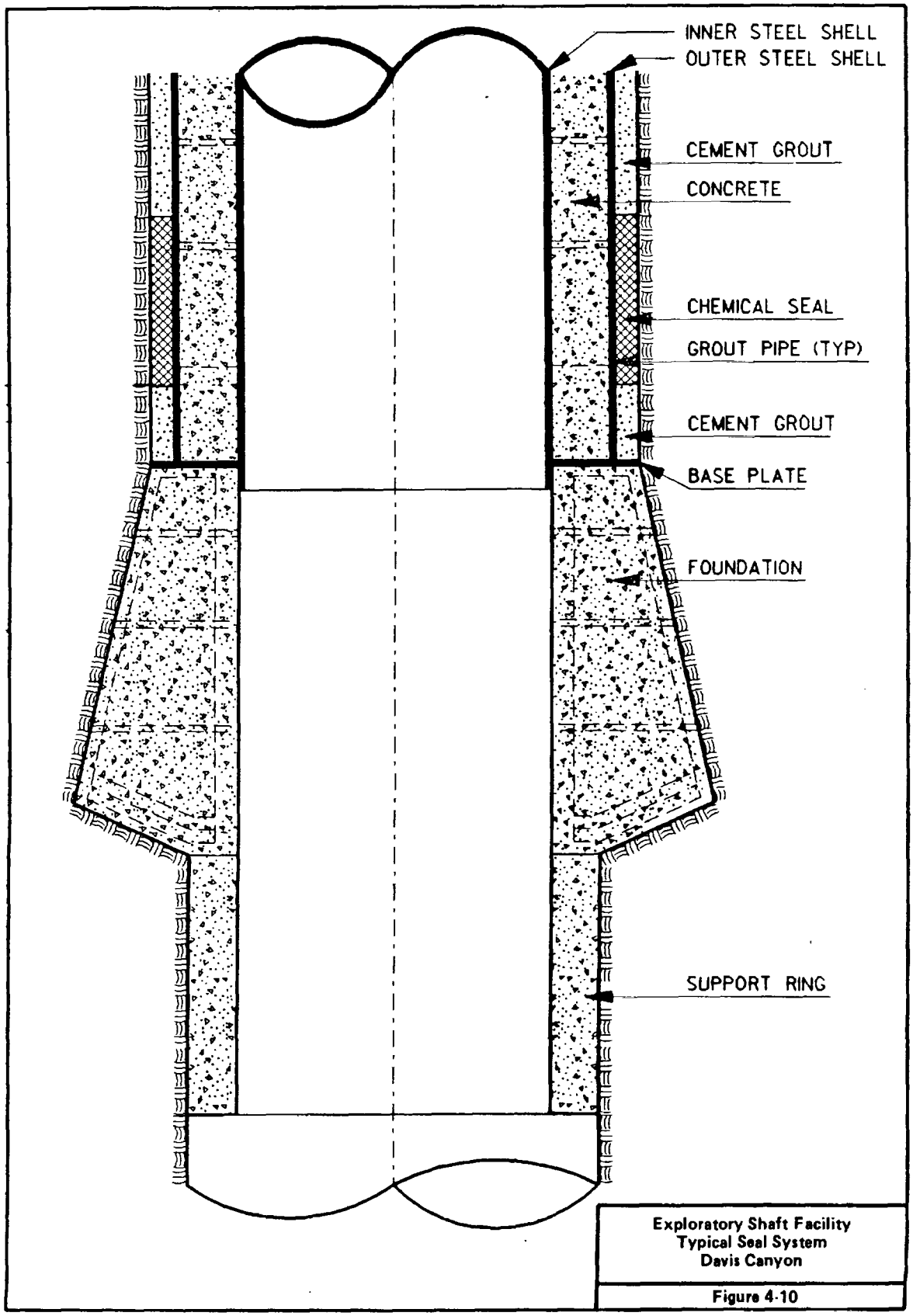
The third form of seal uses a continuous column of asphalt or bitumen from below the lowest aquifer to a few feet below the surface. In this system, the annular space between the lining and the shaft walls is filled with a mixture of asphalt and limestone blended to a specific gravity slightly higher than the specific gravity of brine. Since the hydrostatic head of the asphalt mixture is higher than the brine head, the mixture flows into any cracks that may be present.

Shaft Construction. At the Davis Canyon site the two shafts will be constructed using the conventional drill and blast method. One of the shafts will be used for hoisting excavated material from the underground development (the production shaft), while the other will be used for hoisting personnel and materials (the service shaft). The production shaft will be 928 meters (3,044 feet) deep, and the service shaft will have a depth of 904 meters (2,965 feet). The production shaft is deeper in order to accommodate the material handling and loading area at the bottom of the shaft. The shafts will be excavated with a diameter of approximately 6 meters (20 feet), which will provide a finished diameter of 4 meters (12 feet) after completion of the final lining. Figure 4-11 depicts the basic characteristics of the service and production shafts in the context of the stratigraphy of the Davis Canyon site.

Shaft sinking operators commence with the construction of a 30-meter (100-foot) shaft collar. At that time a headframe is installed on the surface, a sinking stage is installed in the shaft, and the regular drilling, blasting, and mucking operations begin. A sinking stage is a multideck work platform (a seven-deck stage is shown in Figure 4-9). During shaft sinking operations the sinking stage supports the shaft bottom operations of drilling, loading the drill holes with explosives, and mucking (removing broken rock to the surface). The preliminary rock support measures (rock bolting, preliminary lining, etc.) and temporary utilities are installed directly from the stage, concurrently with the shaft bottom operations.

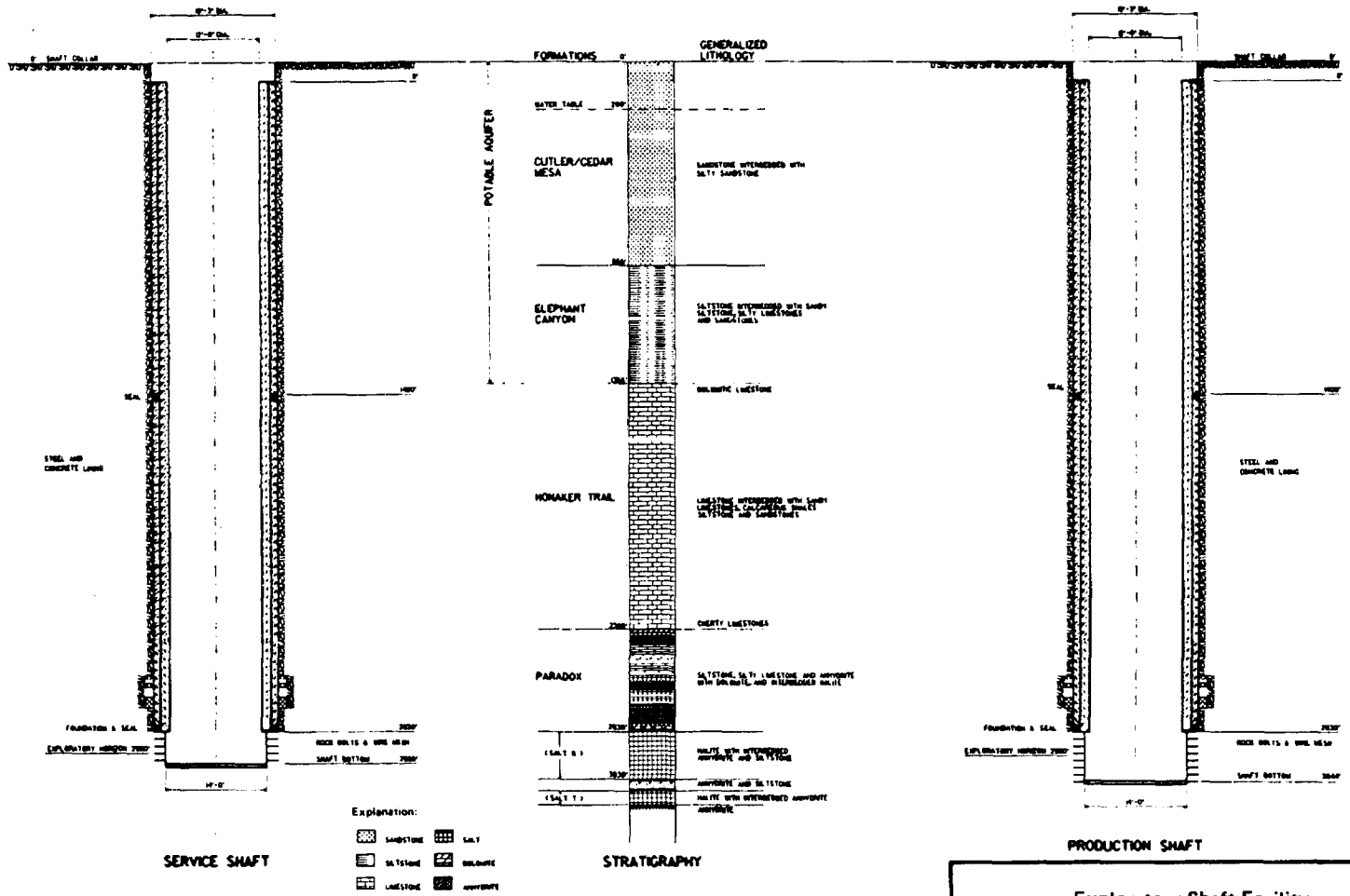
Probe holes are drilled during shaft sinking, extending to a depth of several blasting rounds in advance of the shaft bottom. These probe holes are drilled at constant intervals to safeguard against unexpected water and gas occurrences during shaft sinking.

The shaft sinking operations continue up to a depth of approximately 238 meters (780 feet). A 25.4-centimeter (10-inch)-thick preliminary concrete lining is placed concurrently with the progress of shaft sinking to this point. Below 238 meters (780 feet) a pressure grout curtain is placed in the shaft in advance of drilling and blasting sequence. The purpose of the grouting phase is to mitigate an anticipated inflow of ground water from the Elephant Canyon formation. After the grout curtain has been started, shaft sinking operations and advance probe hole drilling recommence. Once the probe hole confirms lack of water ahead of the shaft, grouting operations are stopped and the normal shaft sinking operations continue. The service shaft is sunk to a depth of 910 meters (2,986 feet), but the preliminary lining is carried only to 863 meters (2,830 feet), from which point the shaft walls are



Exploratory Shaft Facility
Typical Seal System
Davis Canyon

Figure 4-10



Exploratory Shaft Facility
Exploratory Shaft Profile
Davis Canyon

Figure 4-11

supported by rock bolts and wire mesh. Where the shaft penetrates through rocks which are subject to creep, the shaft is overexcavated by 30 centimeters (12 inches) on the radius. The 30-centimeter (12-inch) space between the shaft walls and the preliminary lining is filled with resin foam which can be easily compressed. The same procedure is followed in the production shaft which is excavated to a depth of 933 meters (3,059 feet). At the bottom of the service shaft, a 6.4-meter (21-foot)-high concrete plug is constructed to prevent uplift. Similarly, a 4.6-meter (15-foot)-high concrete plug is constructed in the production shaft. A drift is excavated at the 893-meter (2,930-foot) level to connect the two shafts. Once the shafts are connected, the ventilation circuit is established underground, with fresh air entering the subsurface from the service shaft, and exhausted back to the surface through the production shaft.

Since the formations above and below the Elephant Canyon produce only a small amount of water, and since the flow through the Elephant Canyon is controlled by the grout curtain, the installation of the final watertight lining may not be necessary or may be postponed. Small amounts of water can be collected through water rings, placed at strategic locations in the shaft, and pumped out.

For the final lining, a substantial foundation is constructed at the bottom of the preliminary lining. Above the support ring a steel plate is placed on which the final lining is constructed. The final lining consists of an outer welded steel shell, 1.3 centimeters (0.5 inch) thick and about 66 centimeters (26 inches) of concrete. This final lining is constructed to a depth of approximately 549 meters (1,800 feet). The outer steel shell acts as a watertight membrane. Below 549 meters (1,800 feet) the final lining consists of outer and inner steel shells confining about 61 centimeters (24 inches) of concrete between them. The steel thickness varies from 1.27 centimeters (0.5 inch) through 2.22 centimeters (0.875 inch) depending upon the depth of shaft at which the lining is installed. A 15-centimeter (6-inch) gap is left between the final and the preliminary lining, to be filled later with bitumen seal. Prior to constructing the final lining and pouring bitumen, the preliminary lining is interrupted at 730 meters (2,395 feet), 413 meters (1,355 feet), and 261 meters (855 feet).

The thickness of the zone where the bitumen is in contact with the host rock is approximately 1 meter (3 feet). The continuous bitumen seal, which also fills the interruptions in the preliminary lining, isolates the water-bearing regions, stops vertical and horizontal movement of water, and maintains the shaft in a dry condition.

Installation of the final lining will result in a 3.6-meter (12-foot) finished inside-shaft diameter. The design life of the shaft lining is 100 years.

Surface Facilities Construction. Surface facilities will be erected concurrently with shaft construction operations. Included are the fuel storage system, excavated material storage areas, an evaporation and retention pond, a sediment pond, sewerage system, water supply system, communications system, power system, fire protection system, safety system, and buildings and shaft services. The resources to be consumed during this phase are listed in Table 4-7.

Diesel fuel would be stored on site in a buried fiberglass storage tank with a capacity of approximately 162,755 liters (43,000 gallons). The supply level would be monitored by a liquid level gage, wall mounted in the generator building. Leak detection requirements applicable at the time of installation will be satisfied.

The excavated material storage area capacity will accommodate a mixture of overburden and interbedded salt, estimated to be approximately 57,341 cubic meters (75,000 cubic yards), nonsalt-contaminated overburden, estimated to be approximately 52,754 cubic meters (69,000 cubic yards), and salt from the shaft and drifts, estimated to be approximately 103,214 cubic meters (135,000 cubic yards). The storage area capacities shown in Table 4-3 exceed the anticipated volume of excavated materials.

Possible leaching of brine into the ground will be prevented with liners. These can be made of natural clays or synthetic materials (polyvinyl chloride, polyethylene, or

polypropylene). The existing topsoil overburden will be stripped before emplacement of the liner and the sound subbase. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner so that it can accommodate heavy equipment.

When salt is exposed to the weather, a hard surface crust forms in a few days which tends to shed rain water (Ver Planck, 1958; DOE, 1984). According to the experience of the salt industry, stockpiled salt is not a source of windblown particles, and crusting can be accelerated by wetting the pile. After spreading and compacting, freshly deposited material will be wetted to minimize any wind effects.

It is possible, however, that during salt handling, namely transfer of the salt from the hoist to trucks or other conveyances, and salt pile buildup, salt particles may become windblown.

Salt-contaminated and potentially salt-contaminated runoff from the shafts area, haul roads, and mined material stockpiles will be collected by a system of lined drainage ditches which gravity flow to an evaporation and retention pond. In addition, water collected in the shaft sumps will be periodically pumped to the ditch system for collection at the evaporation and retention pond. The drainage ditches will be designed to convey the runoff from a 500-year storm of a duration and intensity based on time of concentration of the local watershed. This will provide the capability to convey the runoff from duration storms which produce higher peak flows than a 24-hour rainfall event.

The evaporation and retention pond will be designed for an operational volume equivalent to 100 percent of the rainfall volume from a 500-year, 24-hour storm falling on the areas which drain to the evaporation pond. The maximum volume of the pond will include an additional 61 centimeters (2 feet) of freeboard above the operational level. Due to the greater volume available per unit depth in the top of a pond, the freeboard volume available will be almost equivalent to a second 500-year, 24-hour storm volume. The evaporation and retention pond will be designed to the maximum extent practicable to take full advantage of the high evaporation rates applicable in the region. If it becomes evident during design that the goal of total water evaporation cannot be achieved due to area or depth constraints of the pond, then the water would be periodically removed for disposal at an acceptable, offsite facility. Disposal of similar liquids (brine) is a common practice in the oil industry.

The evaporation and retention pond and its system of drainage ditches will be lined with suitable materials to prevent seepage of salt-contaminated water into the ground. The lining of brine ponds is commonly practiced in the oil and salt industries (Staff Industries, 1983). Ponds as large as 20 hectares (50 acres) have been successfully lined with polyvinyl chloride membranes where the liner is not exposed to direct sunlight, or with fabric reinforced, chlorinated polyethylene where the liner is exposed. Natural materials which may be available on site, such as brine-resistant clays, may also be used with or in place of synthetic membranes. The evaporation and retention pond liners are installed over an engineered subgrade which has one or more networks of perforated pipes in an aggregate backfield. The perforated pipe system connects to vertical pipes which terminate above grade at the perimeter of the pond. These vertical pipes serve to vent gases which may collect under the liner system and to monitor the effectiveness of the liners to contain liquids (leachate) above the liner. Monitoring wells, if necessary, can also be used to pump out leachate. The monitoring wells will be sampled frequently to ensure the integrity of the liner system.

Runoff from areas not contaminated by salt, such as the administration area, parking area, topsoil stockpile, and roads not used for mined material haulage, will be collected in ditches which will gravity flow to the sediment pond. The pond will be designed to contain 100 percent of the rainfall volume from 25-year, 24-hour storm falling on the noncontaminated areas. The retention time in the pond will be sufficient to settle out suspended solids to the extent necessary to achieve regulatory discharge limits for solid concentration. Several methods are available to increase sediment pond efficiency, such as baffles, partitioning, inlet energy dissipator, coagulants, and siphon-type riser and spillway arrangement. Periodic removal of collected sediment for transport to an acceptable offsite disposal facility will be

required. The drainage ditches which convey the runoff to the sediment pond will be designed for a 25-year storm of duration and frequency related to the time of concentration in the local watershed. This provides a drainage collection system which is capable of conveying short-duration, high peak-flow rainfall events to the sediment pond.

A system of underground pipes will carry sanitary wastes to a treatment facility. The collection system will be supplemented by chemical toilets during construction. The onsite wastewater treatment facility will have a capacity of about 49,200 liters (13,000 gallons) per day designed to service project and construction management people on site. Any liquid discharge to surface systems will meet all applicable discharge limitations. Residue from the treatment plant will be removed periodically and transported to an offsite permitted disposal facility. Construction personnel will use portable facilities. Wastes will be trucked to an offsite treatment plant.

Oily wastewater from surface facilities, such as the maintenance shop, fire truck garage, and mechanical equipment room will be collected by a network of underground piping. Oil and water separators will be provided in the appropriate maintenance drains in the service buildings, generator building, and other buildings which may have oil or grease waste. Effluent from the oil and water separators will flow to the sanitary waste collection system. Liquids such as oil and water (from the separators and waste cleaners), solvents, thinners, and other hazardous materials will be properly disposed of off site in a licensed facility.

Solid waste generated at the ESF will be collected and disposed of in a permitted landfill located off site. Offsite waste combustion in an approved incinerator is also feasible.

The potable water system is a pressurized distribution network required for domestic and construction usage. Water is supplied by wells, if a suitable water source is located on site, trucked to the site, or a combination of the two. Preliminary information indicates that insufficient ground water exists at the site to satisfy the average expected ESF demand of 60.5 liters (16.0 gallons) per minute.

Offsite communications would use microwave radio transmissions instead of a commercial telephone network. Microwave radio transmission equipment would be located on site for transmission to an existing, remote microwave tower located near Moab.

Preliminary evaluations indicate that 4 gas-fueled generators with 3 gas-fueled generators for emergency use can meet the electrical requirements of the project (PB/PB-KBB, 1986; Griffin, 1986).

The ESF fire protection system is designed to provide detection and alarms in the event of smoke, gases, and fires in designated surface structures and the subsurface area. The water supply for the fire protection system will be provided by a water storage tank(s) with a dedicated capacity of approximately 227,100 liters (60,000 gallons), which would provide for a 2-hour water supply for fire fighting. Fire hydrants will be spaced approximately 76 meters (250 feet apart). The piping system for fire water will be laid out in loops so that water can be diverted to the area in need.

Chemical fire suppression systems will be used in those areas where water is not suitable. The systems include Halon, foam, dry chemical, and carbon dioxide, as appropriate. A four-wheel-drive fire truck will be located in the fire station at the service building. Fire and smoke detectors will be installed in all buildings and will activate audible alarms and extinguishing systems.

The operating status of all systems important to safety will be monitored to assure proper performance. Especially important will be methane and hydrogen sulfide gas detectors located in the shaft and subsurface workings. If excessive gas levels are detected, alarms will sound on underground mining equipment as well as in monitoring rooms on the surface. Individual detectors will be mounted on heavy equipment in the subsurface workings. The detectors will give an audible alarm and automatically shut off equipment if a concentration of gas above a preselected level is detected. First-aid kits and supportive gear will be

placed at key points throughout both the subsurface and surface facilities. An ambulance will be kept on site.

Prefabricated buildings were chosen to house the equipment and systems in the activity area. They will provide 6,500 square meters (70,000 square feet) of working area including the various office and laboratory facilities required for the project.

The equipment associated with the shaft and surface facility construction phase is listed in Table 4-10. The resources estimated to be consumed are listed in Table 4-7. Based on the anticipated staffing for this phase, the increase in average daily automobile traffic over baseline levels is estimated to be 270 round trips to the site by passenger vehicles. Truck traffic is expected to increase from baseline levels by approximately 220 round trips to the site by trucks per month. The estimated vehicular traffic during the shaft construction, testing and final disposition periods is given in Table 4-9.

Worker Health and Safety. The Mine Safety and Health Administration (MSHA) is authorized to administer and enforce certain kinds of safety and health standards for protecting employees in the mining industry, pursuant to the "Mine Safety and Health Act of 1977." The question of formal involvement of MSHA with the Civilian Radioactive Waste Management Program is not resolved at this stage. The principal design, construction, and operating features of the exploratory shaft facility will include provisions for worker protection according to the relevant requirements of "Safety and Health Standards - Metal and Non-Metal Underground Mines" (30 CFR Part 57). Fire control, ventilation, illumination and use of equipment and explosives are being designed to comply with MSHA regulations governing "gassy" mine conditions.

Specific areas of interest in maintaining occupational safety during mining include:

- Mining methods
- Fire prevention control
- Working environment
- Ventilation systems
- Materials handling and storage
- Underground utility systems
- Occupational safety programs and personnel protection
- Inspection, testing, and maintenance
- Emergency plans.

The Occupational Safety and Health Administration (OSHA) administers the "Occupational Safety and Health Act of 1970," as amended. The purpose of OSHA is to establish standards with which industries are generally familiar and on whose adoption interested and affected persons already have had an opportunity to express their views. Such standards are either national consensus standards whose adoption by affected persons have reached substantial agreement, or Federal standards already established by Federal statutes or regulations. The DOE will utilize the OSHA regulations, in particular 29 CFR Part 1910, "Occupational Safety and Heath Standards," and 29 CFR Part 1926, "Safety and Health Regulations for Construction," as applicable.

MSHA has compiled statistics regarding recent injury experience on the nonmetal (except coal and stone) mining industry. During the period 1976 through 1982, an average of 5.86 injuries (values range from 4.57 in 1982 to 7.62 in 1978) were reported for labor and administrative personnel for every 250,000 work hours. This same group experienced an average of 0.04 fatalities (values range from 0.03 to 0.05) per 250,000 work hours over this same period.

Based on MSHA's experience, during the five-year life of the ESF project, with approximately 2.94 million work hours, 69 injuries and one fatality are projected. However, by rigid implementation of DOE Orders 5480.1A and 5480.4 for "Environmental Protection, Safety and Health Protection Program for DOE Operations" the actual injury experience should be less than projected.

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
SHAFT CONSTRUCTION				
Sinking Plant	1	Crane	180	180
Set-up for Shaft	1	Forklift	50	50
Construction	1	Truck	250	250
Production Shaft	2	Welding rigs	50	100
(6 months)	1	Wheel loader	270	270
	1	Backhoe	135	135
	1	Mobile compressor	120	120
	1	Vent fan	25	--
	1	Pickup truck	135	135
				1,240
Shaft Sinking for	1	Forklift	50	50
Production Shaft	1	Crane	180	180
(11 months)	1	Hoist	1,000	--
	4	Stage hoists	40	--
	1	Vent fan	60	--
	3	Compressors	80	--
	1	Mucker winch	20	--
	1	Batch plant	70	--
	1	Truck	250	250
	1	Wheel loader	270	270
	1	Welding rig	50	--
	1	Generator	3,600	3,600
	1	Oiler	200	200
	2	Pickup trucks	135	270
				4,820
Final Lining	1	Forklift	50	50
Installation for	1	Generator	3,600	3,600
Production Shaft	1	Vent fan	60	--
(11 months)	1	Hoist	1,000	--
	2	Compressors	80	--
	1	Batch plant	70	--
	1	Truck	250	250
	3	Welding rigs	50	--
	4	Stage hoists	40	--
	1	Crane	180	180
	1	Wheel loader	270	270
	1	Oiler	200	200
	2	Pickup trucks	135	270
				4,820
Sinking Plant	1	Crane	180	180
Set-up for	1	Forklift	50	50
Service Shaft	1	Truck	250	250
(6 months)	2	Welding rigs	50	100
	1	Wheel loader	270	270
	1	Backhoe	135	135

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage
(Page 2 of 3)

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Sinking Plant Set-up for Service Shaft (6 months) (Continued)	1	Mobile compressor	120	120
	1	Vent fan	25	--
	1	Pickup truck	135	135
				1,240
Shaft Sinking for Service Shaft (11 months)	1	Forklift	50	50
	1	Crane	180	180
	1	Hoist	1,000	--
	4	Stage hoists	40	--
	1	Vent fan	60	--
	3	Compressors	80	--
	1	Mucker winch	20	--
	1	Batch plant	70	--
	1	Truck	250	250
	1	Wheel loader	270	270
	1	Welding rig	50	--
	1	Generator	3,600	3,600
	2	Pickup trucks	135	270
				4,620
Final Lining Installation for Service Shaft (11 months)	1	Forklift	50	50
	1	Generator	3,600	3,600
	1	Vent fan	60	--
	1	Hoist	1,000	--
	2	Compressors	80	--
	1	Batch plant	70	--
	1	Truck	250	250
	4	Welding rigs	50	--
	4	Stage hoists	40	--
	1	Crane	180	180
	1	Wheel loader	270	270
	2	Pickup trucks	135	270
				4,620
Surface Facility Construction (7 months)	1	Batch plant	70	--
	2	Concrete finishers	7	14
	2	Cranes	180	360
	1	Forklift	50	50
	1	Generator	3,600	3,600
	2	Trucks	250	500
	2	Welding rigs	50	--
	1	Backhoe	135	135
	1	Track loader	65	65
	1	Compressor	200	--
	1	Oiler	200	200
	1	Pickup truck	135	135
				5,059

Table 4-10. Equipment for Shaft and Surface Facility Construction Stage
(Page 3 of 3)

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Service Facilities for Production Shaft (2 months)	1	Forklift	50	50
	1	Crane	180	180
	1	Batch plant	70	--
	1	Truck	250	250
	1	Welding rig	50	--
	1	Compressor	200	--
	1	Backhoe	135	135
	1	Track loader	65	65
	1	Concrete finisher	7	7
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,022
Service Facilities for Service Shaft (4 months)	1	Track loader	65	65
	1	Backhoe	135	135
	1	Forklift	50	50
	1	Crane	180	180
	1	Batch plant	70	--
	2	Trucks	250	500
	2	Welding rigs	50	--
	1	Compressor	200	--
	2	Concrete finishers	7	14
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,279

Shaft stations consisting of approximately 46 meters (150 linear feet) of approximately 4 by 4 meters (12 by 14 feet) drift will be developed from both shafts by conventional drill and blast methods. Equipment, including a continuous miner, is then assembled in the stations. This miner is used to drive 160 meters (525 feet) of 4 by 6 meters (12 by 20 feet) connecting drift. A small load, haul, and dump scooptram will be used to move muck (excavated material) to the shaft for hoisting to the surface. Thus, the initial excavation consists of approximately 252 meters (825 feet) of linear excavation as indicated in Figure 4-12. The initial excavation stage will also support some of the requirements for testing, which will be performed concurrently with further excavation. When the connection drift and shaft outfitting are completed, sufficient ventilation and alternative egress from the underground workings will be provided to support the testing phase. Figure 4-8, exploratory shaft facility construction and testing schedule, illustrates the relationship between underground excavation and the testing programs.

Equipment necessary for this phase of construction is listed in Table 4-11. Vehicular traffic is expected to increase from baseline levels to include approximately 220 round trips to the site by passenger vehicles per day and 115 round trips to the site by trucks per month. The estimated primary consumable resources are listed in Table 4-7.

4.1.2.2.3 Outfitting. Prior to outfitting, but after the shafts have reached total depth, excavation to connect the two shafts will commence. Current plans call for outfitting both shafts with hoists to accommodate testing. The headframe will be approximately 38 meters (125 feet) high. The service shaft will be used as a service shaft for personnel access and will supply the underground working with fresh air and utilities. The production shaft will be used for exhaust and for transporting muck during expanded excavation and testing, to the surface.

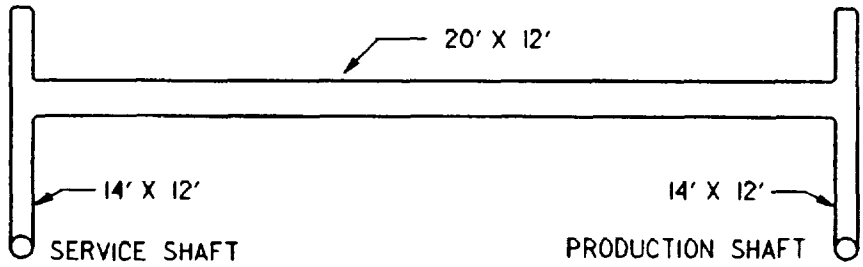
The vehicular traffic for this stage of construction is estimated to increase from baseline levels to include approximately 270 round trips to the site by passenger vehicles and 40 round trips to the site by trucks per month. These values are given in Table 4-9. Table 4-12 contains a list of required equipment, and the resources consumed are listed in Table 4-7.

4.1.2.2.4 Expanded Underground Excavation. In situ testing will occur concurrently with expanded underground excavation. The ESF consists of an additional 1,410 meters (4,595 feet) of drifts with a cross section from 4.3 meters wide by 3.6 meters high (14 by 12 feet) to 6.1 meters wide by 7.3 meters high (20 by 24 feet) (Figure 4-13). Equipment necessary for this phase of construction is listed in Table 4-13. Primary consumable resources are listed in Table 4-7. Vehicular traffic is expected to increase from baseline levels by 250 round trips to the site by passenger vehicles per day and 55 round trips to the site by trucks per month, as given in Table 4-9.

4.1.2.3 Testing

A test plan for the candidate salt sites has been developed. This plan outlines a proposed program of in situ testing which constitutes part of the overall effort to determine site suitability for development as a repository, provide data for repository design and performance assessments, and prepare licensing documentation for radioactive waste disposal in salt. The latter includes compliance with the regulatory requirements for performance (e.g., 10 CFR 60.113 [a]), information (e.g., 10 CFR 960.4-2-1 [b][4][i]), and testing (e.g., 30 CFR 57.3-53).

The proposed test methods can be categorized by being either surface based within boreholes drilled from the surface, in the laboratory, or within an in situ test facility. At this stage, all available test methods are being considered because many of the information needs may be more satisfactorily addressed by surface-based and laboratory testing, thus eliminating the need for certain in situ tests. However, in situ tests are generally more suitable for model validation or design evaluation.



Exploratory Shaft Facility
Subsurface Plan –
Initial Underground Excavation
Davis Canyon

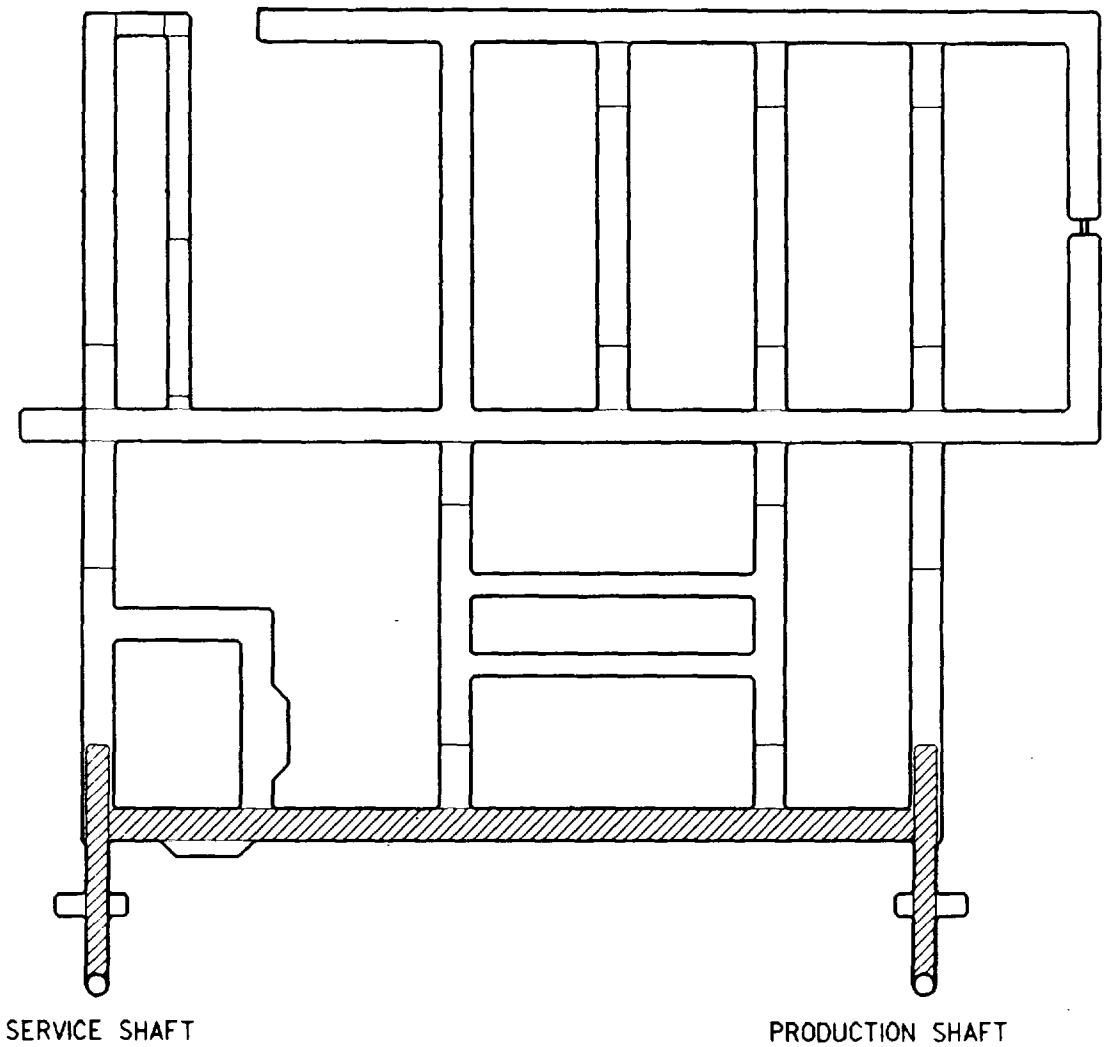
Figure 4-12

Table 4-11. Equipment for Initial Underground Excavation Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Initial Underground Excavation (2 months)	1	Wheel loader	270	270
	2	Vent fans	60	--
	1	Auxiliary fan	50	--
	1	Hoist	1,000	--
	1	Hoist	500	--
	8	Stage hoists	40	--
	2	Compressors	80	--
	1	Mucker winch	20	--
	1	Continuous miner	410	--
	2	Welding rigs	50	--
	1	Scooptram (5-cu-yd)	150	150
	1	Crane	180	180
	1	Forklift	50	50
	1	Truck	250	250
	1	Oiler	200	200
	2	Generators	3,600	7,200
	2	Pickup trucks	135	270
				8,570

Table 4-12. Equipment for Shaft Outfitting Stages

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Outfitting Production Shaft (3 months)	1	Vent fan	60	--
	1	Crane	180	180
	2	Forklifts	50	100
	4	Stage hoists	40	--
	1	Hoist	500	--
	1	Compressor	80	--
	2	Welding rigs	50	--
	1	Generator	3,600	3,600
	1	Pickup truck	135	135
				4,015
Outfitting Service Shaft (3 months)	1	Vent fan	60	--
	1	Crane	180	180
	2	Forklifts	50	100
	1	Hoist	500	--
	4	Stage hoists	40	--
	1	Compressor	80	--
	2	Welding rigs	50	--
	1	Generator	3,600	3,600
	1	Pickup truck	135	135
				4,015



NOTES:

1. ROOM SIZE VARIES FROM 14'w x 8'h to 20'w x 24'h
2. INITIAL EXCAVATION
3. EXPANDED EXCAVATION

Exploratory Shaft Facility Subsurface Plan – Underground Excavation Davis Canyon

Figure 4-13

Table 4-13. Equipment for Expanded Underground Excavation Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Underground Excavation (6 months)	1	Wheel loader	270	270
	1	Hoist	1,000	--
	1	Scooptram (2-cu-yd)	100	100
	2	Scooptram (5-cu-yd)	150	300
	2	Trucks	250	500
	2	Continuous miners	410	--
	1	Roof bolter	40	--
	1	Scaler	85	85
	2	Auxiliary fans	50	--
	1	Crane	180	180
	1	Forklift	50	50
	1	Generator	3,600	3,600
	2	Pickup trucks	135	270
				5,355

Testing will be performed in two phases. The first phase, "construction testing," starts with the beginning of shaft construction and ends when the shafts are connected underground. Specifically, construction testing includes activities such as the following:

- Initial monitoring of shaft behavior
- Initial monitoring of aquifer seal performance
- Horizon selection and verification
- Geologic mapping of shafts
- Geologic mapping of initial underground openings
- Blasting performance monitoring
- Initial air quality measurements
- General observations of underground stability
- Documenting any evidence of ground-water inflow or seeps
- Initial ground closure observations.

Following completion of the underground connection between the two shafts, the second phase of testing can begin. In situ testing will include ongoing construction testing activities such as geologic mapping and geomechanical and hydrological performance monitoring in the expanded facility. In addition, detailed site characterization testing (e.g., in situ stress measurement, in situ strength of bedding surfaces, thermal conductivity, hydraulic conductivity, etc.) will be undertaken during and immediately following the completion of the ESF construction. Finally, specific engineered system designs will be evaluated and performance and design models validated by a series of major in situ tests (e.g., canister scale and room scale heater tests, backfill tests, etc.). The in situ testing phase will support the environmental impact statement (EIS) and license applications.

The in situ testing program consists of five major categories, each category being supported by a suite of specific tests. Table 4-14 lists the categories and their respective tests. Details of the current generic test program for the salt sites can be found in the "Draft Test Plan for In-Situ Testing in an Exploratory Shaft in Salt" (Golder Associates, 1985).

The increase in average daily automobile traffic from baseline levels is estimated to include 260 round trips to the site by passenger vehicles. The truck traffic increase from baseline levels has been estimated to include approximately 120 round trips to the site per month. An estimate of the equipment required to conduct testing is identified in Table 4-15. Resources to be consumed during the testing period can be found in Table 4-7.

4.1.2.4 Final Disposition

The "Nuclear Waste Policy Act of 1982" (NWPA) (Section 113) requires that the site characterization plan for a candidate site contain provisions for the decontamination and decommissioning of the site. The current plans for site characterization at the Davis Canyon site do not include the use of high-level radioactive waste. The NWPA states that the Secretary of Energy may not use any radioactive material at a candidate site unless the NRC concurs that such use is necessary to provide data for the preparation of environmental reports and an application for construction authorization. Therefore, no decontamination of the site is expectd to be required after site characterization.

If the site is found suitable and is selected for the first repository, the exploratory shaft facility in full or in part may be incorporated into the repository design. If the site is not selected for the first repository, it may still be considered for use as a subsequent repository; in such an event the site would be maintained, including all buildings, the headframes, and the access road. Full security will remain in effect even though a minimum functional level will exist.

Table 4-14. Proposed In-Situ Test Program

Geology	Thermomechanics
Geologic Mapping (Exploration Drifts)	Thermal Conductivity Probe
Drilling (Core Sampling, Field Logging)	Canister-Scale Heater Test
Geophysical Well Logging	Room-Scale Heater Test
Electric Surveys	Facility Thermal Response Monitoring
Underground Gravity Surveys	Room Backfill Test
Radar Probing	**Geohydrology**
Seismic Surveys	Single Borehole Hydraulic Conductivity Test
Seismicity Monitoring	
Block Sampling (for Laboratory Testing)	Cross-Hole Hydraulic Conductivity Test
Geomechanics	Cross-Hole Tracer Test
In Situ Stress Measurement	Tracer Diffusion Test
Borehole Pressuremeter/Jacking	Borehole Seal Performance Test
Borehole Condition/Convergence Monitoring	Room Seal Performance Test
Torsional Shear Test	Brine Migration Test
Acoustic Emission Monitoring	Grout Injection Test
Mine-by Test	Facility Hydrological Response Monitoring
Rock Bolt Pullout Test	
Facility Mechanical Response Monitoring	**Geochemistry**
	Formation Fluid Sampling

Table 4-15. Equipment for Testing Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Testing (3 years)	4	Auxiliary fans	25	--
	1	Vent fan	400	--
	1	Vent air conditioning system	1,050	--
	1	Hoist	500	--
	1	Compressed air system	200	--
	--	Test equipment	80	--
	--	Heaters	260	--
	1	Forklift	50	50
	1	Shop (Subsurface)	80	--
	2	Core drills	50	--
	1	Scooptram (2-cu-yd)	100	100
	1	Utility truck	100	100
	1	Crane	180	180
	1	Shop (Surface)	150	--
	1	Oiler	200	200
	1	Dewatering system	360	--
	2	Generators	3,600	7,200
	2	Pickup trucks	135	270
				8,100

If the site proves unsuitable for further development, it will be restored as closely as possible to its original condition. Site restoration will proceed in accordance with applicable Federal and State regulations, and will include the following:

- Filling the subsurface excavations with the sorted salt and the shafts with salt and other mined rock as needed to provide structural stability
- Limiting the use of salt or salt-contaminated material to layers below potable water-bearing strata to protect water quality
- Placing concrete, polymer seals, clay plugs, or some combination of these at required intervals to prevent vertical migration of water; a plug would be located in each shaft at the bottom of the lined or cased portions of the shafts
- Removing buildings, piping, and other surface facilities, including the electric and communication lines
- Returning the site, including the site access road and any other temporary roads, to its approximate original contours
- Top soiling, mulching, seeding, and revegetating these disturbed areas to the specifications of the surface management agency.

Reclamation of the ESF site could take approximately 22 months (Figure 4-14). The actual time needed for site restoration will be based on the final reclamation plan, to be prepared in accordance with applicable Federal, State, and local regulations. The necessary activities and the sequence could be as follows:

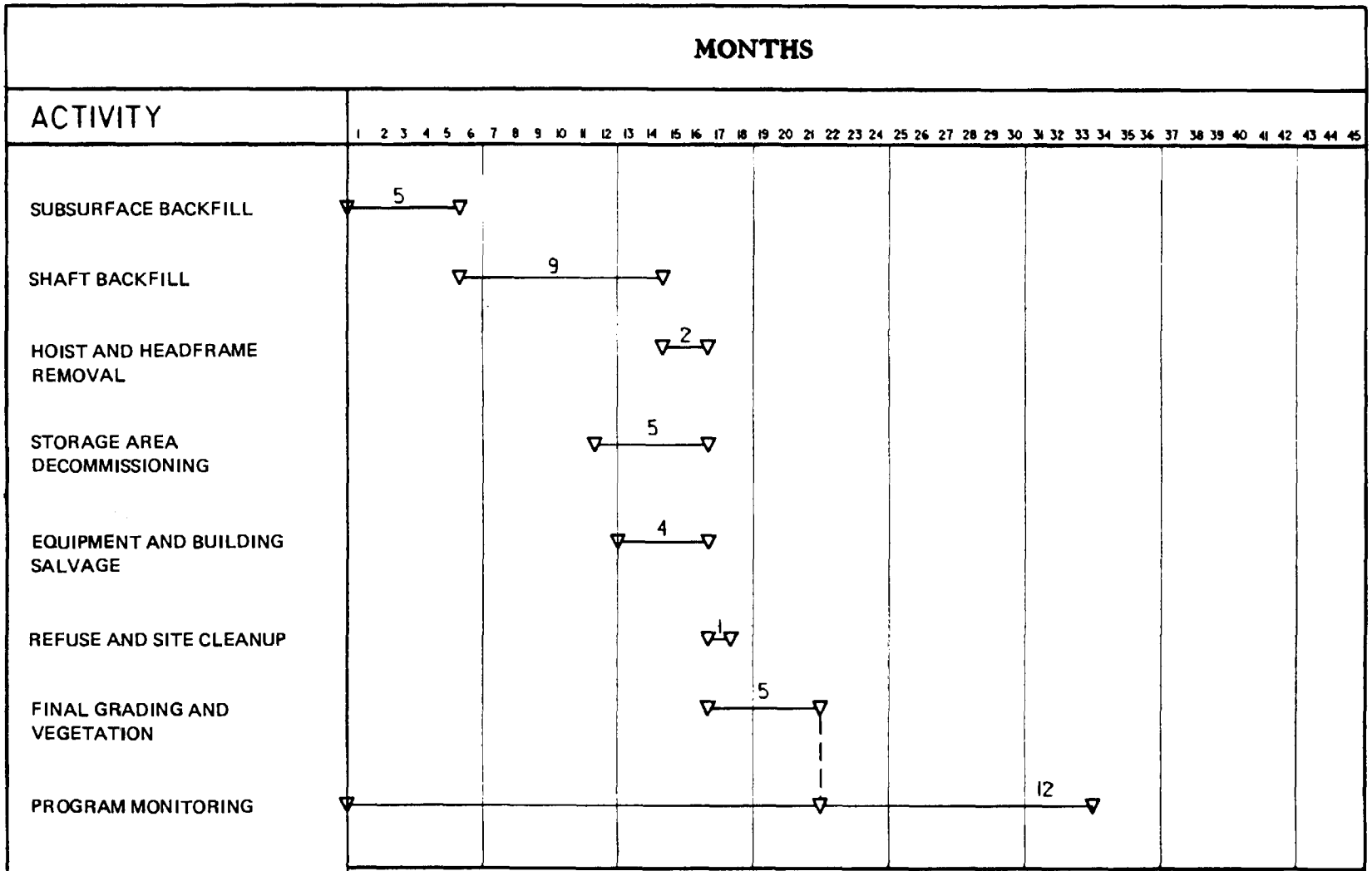
- Subsurface backfill
- Shaft backfill
- Hoist and headframe removal
- Surface storage area reclamation
- Equipment and building salvage
- Excess salt disposal
- Refuse and site cleanup
- Final grading, topsoil replacement, and revegetation.

The current plans for site characterization at the Davis Canyon site do not include the use of high-level radioactive waste. Therefore, no decontamination of the site will be required after site characterization.

4.1.2.4.1 Subsurface Backfill. The subsurface backfilling begins by setting up a bulkhead in the center of the connection drift and working back toward each shaft. The procedure will begin with backfilling the test alcoves and drill set-up areas that are farthest from the shaft stations. Previously excavated salt stored above ground in the salt storage stockpile area will be transported by truck from the stockpile back to the headframes and front-end loaded into a crusher unit to reduce the salt to an acceptable material size for transport down to the subsurface shaft stations. Backfilling of the drifts with a pneumatic stowing system will assure that these volumes would be filled with salt compressed to approximately 65 percent of its original in situ density. This will facilitate proper roof support and ground stabilization for the test alcoves, drill set-up areas, and main access drifts.

As the farthest drift areas are completely backfilled, the pneumatic stowing operation will continue working back to the shaft(s) until the subsurface drift area has been completely backfilled, including the shaft stations and sump areas. Pneumatic stowing will continue placing crushed salt in the unlined portion of the shafts to the bottom of the lining of each shaft. Excess salt will be disposed of off site.

Concrete plugs and polymer seal rings will be constructed at the location of the seals at the bottom of the lining of each shaft. A keyway will be cut into the shaft walls. The bottom concrete plugs will then be poured into place.



Exploratory Shaft Facility Schedule for Reclamation of Exploratory Shaft Site
Davis Canyon

Figure 4-14

4.1.2.4.2 Shaft Backfill. Once subsurface backfill is complete, the remaining unlined portions of the shaft are backfilled with salt up to the bottom of the final lining. Concrete plugs and polymer seal rings will be constructed at the location of the seals at the bottom of the lining of each shaft. A keyway will be cut into the shaft walls. The bottom concrete plugs will then be poured into place. After the bottom concrete plugs are in place, the remaining sections of the shafts will be backfilled. The backfill material to be used in the shafts will be salt-contaminated mined material up to the base of potable water. Concrete plugs with polymer seals will be located at the base of the potable aquifer to isolate the salt-contaminated backfill. Above the plugs, uncontaminated mined materials will fill parts of the shafts which extend up through the potable aquifers to within approximately 5 meters (17 feet) of the surface ground elevation.

Final concrete plugs approximately 3 meters (10 feet) thick will then be constructed. The remaining 2 meters (7 feet) above the plugs will be backfilled with the surface material. The final concrete seals and caps will be below the root zone of native flora. They will be designed to withstand the overburden and any planned activity to be conducted over them in the future. These final seals and caps will also prevent ground water from seeping into the abandoned, backfilled shafts. From this point, reclamation activities are considered part of the surface reclamation activities.

4.1.2.4.3 Hoist and Headframe Removal. When shaft backfilling operations are complete, equipment will be removed from the shaft collar areas. The headframe foundations, structural supports, and shaft collars will be removed to 2.4 meters (8 feet) below reclamation grade. This is accomplished prior to placing the final concrete plug.

4.1.2.4.4 Surface Storage Area Reclamation. The drainage system will be kept intact until backfill operations have been completed. The mined materials stockpiled in the storage area and remaining after backfill is completed will be removed from the site and disposed of in an offsite permitted landfill, as needed.

The sediment pond, located at low points of the site perimeter, will be maintained throughout the reclamation period until the disturbed area is restored, vegetation requirements are met, and all drainage entering the basin meets the applicable State and Federal water quality requirements for the receiving water body. After final site grading, soil stabilization, and revegetative measures are incorporated, the sediment detention basins will be reclaimed.

The evaporation and retention pond will remain functional until all the stockpiled material is removed and all associated salt-contaminated soil is disposed of properly. The concrete pavement around the shaft houses and service buildings and the subsurface drainage system will be removed prior to reclaiming the evaporation and retention ponds. Fluids in the ponds will be reduced by evaporation and the residues transported to an acceptable offsite disposal area.

The liner under the storage area will be removed such that it will not contaminate the soils under the liner. Once the material and liner are removed, the pit will be backfilled with acceptable material and graded to a final configuration consistent with the surrounding topography and land-use patterns.

4.1.2.4.5 Equipment and Building Salvage. Single-unit modular buildings will be disconnected from service and anchor connections, loaded onto trucks, removed from the site, and salvaged. Multiple modular unit buildings will be disassembled. Salvageable items are to be separated, stockpiled in a protected manner, and prepared for offsite salvage. Modular units shall be treated in the same manner as the single units.

The prefabricated buildings are to be emptied of their contents, disassembled, and trucked off site for salvage or disposal to an environmentally acceptable disposal site or landfill.

All equipment will be removed from the site and salvaged or disposed of in an appropriate landfill.

All underground utilities less than 61 centimeters (24 inches) from final reclamation grade will be removed from the site. The sewage treatment facility will be removed and salvaged or disposed of in an appropriate landfill. Utilities that are buried at depths greater than approximately 61 centimeters (24 inches) of final reclamation grade will be left in place unless by their nature they are considered a hazard or would preempt future land-use plans.

4.1.2.4.6 Excess Salt Disposal. If the exploratory shafts are backfilled to approximately 65 percent of the original in situ salt rock density, approximately 30,000 cubic meters (39,000 cubic yards) of excess salt would remain. Several methods of disposing of this excess salt are being studied. The final decision will be made during final design and will take into account a number of factors including the permit process. Disposal options under consideration include onsite land filling, offsite land filling, offshore brine disposal, storage in existing or abandoned mines or salt flats, and commercial use (Section 4.3.4.2).

Contact has been made with Federal, State and local officials regarding the disposal of salt and salt-contaminated wastes. As a result, it has been concluded that these wastes can be disposed of in commercially operated hazardous waste facilities. There is more available capacity in these commercially operated facilities than there is in either nonhazardous commercial facilities or those operated by local units of government.

In Utah, a hazardous waste management facility is located in the desert north of I-80 and approximately 24 kilometers (15 miles) east of the Bonneville Speedway. This site is projected to operate until 2020. Waste management cells have a 153,000-cubic-meter (200,000-cubic-yard) capacity and are partly excavated with above surface capacity. They are clay-polypropylene lined and bermed to meet applicable standards for hazardous solid waste disposal sites.

The preferred route for the transportation of excess salt will be from the site to U.S. 191, U.S. 191 to I-70, I-70 to U.S. 6/191, U.S. 6/191 to I-15, I-15 to I-80 to Bonneville Speedway exit, local to site. This results in a travel distance of approximately 640 kilometers (400 miles) from the ESF site.

The excess salt and salt-contaminated material to be transported can be contained and cleaned up relatively easily if a traffic accident occurs. The nature of the material is such that long-term adverse effects will not persist after cleanup. Proper loading and protection of the load from wind during transport will minimize adverse effects from routine operation.

4.1.2.4.7 Refuse and Site Cleanup. Wastes generated during construction and testing of the exploratory shaft facility include sewage treatment effluent, combustible solids such as paper and cartons, excavated solids, and salt. These waters are not expected to be hazardous. The sewage treatment facility, if called for as part of the ESF, would be designed so that effluent can be discharged to surface waters or used on site for nonpotable purposes.

The nearest licensed landfill site is at Moab. The future capacity of this landfill is currently unknown. Other landfills are located within 258 kilometers (160 miles) of the site. Access to the Moab landfill is from Utah 211, north along U.S. Highway 191 to the town of Moab.

4.1.2.4.8 Final Grading, Topsoil Replacement, and Revegetation. Grading and backfilling may commence in a sequential fashion as various areas of the site are decommissioned or in accordance with applicable procedures specified by regulating agencies. The preparation and development of the site were based on performing minimum grading and earth moving to provide adequate drainage and acceptable slopes. Fill used during site development will come from the ponds, pits, and site areas and will be graded.

The site will be regraded to a configuration consistent with the surrounding topography. Stabilized areas will be disked and stockpiled material replaced.

When a road or pond is to remain, the surrounding surface grading and the associated drainage structures will also remain. Adjacent areas will be blended to provide surface drainage in a condition suitable for continued use.

Backfilling is to be accomplished in a manner that minimizes the movement of earth and dust generated by the grading activity. Once backfilling and surface grading have been completed, the topsoil and overburden will be replaced and graded to a final contour to blend as nearly as possible with the natural topography.

Regraded subsoil will be scarified prior to topsoil and overburden redistribution, to ensure adhesion of the topsoil layer to the subsoil. Topsoil material will then be replaced over the disturbed areas to a depth corresponding to the amount removed from any given area. All rehabilitated areas will be seeded in accordance with Bureau of Land Management (BLM) seeding specifications. Equipment utilized for the final disposition phase is provided in Table 4-16.

The projected consumable resources for the final disposition phase are presented in Table 4-7. Vehicular traffic will increase slightly from baseline levels to include 90 round trips to the site by passenger vehicles per day and 550 round trips to the site by trucks per month.

4.1.2.5 Required Permits and Approvals

The DOE intends to comply with all applicable Federal, State, and local permits not inconsistent with its responsibilities under the NWPA. The DOE intends to consult with State and local officials concerning sites that are recommended.

4.1.2.6 Detailed Discussion of ESF Waste Management

Waste disposal planning is based on an analysis of the types of wastes generated by ESF activities and a telephone survey to identify existing municipal and commercial disposal facilities.

Table 4-17 presents details important to waste management by type of waste, and identifies a feasible method of disposal for each waste currently available. Existing permitted offsite facilities which appear available for disposal of ESF wastes are preferred over the DOE-constructed facilities.

Table 4-17 also indicates the location of usable disposal facilities available for each waste. "Usable" means that it can lawfully accept wastes of the type generated, and can accommodate the volume of waste to be disposed. "Available" means the operator (or owner) has indicated that the DOE should be able to obtain the applicable permits or approvals necessary to use the facility.

Other existing disposal locations, at approximately the same distance indicated in the table, were not surveyed once a usable and available facility was identified for each waste. Use of one or a combination of facilities involves additional information and final selection could be based on competitive bidding. Therefore, final selection of disposal facilities for the various types of waste will be deferred until after ESF site selection.

Eight types of waste have been identified. Rubbish is defined as combustible with not more than 20 percent garbage and can be reduced in volume by onsite incineration. However, current plans call for disposal of rubbish in an offsite permitted sanitary landfill.

The volume of excavated solids to be disposed of is reduced by using this material for backfilling the underground workings and shafts if the site is to be decommissioned. If the site is selected for a repository, this material will be included in repository planning. There are few limitations on the disposal of excavated material that is not contaminated by salt or brine. It was assumed that all material would be disposed of off site. The characteristics of the strata to be excavated suggest that the excavated material would be classified as nonhazardous.

Table 4-16. Equipment for the Final Disposition Stage

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Subsurface Backfill (5 months)	2	Generators	3,600	7,200
	3	Compressors	125	--
	2	Hoists	500	--
	1	Vent fan	400	--
	1	Vent air conditioning system	1,050	--
	1	Auxiliary fan	60	--
	2	Crushers	75	--
	2	Trucks	250	500
	2	Wheel loaders	270	540
	1	Crane	180	180
	1	Forklift	50	50
	1	Oiler	200	200
	1	Dozer	300	300
	2	Pickup trucks	135	270
				9,240
Shaft Backfill (9 months)	1	Compressed air system	200	--
	2	Hoists	500	--
	4	Stage hoists	40	--
	2	Vent fans	60	--
	2	Crushers	75	--
	2	Trucks	250	500
	2	Wheel loaders	270	540
	1	Dozer	300	300
	1	Crane	180	180
	1	Forklift	50	50
	1	Oiler	200	200
	1	Generator	3,600	3,600
	2	Pickup trucks	135	270
				5,640
Hoist and Headframes Removal (2 months)	2	Cranes	180	360
	1	Wheel loader	270	270
	2	Trucks	250	500
	1	Compressor	200	--
	1	Generator	3,600	3,600
	1	Pickup truck	135	135
				4,865
Storage Area Decommission (5 months)	1	Dozer with ripper	300	300
	2	Trucks	250	500
	1	Wheel loader	270	270
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,405

Table 4-16. Equipment for the Final Disposition Stage
(Page 2 of 2)

Phase (Time Period)	Equipment No.	Equipment Name	Equipment hp	Peak Cumulative hp
Equipment and Building Salvage (4 months)	2	Cranes	180	360
	1	Forklift	50	50
	2	Trucks	250	500
	1	Cherry picker	50	50
	1	Dozer	300	300
	1	Wheel loader	270	270
	2	Breakers	50	100
	1	Oiler	200	200
	1	Pickup truck	135	135
				1,965
Refuse and Site Cleanup (1 month)	1	Wheel loader	270	270
	1	Dozer	300	300
	1	Oiler	200	200
	2	Trucks	250	500
	1	Pickup truck	135	135
				1,405
Final Grading and Vegetation (5 months)	1	Grader	180	180
	2	Scrapers	450	900
	6	Trucks	250	1,500
	2	Dozers	300	600
	1	Wheel loader	270	270
	1	Water truck	250	250
	1	Oiler	200	200
	1	Pickup truck	135	135
				4,035

Table 4-17. Description of Wastes and Estimated Quantities Relating to Disposal - Davis Canyon

	Waste Type	Nature of Waste	Volume Generated[b]	Rate of Generation	Disposal Method[c]	Volume Disposed[d] (Truck Loads)	Location[e]
1.	Rubbish[a]	Combustible with no more than 20 percent garbage. Nonhazardous.	23,000 cu. yd.	12.8 cu. yd/day	Offsite landfill	23,000 cu. yd. (222)	Rubbish to be hauled to permitted landfill within 60 miles near Moab or Blanding, UT
2.	Excavated Material, Non-Salt Contaminated	Rock and unconsolidated material removed from the shaft which has not been intimately mixed with salt. Expected to be nonhazardous.	56,000 cu. yd.	343 yd^3/day	Used as backfill during reclamation; residual will be disposed in approved offsite landfill.	20,000 cu. yd. (952)	West of Salt Lake City - 400 miles from site; (operated by U.S. Pollution Control) Farmington, NM, or vicinity of site[f]
3.	Salt-Contaminated Rock	Rock and unconsolidated material removed from the shaft which has been intimately mixed with salt. Expected to be nonhazardous.	61,000 cu. yd.	343 yd^3/day	Used as backfill during reclamation; residual will be disposed in approved offsite landfill.	22,000 cu. yd. (1,048)	50 miles west of Salt Lake City - 400 miles from site; (operated by U.S. Pollution Control)[f]
4.	Salt	Essentially pure salt excavated from the target horizon on salt dome. Nonhazardous.	109,000 cu. yd.	280 yd^3/day	Used as backfill during reclamation; residual will be disposed in approved offsite landfill.	39,000 cu. yd. (1,857)	50 miles west of Salt Lake City - 400 miles from site; (operated by U.S. Pollution Control)[f]
5.	Potentially Salt-Contaminated Runoff[a]	Runoff from salt handling and storage areas and water pumped out of the mined shaft during construction. Expected to be nonhazardous.	3.6 million ft^3	Varies with rainfall	Evaporation; residual to approved offsite landfill.	3.6 million ft^3	50 miles west of Salt Lake City - 400 miles from site; (operated by U.S. Pollution Control)[f]
6.	Domestic Wastewater[a]	Wastewater from human activities and vehicle washwater. Nonhazardous.	10.8 million gal.	5.0 gal/min	Treatment onsite for non contractor staff; offsite for contractor. Liquids discharge or reused for nonpotable purposes; sludges disposed offsite.	10.8 million gal.	Discharged to drainage for onsite plant; municipal sewage plant for contractor.
7.	Non-Salt-Contaminated Runoff[a]	Runoff from areas not contaminated by salt. Suspended solids reduced in sediment retention pond. Nonhazardous.	4.7 million ft^3	Varies	Discharged from site.	4.7 million ft^3	Discharged to drainage.
8.	Miscellaneous[a]	Oils and other fluids drained from vehicles during maintenance, cleaners and solvents, and the like. Hazardous.	To be determined	To be Determined	Collected and stored in drums for recycling or disposal at a permitted offsite facility.	To be determined.	50 miles West of Salt Lake City - 400 miles from site; (operated by U.S. Pollution Control)[f]

(a) Waste streams expected to continue through testing at the following generation rate:
Rubbish - 15 lb/person/day
Potentially salt-contaminated runoff - 520,000 ft^3/yr (18 acre-feet)
Domestic wastewater - 35 gal/cap/day
Nonsalt contaminated runoff - 21.6 acre-feet per year
Miscellaneous - to be determined.

(b) Estimated total volume generated through end of expanded underground excavation.

(c) Most reasonable method based on information currently available.

(d) Remaining volume after allowing for backfill or discharge as appropriate.

(e) A facility which has capacity and accepts wastes of the type generated is located at or within distance indicated. References to cities does not imply any landfill has agreed to accept ESF generated waste, now or in the future.

(f) From Pittman, 1984.

The ESF is designed to minimize the runoff volume that could be contaminated by salt. Runoff from the area around the headframe, where salt may be spilled, is directed to the evaporation and retention pond. This pond, designed to accommodate a 500-year storm event, also collects runoff from the storage area. A concrete apron around the headframe will facilitate cleaning up salt spills to minimize the potential for contamination. The water collected in the evaporation and retention pond is expected to have a low ionic content once the salt storage pile has been formed and the contents exposed to atmospheric conditions. Water will be discharged from the evaporation and retention pond only if testing verifies that it meets applicable discharge criteria. If it does not meet discharge criteria, the water will be evaporated or trucked to a permitted offsite disposal facility. If chronic elevated ion concentrations are detected, improved house cleaning, covering the salt pile, isolating salt pile runoff, or other management techniques will be investigated. Runoff from those areas of the site where salt handling has not occurred will be directed to a sediment pond. The accumulation of soils in both the evaporation and retention and sediment ponds will be dependent upon actual suspended solids concentrations, evaporation rates, etc. These solids will be disposed of as required in offsite facilities.

Domestic wastewater will be contributed from commodes. These wastes will be treated in an onsite sewage treatment facility. Effluent from the wastewater treatment facility will undergo tertiary treatment consisting of duplex dual media gravity filters. Such treatment will reduce effluent suspended solids to approximately 1 milligram per liter and produce a effluent containing not more than 20 milligrams per liter biochemical oxygen demand (BOD). Any liquid discharge to surface systems will meet the maximum permissible levels for such discharge. Construction contractors will provide chemical toilets and truck waste to an offsite facility.

The only wastes generated at the ESF which will be classified as hazardous will be oils, thinners, solvents, and lubricants. These wastes were not included in the waste report and their volume has not been estimated. If a recycling facility is not readily available, these fluids can be disposed of in hazardous wastes landfills as indicated in Table 4-17.

4.1.3 Other Activities

This section describes other site-specific investigations that will be performed in conjunction with site characterization including environmental and socioeconomic studies. Many of these activities will begin before the construction of the exploratory shaft. The total on site work force for these activities will range from 4 to 20 persons.

The presentation of this section has two objectives. The first is the description of the type and extent of environmental socioeconomic field studies and site activities in order to disclose the full extent of potential impacts arising from these activities.

The second objective is to give a brief description of the planned environmental and socioeconomic studies. These studies are predicated on information needed to satisfy diverse requirements for the following:

- Permit and statutory compliance information for site characterization activities
- Monitoring of site characterization impacts
- Development of mitigation plans for the effects of site characterization
- Analyses of the repository and the site to determine safety
- Analyses of the repository and the site for evaluation against DOE guidelines (10 CFR Part 960)
- Determination of engineering design parameters for the ESF (final design) and for the repository.

- Determination of existing environmental and socioeconomic conditions to be used in the environmental impact statement (EIS) that will be issued after site characterization.

After the EIS scoping meetings, environmental study plans for the EIS will be revised and implemented. Regulatory agencies (and the public) will have opportunities to comment on the design of the environmental and socioeconomic studies. Specific opportunities will occur in the permitting process.

The scheduling of the environmental field studies is tied to the activities described in Sections 4.1.1 and 4.1.2, and is shown in Figure 4-15. The ESF construction is scheduled to begin 10 months after site selection. That provides adequate time to collect and direct environmental and socioeconomic field data undisturbed by ESF construction. In addition, there is an initial two month period without any site activities, sufficient to allow qualitative biological surveys and archaeological field work. Subsequent to the 2-month period, but prior to the start of the ESF, there are borehole drilling activities at the EDBH site (beginning in month three), and geophysical services beginning in month eight, neither of which are expected to significantly interfere with environmental and socioeconomic field data collection.

4.1.3.1 Enviromental Field Studies

This section describes environmental studies to be conducted during site characterization, including studies of land use and mineral resources; terrestrial and aquatic ecosystems; air quality and meteorology; water quality and hydrology; soils; noise; aesthetic resources; archaeological, cultural, and historical resources; radiological background; and transportation and utilities.

4.1.3.1.1 Land Use and Mineral Resources. The initial purpose of these studies is to document specific land uses to allow for the layout of utilities and roads to the repository site, and to determine whether there are additional sensitive land uses that need to be protected during repository construction. These land-use studies (out to a radius of 80 kilometers [50 miles]) will support repository safety analyses, which in turn also determines repository design. Updated information on existing and planned uses at the site and in proximity to the site will be obtained.

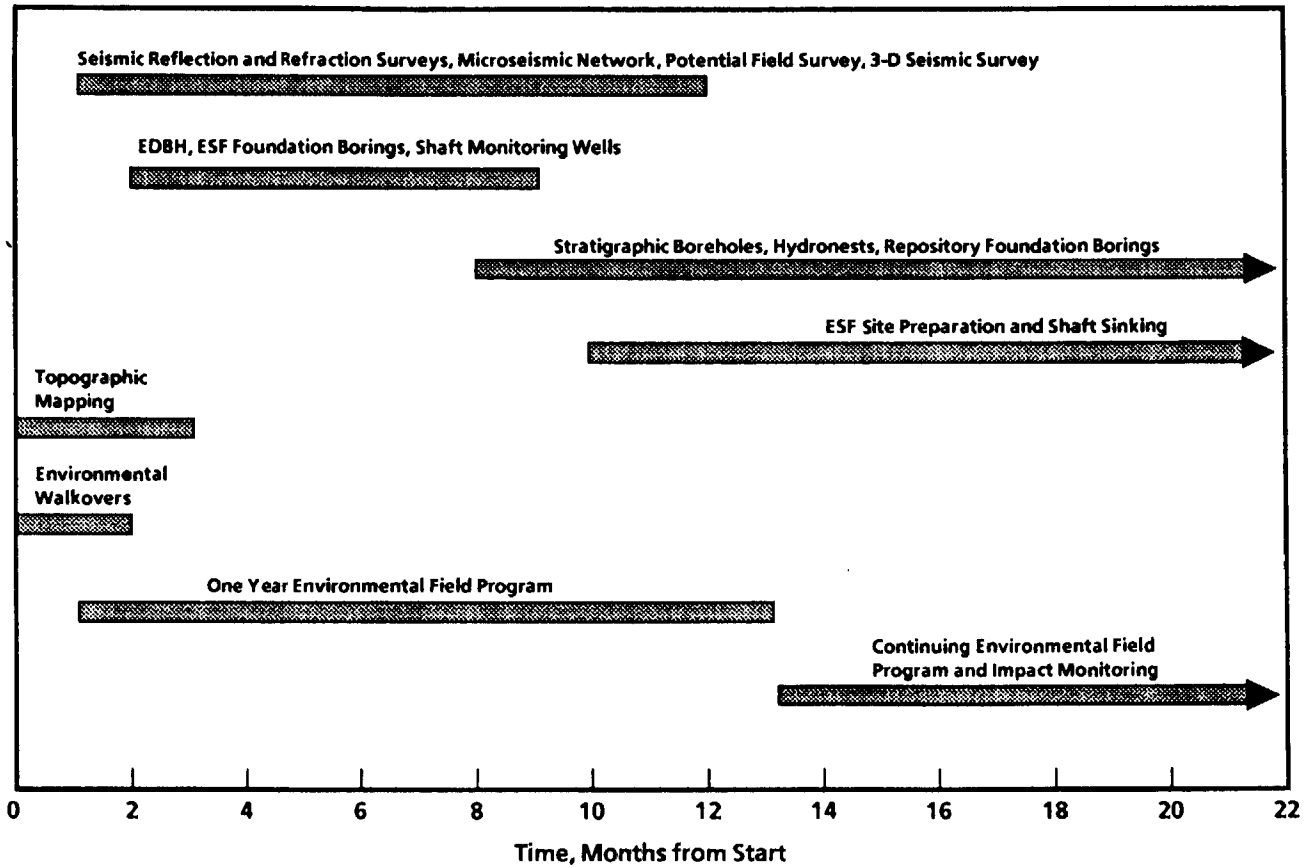
Data will be based on the interpretation of aerial photographs, supplemented by site reconnaissance and review of data from local planning agencies and other resource agencies. The study areas to be examined are presented in Figure 4-16.

Geologic data obtained from site characterization will be reviewed for indications of potential mineral resources.

4.1.3.1.2 Terrestrial and Aquatic Ecosystems. These studies serve two purposes. The first is to conduct surveys of the site for evidence of species protected under applicable Federal and State statutes. The second purpose is to perform a quantitative assessment of biological pathways for repository safety studies and repository design work.

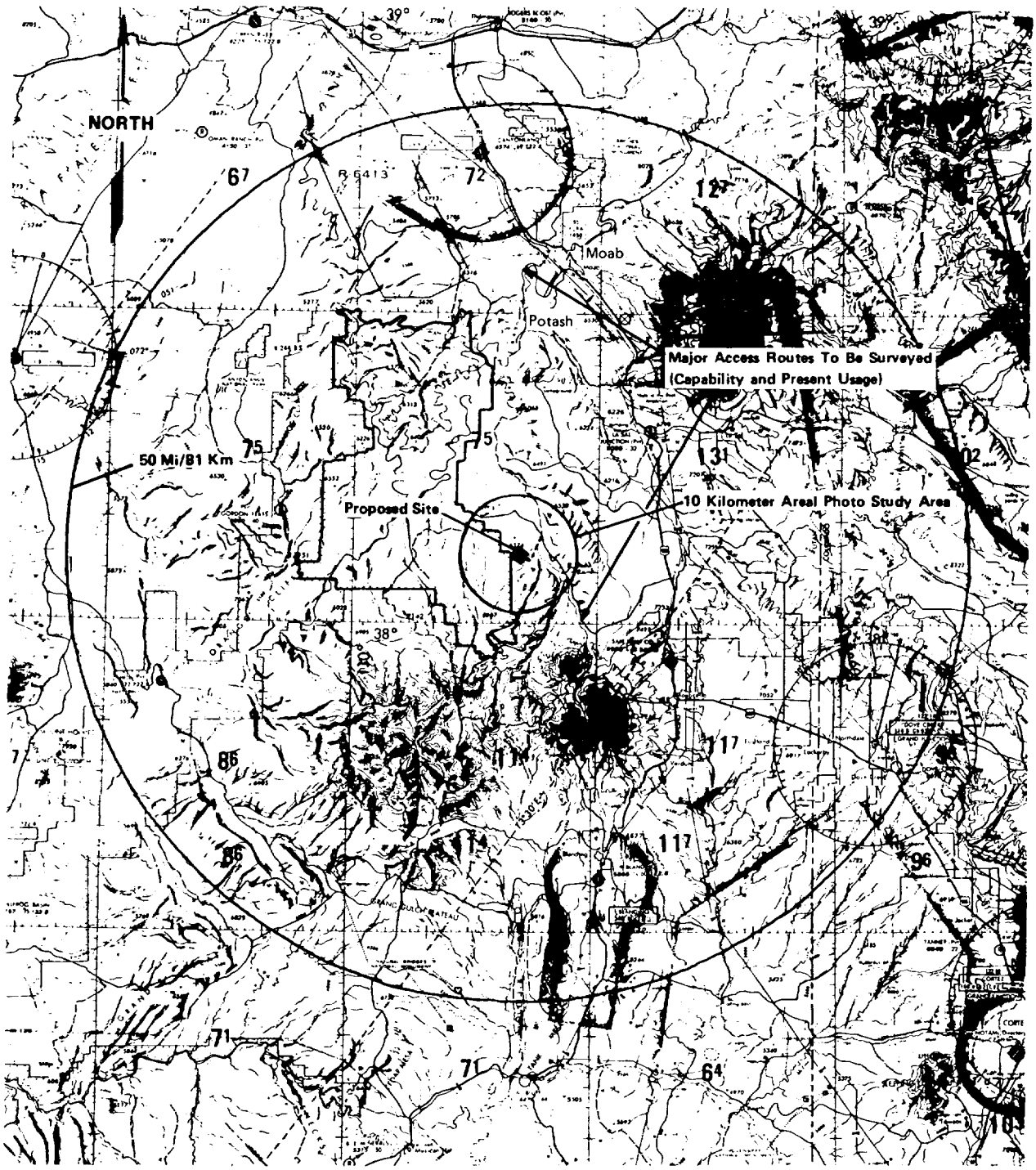
Terrestrial and aquatic studies will be conducted in two separate programs: site reconnaissance of areas affected by field activities (Section 4.1.1), and seasonal ecological studies in areas affected by potential repository development.

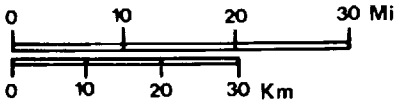
Prior to initiation of geologic and hydrologic borehole activities described in Section 4.1.1, a site reconnaissance for threatened and endangered species will be conducted at each activity site. Each reconnaissance will require a plant ecologist and a wildlife ecologist to investigate both the area to be disturbed and a surrounding buffer strip. If threatened and endangered species or their habitats are identified at any site, discussions will be conducted between the DOE and the Fish and Wildlife Service, to either modify the field activities, or in some other way provide adequate mitigation of the conditions for the species of concern.



Relationship of Environmental Field Program to Geotechnical and Exploratory Shaft Programs Davis Canyon Site

Figure 4-15





Source: NOAA, 1985.

Proposed Locations (Approximate)
for Environmental Study Sampling
Land Use and Transportation
Davis Canyon

Figure 4-16

The second set of studies includes the seasonal ecological studies for the proposed repository site, the controlled area, and access corridors. The studies will focus on qualitative and quantitative assessments of existing terrestrial and aquatic ecosystems. A comprehensive radiological program will be integrated into these studies for an evaluation of radionuclide uptake and content in edible crops and natural vegetation, livestock, wildlife, and components of the aquatic ecosystem.

The seasonal ecological studies will involve a seasonal survey of the terrestrial and aquatic environments from which species lists will be generated and major habitats defined and mapped. Special emphasis will be given to surveys for State and federally listed threatened and endangered species and for other important species of recreational, commercial, or ecological value. Control sites for ongoing monitoring will be selected in adjacent areas where no impacts are anticipated. These will provide a means for comparing project-induced changes with natural environmental changes in the vicinity.

Terrestrial Ecology. The terrestrial field program will survey and sample all major components of the terrestrial ecosystem. The focus of the field program will be a complete ecological description, including species composition, population abundance, location and extent of vegetation types and wildlife resources, successional stage of plant community, wildlife movement patterns, preferred habitats and habitat requirements, trophic structure and productivity, and preexisting environmental stress.

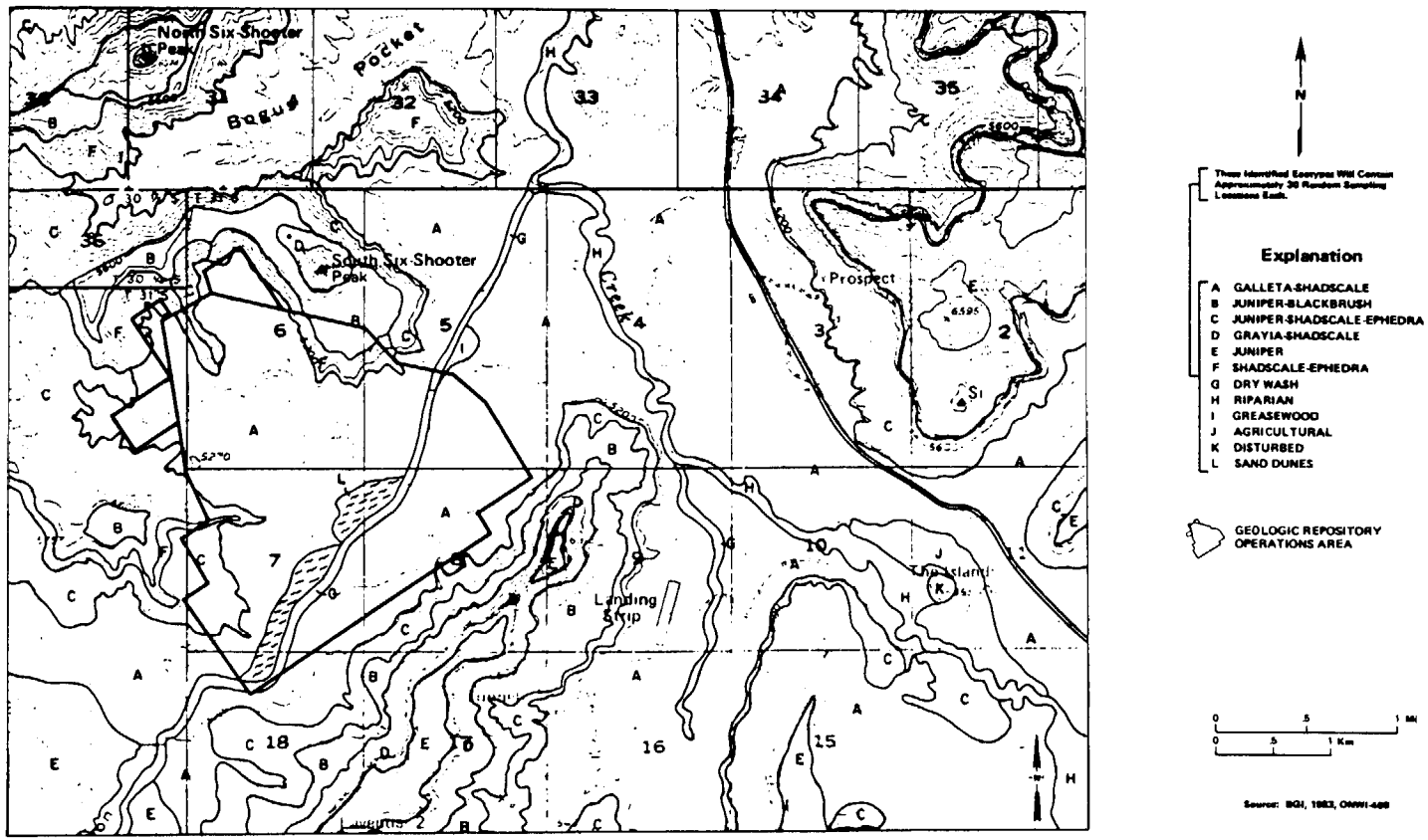
The plant communities of the Davis Canyon site will be quantitatively sampled to obtain data to characterize the vegetation structure. An inventory of plant species within each vegetative community will be compiled during the initial phases of the quantitative sampling program. The species list will be annotated to include data on plant form, habitat preference, and relative abundance. Standard ecological sampling procedures will be employed (e.g., rectangular quadrants, nested quadrants). Federal and State agency consultation will augment sampling procedures to address habitats and species of concern. From the sampling data, descriptive parameters such as density, abundance, frequency, percent cover, and dominance will be calculated. This information will also help determine the productivity and successional stage of the plant community. Approximate locations of sampling sites are shown in Figure 4-17.

Wildlife studies will utilize existing published and unpublished information pertinent to the study area, as well as specific field surveys to provide information on species presence, abundance, seasonal distribution, and important ecological interrelationships. The local value of wildlife to sporting, commercial, and recreational users will also be evaluated. Standard field sampling techniques will be used for these studies, including trapping small-to medium-sized mammals, spotlighting for large mammals, and trapping and visual surveys for reptiles, amphibians, and invertebrate species.

Avian populations will be surveyed to address the hunting potential for different game birds. The relative abundance of game birds (e.g., chukar partridge) and upland migratory game birds (e.g., mourning doves) will be determined by conducting stratified censuses along transects. Nongame bird populations will also be sampled using transect methods. Call counts will be conducted according to established techniques.

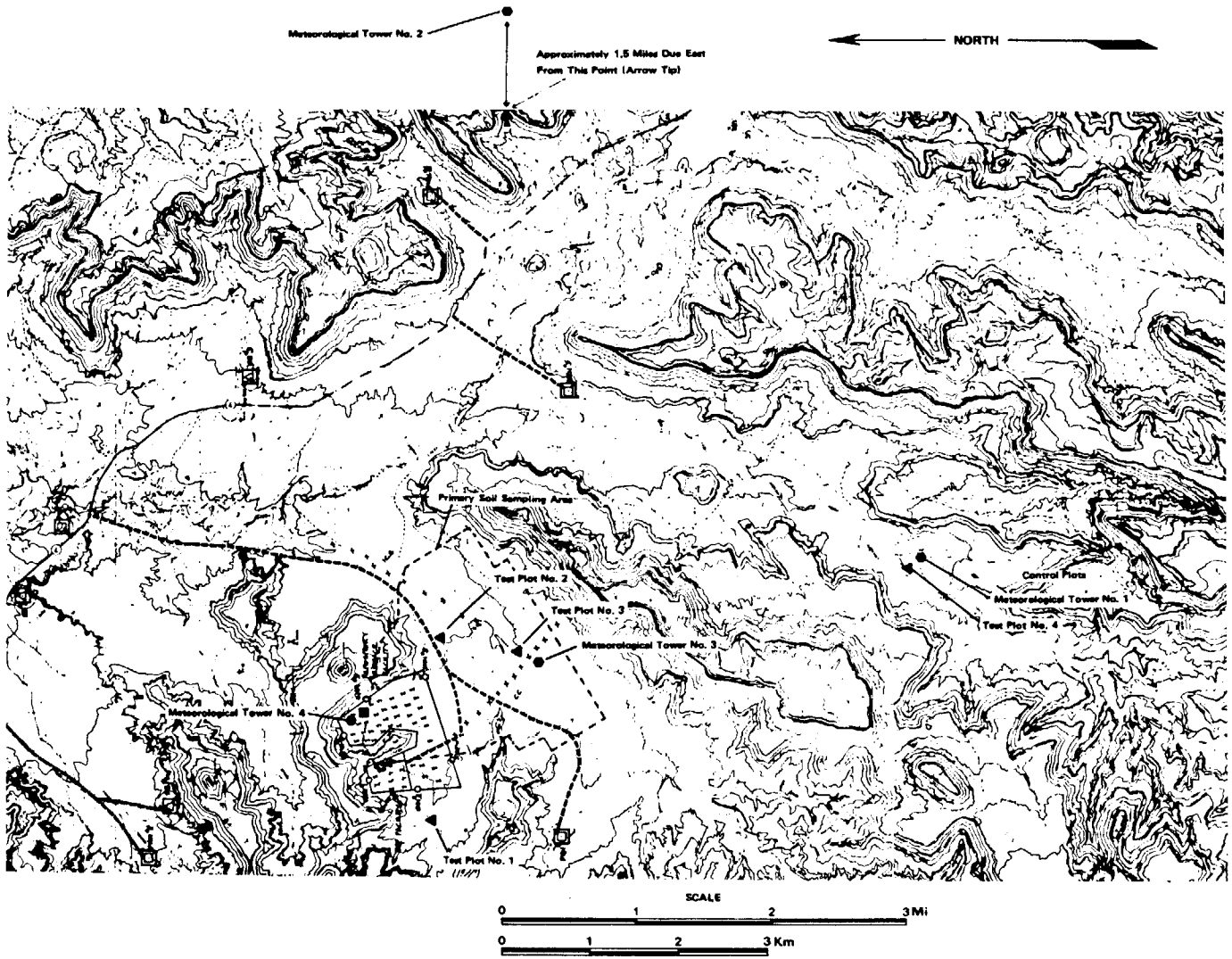
The terrestrial field program will be restricted to Davis Canyon and the selected transportation corridor. Vehicular traffic will be confined where possible to existing access roads, jeep trails, and dry washes. Sampling will take place over a four-season period. The duration of each sampling effort (once per season) will be approximately three weeks.

A program to monitor salt impacts will be established. Test plots (see Figure 4-18) established near and distant from the salt site will be intensively studied. The salt conditions and biotic responses in the test plots will be monitored before, during, and after salt excavation.



Proposed Locations (Approximate) for Environmental Study Sampling Biota/Ecosystems

Figure 4-17



Explanation

Approximate Location, Foundation Boreholes

10 Acre Soil Sampling Area For Remote Boreholes (4 Samples Per Borehole Location)

Salt Penetration Monitoring Station

*Note: Radiological monitoring (i.e. grab samples and pole mounts) will coincide with these and other mapped sampling locations.

Source: Woodward - Clyde Consultants, 1984

Proposed Locations (Approximate) For Environmental Study Sampling: Soils, Radiological, Meteorological/Air Quality, and Salt Impacts

Figure 4-18

A larger reproduction of this figure appears at the back of this volume.

Aquatic Ecology. An aquatic ecology survey will be conducted concurrently with the terrestrial program. Because of the intermittent nature of drainage from Davis Canyon, the aquatic field program will be restricted to the perennial portion of Indian Creek. Sampling will occur upstream and downstream of the confluence of the Davis Canyon drainage and will use standard field equipment and techniques.

Sampling will be undertaken to determine species composition and relative abundance. Major groups to be surveyed include aquatic and wetland plants, aquatic invertebrates (benthos, nekton, plankton), and fishes. Emphasis will be placed on special status species and species that are indicators of environmental stresses. Efforts will be coordinated with terrestrial field surveys.

Fisheries resource surveys will be conducted to determine any possible distribution patterns, breeding and spawning grounds, and in-migration patterns. If needed, quarterly field collections will be conducted at representative locations within the site vicinity. A variety of sampling devices will be used to ensure that resident fish species are adequately sampled. Concurrent with the fisheries resource field survey program, benthic invertebrates and emergent aquatic insects, which may be critical to the structure and function of the ecosystem or a necessary food item for other important species, will be collected.

To aid in defining the temporal and spatial distribution patterns and abundance of important organisms in aquatic communities, water quality data will be included in the sampling program; water samples would be collected concurrently with the aquatic ecology sampling.

Threatened and Endangered Species. Sites of all project activities and adjacent areas will be further surveyed for the presence of designated and proposed threatened and endangered plants and animal species. Field survey programs will be developed to determine the actual presence of threatened and endangered species and their habitats in the project area. These surveys will coincide with the terrestrial and aquatic surveys. Special attention will be given to the inspection of cliffs to check for peregrine falcon eyries.

4.1.3.1.3 Meteorology and Air Quality. The immediate need for onsite meteorology is to satisfy information requirements for the design of the repository. To characterize local weather conditions and atmospheric transport and dispersion processes, onsite meteorological monitoring will be conducted. Airflow patterns and atmospheric stability will be studied on a continuous basis with meteorological towers.

The complex terrain of the Gibson Dome Area necessitates the collection of meteorological and air-quality data at multiple stations. One 10-meter (39-foot) meteorological tower would be placed near the center of Davis Canyon (MT-3). Similar towers would be erected on Harts Point (MT-2) and near the center of Lavender Canyon (MT-1). These stations would monitor meteorological conditions and collect air-quality data. A 60-meter (197-foot) tower is proposed for the Davis Canyon cul-de-sac (MT-4) to collect meteorological data only. These data would be used for modeling local air movements. The four monitoring stations would require a total fenced land area of approximately 1.6 hectares (4 acres), and would require short access roads off of existing or planned roads.

Meteorological parameters to be monitored at the station will include wind direction, wind speed, and temperature at two or three levels: dew point temperature; precipitation; incoming sunlight; and barometric pressure. Additional meteorological data will be collected from records available from the National Weather Service and nearby climatological stations.

Air quality monitoring may be conducted on site to calibrate background concentrations of all atmospheric contaminants regulated by the "National Primary and Secondary Ambient Air Quality Standards "(NAAQS) (40 CFR Part 50) and the Utah State Air Conservation Regulations. Federal Prevention of Significant Deterioration (PSD) (EPA, 1978) regulations, if applicable, will require 1 year of onsite meteorological data. Air-quality parameters such as total suspended particulates, PM_{10} particulates, sulfur oxides, nitrogen oxides, carbon monoxides, ozone, and lead will be measured and monitored.

Information from the onsite meteorological and air quality monitoring station and recent nearby air quality and meteorological records will be used to further describe the site with respect to the following:

- The influence of terrain on meteorological factors
- Monthly and annual frequencies of wind speed and direction by atmospheric stability class
- Total precipitation (rain and snow) by month, the number of hours with precipitation, and the rainfall rate distribution
- Ambient air quality
- Cumulative frequency curves of monthly average precipitation and evaporation
- Estimates of the wind erosion index
- Monthly and annual dry bulb air temperature, vertical temperature difference, and dew-point temperature summaries, including averages, measured extremes, and diurnal range.

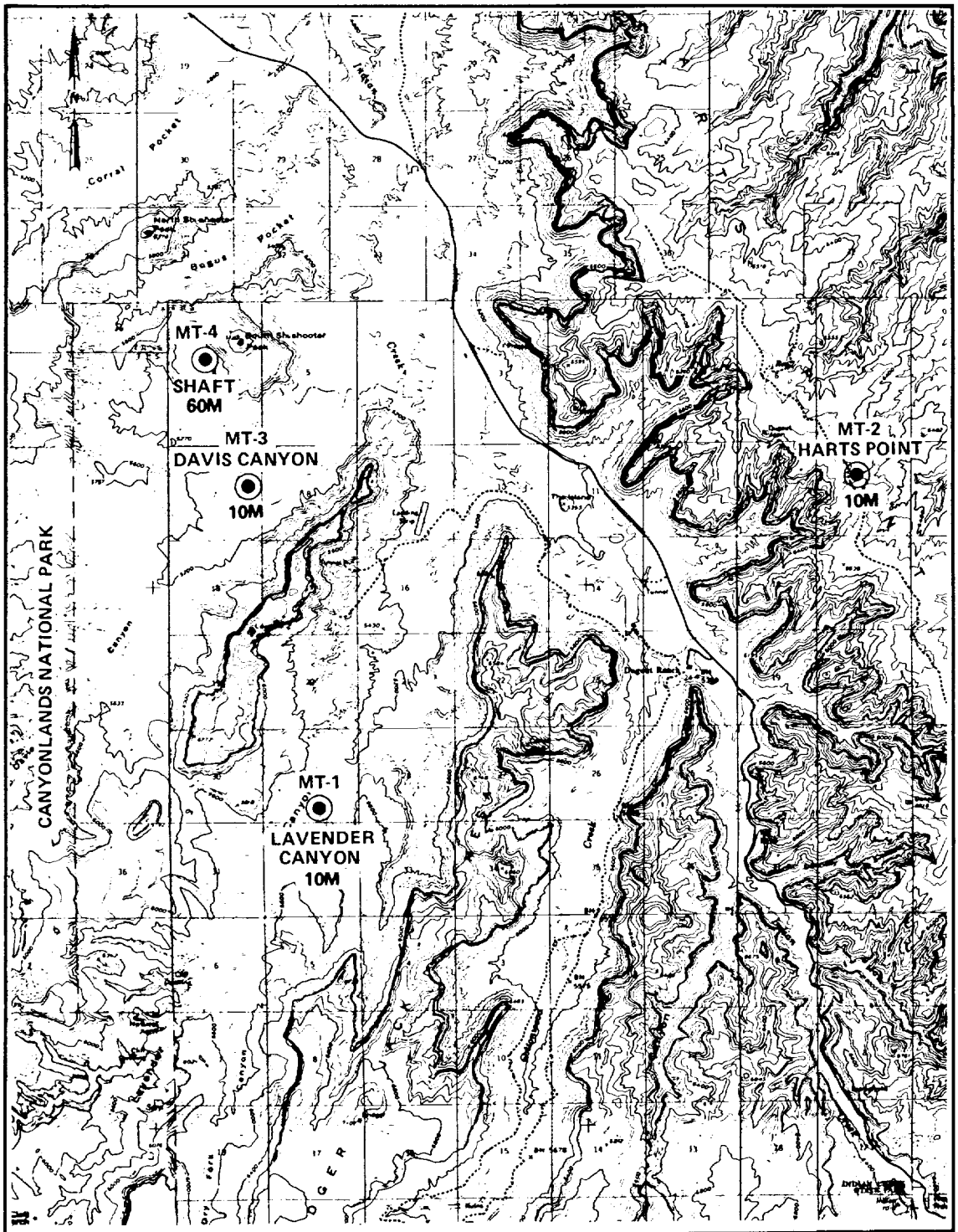
The locations of meteorological towers are shown in Figure 4-19. Tower site MT-3 would be located 2.2 kilometers (1.4 miles) south of the exploratory shaft site and require approximately 1.6 kilometers (1 mile) of new access road. Tower site MT-2 would be located on Harts Point. Access would be off an existing unpaved road originating from Utah 211 with approximately 0.4 kilometer (0.25 mile) of new access road being required. Tower site MT-1 would be located in Lavender Canyon. Access would be off the Lavender Canyon wash. Approximately 0.4 kilometer (0.25 mile) of new access road would be required. Since the 60-meter (197-foot) tower (MT-4) would be located at the exploratory shaft facility site, no additional access would be required.

4.1.3.1.4 Hydrology and Water Quality. An intensive field investigation and data collection program is planned to define the hydrologic and water quality conditions of the area, monitor the impact of site characterization activities and future repository operations, and implement site-specific mitigating measures. Detailed characterization of the hydrologic regime and water quality of the surface water will include stream gaging, discharge measurements, and water quality sampling and analysis.

Initial studies will be directed at the collection of data to satisfy National Pollutant Discharge Elimination System (NPDES) permitting requirements for site characterization activities, and to support additional floodplain analyses for the repository design. Subsequent studies will include monitoring according to the provisions of the NPDES permit are to confirm the floodplain analyses.

The permanent water-quality sampling stations proposed for the Davis Canyon site are shown on Figure 4-20. One of the stations is on the ephemeral stream draining the project facilities. The other stations are on the ephemeral Davis Canyon Creek, and are in a predominantly downwind direction from the site. Additional grab samples will be taken along Indian Creek, in support of the aquatic ecology studies.

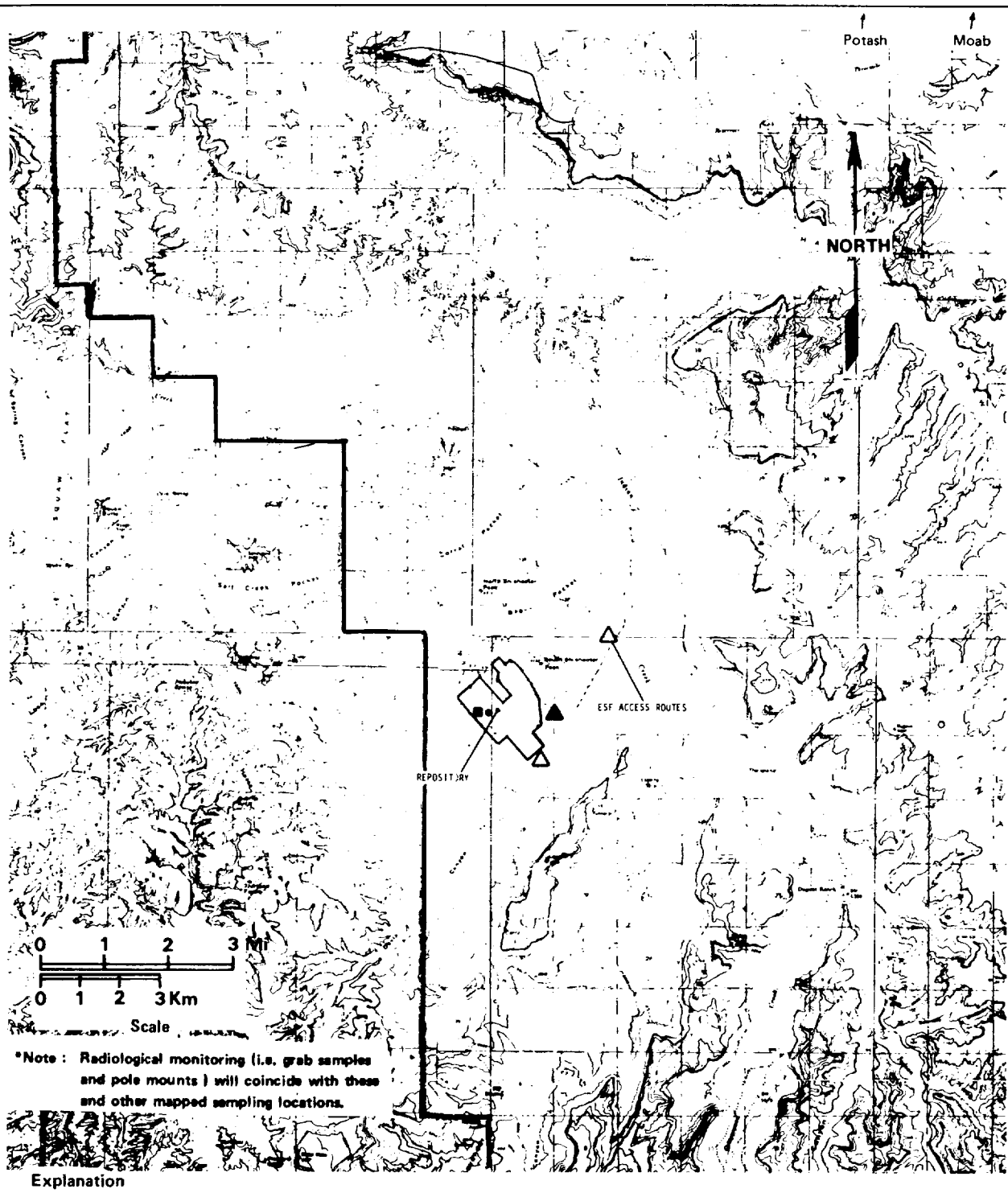
Water-quality sampling at the monitoring stations will be conducted on a monthly basis to examine the flow, and general chemical, nutrient, and organic parameters, while bimonthly samples will be collected for trace metals. Monthly inspections of the other stations will be conducted and samples will be collected according to this same schedule. However, due to the expected intermittent nature of the flows at these stations, water-quality samples will only be collected when flows allow. Sediment sampling at the sediment monitoring stations will consist of depth-integrated suspended-sediment sampling on a monthly basis (when stream flows allow), and the installation of single-stage samplers to collect sediment data during flow events.



Source: BGI, 1984, ONWI-471.

Proposed Atmospheric Monitoring Stations
Davis Canyon

Figure 4-19



Explanation

- ▲ Discharge, water quality, and sediment discharge station
- △ Discharge and water quality station
- ● Rainfall station
- ■ Evaporation station

Source: USGS, 1968.

Proposed Locations (Approximate) for Environmental Study Sampling Water Resources Davis Canyon

Figure 4-20

Ground-water quality samples will be obtained from existing wells in the vicinity of the site. The same parameters sampled for surface water will be sampled for ground water using standard techniques. Geohydrologic properties of the aquifer and water quality samples of the deep aquifers will be obtained from the geologic field studies program as part of site characterization (Section 4.1.1).

The surface-water and ground-water quality field study will require access and entrance to private or State lands to sample wells or surface-water bodies.

4.1.3.1.5 Soils. The purpose of these studies is to provide repository and exploratory shaft design data. Specifically needed are shallow soil engineering property data, soil depth and classification (to allow development of a stripping and stockpiling and reclamation plan), and soil hydrologic properties (to estimate and mitigate soil erosion). Although the existing soil already has been classified generally and erosion rates have been calculated for the area (BNI, 1984a), additional soil studies will be required. Information on soils will be collected by soil surveys. Soils will be collected by hand auger to a depth of 1.5 meters (5 feet) or bedrock. Soil characteristics such as texture, color, chemistry, size distribution, slope, drainage, and permeability will be collected. The general locations shown in Figure 4-18 will be sampled.

4.1.3.1.6 Noise. The first goal is to determine existing background sound levels. The second is to collect site-specific sound attenuation (propagation) data for calibration and validation of noise propagation models to be used in future noise analysis. The third is to monitor sound levels from site characterization activities and repository development in order to determine the effectiveness of noise control measures and the need for further mitigative measures. Seasonal sound-level data will be collected quarterly, including weekdays and weekends, and for day and night. Sampling periods will be designed to develop a representative statistical statement of the background sound levels at the Davis Canyon site. Planned survey points are located on Figure 4-21. Existing noise sources at the site will be identified and octave band analyses will be performed to characterize significant noise sources. These data will be used to determine sound levels at each location. To provide correlations with measurements, additional information on other parameters will also be recorded during the survey. Meteorological observations including wind speed, wind direction, temperature, and relative humidity will be made. Measurements obtained near roadways will be accompanied by a traffic count. Sound source observations will be recorded during each sample and include a notation of the predominant sound sources. Sound-level data will be used in the analysis of impacts due to repository construction and operation.

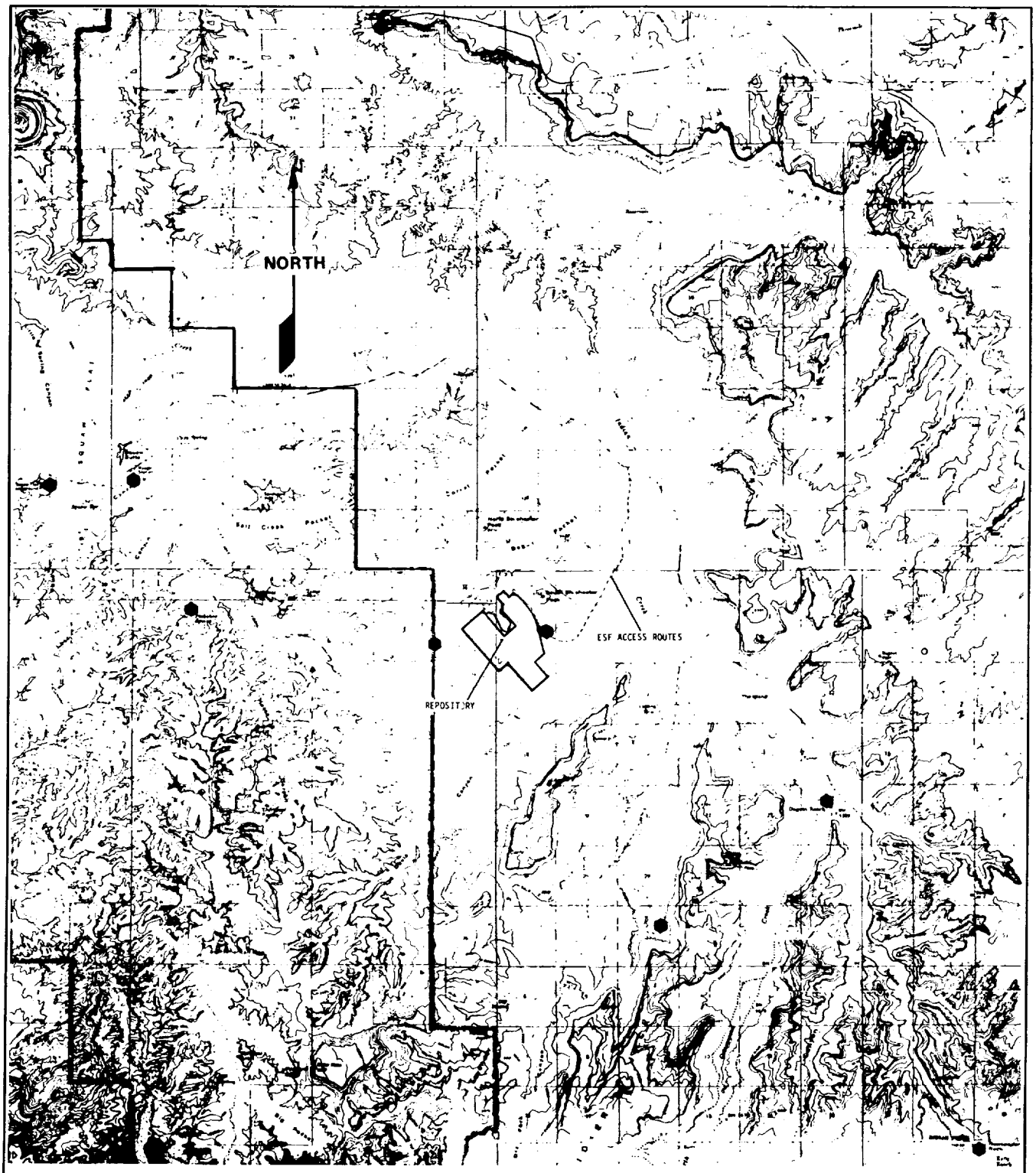
4.1.3.1.7 Aesthetic Resources. Additional field studies to determine the potential visual impacts associated with repository construction, operation, and decommissioning activities will be conducted. Potential impacts attributable to nightlighting and to transportation and utility corridors will be evaluated.

4.1.3.1.8 Archaeological, Cultural and Historical Resources. Intensive cultural resource surveys will be conducted in the project area pursuant to the provisions of a Programmatic Memorandum of Agreement between the DOE, the Advisory Council on Historic Preservation, and the Utah State Historic Preservation Officer currently being developed (DOE, 1985a). Studies will be coordinated with the Utah SHPO and may include:

- A pedestrian survey of 100 percent of the areas occupied by the exploratory shaft, access routes, and those parts of the study area which probably contain prehistoric and historical cultural resources

- A pedestrian survey of a sample of the remainder of the study area to test the proposition that the area probably contains no prehistoric and historic sites

- An intensive archival and information search to identify important historic sites in the study area, followed by a reconnaissance survey of the historic site locations identified.



Explanation

Proposed Sound Level Monitoring Locations

0 1 2 3 Mi

0 1 2 3 Km

Scale

Source: USGS, 1968.

Proposed Locations (Approximate) for Environmental Study Sampling Sound Levels Davis Canyon

Figure 4-21

The goals of the investigation will be to locate all cultural resources in the areas surveyed, to assess the significance of the resources located, and to make additional projections concerning the number, kind, and significance of the resources located. Projections of the number, kind, and significance of resources in areas not surveyed will also be made. In addition, recommendations for further cultural-resources work will be provided.

4.1.3.1.9 Radiological Background. A radiological baseline sampling program would be established to evaluate background radiation levels in, and adjacent to, the proposed site. The initial purpose of this program is the development of safety analyses to determine repository design. Subsequent work would support the repository license application to the NRC. Preoperational radiation surveillance of the environment would be performed prior to site development to:

- Identify the probable critical exposure pathways
- Identify affected geographical areas
- Characterize sample media and sample site locations
- Interpret data to determine background levels.

The collection of samples would be coordinated with the soils, ecosystems, water quality, air quality, and monitoring programs as discussed below and as shown on Figure 4-18.

Soils. Samples would be collected (Section 4.1.3.1.5) to measure radionuclides in the soil.

Terrestrial and Aquatic Ecosystems. Radiological analysis of background radiation conditions in terrestrial and aquatic ecosystems would be integrated into the ecosystem program described in Section 4.1.3.1.2. These studies will emphasize radionuclide uptake and content in important food chains (including edible crops and vegetation, livestock, wildlife, milk, fish, invertebrates, benthic sediment, and plankton).

Surface and Ground Water. Surface- and ground-water samples would be collected and analyzed for radionuclide contamination in conjunction with the water quality program (Section 4.1.3.1.4). Surface-water samples would be taken upstream and downstream from the site monthly. Ground-water samples from boreholes described in Section 4.1.1.1 would be taken quarterly upgradient and downgradient from the site.

Air and Precipitation. The background radiation monitoring program would be operated in conjunction with the air-quality monitoring program (Section 4.1.3.1.3). Weekly air samples measuring airborne particulates and gaseous radionuclides would be collected from several locations on site and off site. Precipitation samples would be collected when available at the sampling station nearest the site in the direction of the prevailing wind.

Ambient Beta and Gamma Radiation. Environmental levels of beta and gamma radiation would be monitored quarterly at several locations on site and off site. Locations would include points along the perimeter of the site, and locations within a 16-kilometer (10-mile) radius of the site in the greatest and least prevalent annual wind direction.

4.1.3.1.10 Transportation. This section discusses the transportation-related studies specified in Section 4.1.2 that will be conducted during site characterization and the consequential environmental impacts discussed in Section 4.2. These studies are primarily conducted to support engineering design of access corridors for the exploratory shaft facility (ESF) and for the repository. These efforts include environmental and safety analyses of alternative repository corridor alignments, and monitoring and mitigation studies for possible traffic congestion during site characterization.

It appears that Utah 211 is structurally adequate to handle peak traffic loads (Section 3.5.1 and 4.2.1.10). Monitoring for congestion, other traffic problems, and road deterioration will be conducted to confirm the adequacy of the road and to form the basis for maintenance plans. This may include traffic monitoring along Utah 211 and at the intersection

of U.S. 191 and Utah 211. Section 4.2.1.10 identifies mitigation measures that will be employed.

During site characterization, detailed repository transportation studies will be conducted to further assess the existing transportation infrastructure, state and local emergency response capability, overflight hazards, and alternative routes for development of highway and railroad access routes to the repository. This information will be used to support the decision regarding preferred transportation routes.

These studies will be performed to determine necessary infrastructure development and mitigation for anticipated repository-related traffic congestion at key locations in the site vicinity. Detailed studies of the existing highway and rail transportation infrastructure will include: evaluation of the local and regional highway and rail characteristics, current condition, and need for upgrading; planned changes or improvements; present traffic levels and capacities; accident and weather disruption experience; compatability of repository transportation plans with local and regional plans; and assessment of costs and types of potential mitigative actions. The results of these studies will be used to better define potential impacts from repository-related traffic and the necessity, location, and nature of any improvements or modifications to the existing infrastructure.

Studies will be performed to assess the capabilities of local and state agencies to respond to transportation-related emergencies including: agencies responsible for disaster and accident response; evaluation of response plans, available equipment, and trained personnel; degree of interagency coordination; and the need for Federal assistance and funding. This will ultimately be used to determine the necessity of improving existing capabilities and the nature of such improvements.

Studies of the overflight hazard will include detailed examination of the use of airspace in the repository area by volume and type of aircraft, as well as an assessment of capabilities and use characteristics of airports at various distances from the repository.

Studies will be conducted to further identify engineering requirements and environmental and social impacts of alternative highway and railroad access routes (Section 5.1.2.2). The studies will include locating the constraints and opportunities to siting which exist in the region.

Siting the rail and highway access route will be guided by the siting guidelines, program and engineering requirements, public concerns, and applicable local, State, and Federal laws. The evaluation of environmental impacts will require the conduct of studies to assess existing environmental conditions along proposed alignments. The preferred access routes will be selected based on the results of these studies and a comparison of economic, safety, social, environmental, and cost impacts and engineering requirements for each alternative route (Section 5.1.2.2).

Additional studies may be conducted to investigate nationwide transportation issues.

4.1.3.1.11 Utilities. Utility-related studies during site characterization will be centered around supplying the utilities required for repository construction and operation and meeting the repository-generated waste disposal needs. Utility requirements for site characterization are specified in Section 4.1.2, and consequential environmental impacts are discussed in Section 4.2.

Initially, an evaluation of project utility needs will be made. These include natural gas, electric power, water, sewage, sludge disposal, and communications. Natural gas, electricity, and communications capabilities will be supplied by connecting with existing offsite systems. Studies will involve assessing current and forecasted demand and capacity of these offsite systems and the effects that the project will have on them. Connecting the existing systems with the repository will involve the study of alternative utility access corridors (Section 5.1.2.2) and the impacts associated with the alternatives.

Waste disposal studies will involve defining the quantities, types, and production schedule for projected generated wastes. An inventory will be developed on potential offsite disposal areas for hazardous and nonhazardous wastes. This will include locations, projected capacities, and waste types acceptable to each facility. These studies will also assess regional waste disposal plans and the potential need for new facilities.

4.1.3.2 Socioeconomics

Impact assessment, monitoring, and planning activities will occur during site characterization. The purpose of assessment activities will be to project repository impacts. The role of impact monitoring will be to provide the data necessary to make the repository assessments more accurate and to identify potential site characterization effects. If the monitoring program were to identify impacts of site characterization, mitigation activities would be established. Mitigation plans would outline the process that the DOE would follow in working with the States, and local communities to minimize or mitigate adverse impacts which may be identified by the monitoring program.

There are many different effects that communities could experience from a repository project. Five types of impacts have been identified at other large-scale facility sites. Demographic impacts result from the influx of new project workers and their families. There will be a larger community population, as well as potential change in the age and family characteristics of the population. Economic impacts include changes in business activity and employment in rural areas. At least temporarily, wages and costs often increase from levels existing before the project begins, and business sales and income from project-related activities increase the overall economic activity in the area.

Community Services impacts may also be experienced with local population growth. This growth may affect the fire protection, schools, water and sewer systems, and road maintenance. Fiscal impacts may be experienced with the additional service demands and costs associated with the rapid population increases that accompany large-scale development. Offsetting possible increase in demands and costs, there may be an increase in local tax revenues. These new revenues are often a resource for much needed service improvements, such as new schools, water and sewer systems, and service facilities. Social impacts may result from the influx of large numbers of people. The informality and intimate nature of social relationships in a rural area may change. As a result, longtime residents sometimes feel that the communities become less familiar, less friendly, and less harmonious.

Assessing these socioeconomic impacts is a critical element in meeting the requirements of the Nuclear Waste Policy Act and the Mission Plan (DOE, 1985, DOE/RW-0005, Vol. I). The DOE has developed a modeling system that may be used in evaluating repository impacts. This model has six major components: an economic module, a demographic module, and an economic-demographic interface module, a residential allocation module, a community service requirements module, and a fiscal module.

The modeling system projects demographic and economic changes. In addition, the residential allocation module distributes new residents to communities near the site. Community service and fiscal impacts are then evaluated for communities receiving new population. A social assessment methodology will be used to analyze social impacts.

For the impact assessment activities, site and area visits would be made to verify existing data and to collect additional data. The types of data to be collected and data sources are listed below:

Economic

- Employment: by industrial group and occupation - Census data, Bureau of Economic Analysis, State and regional planning agencies

- Income: per capita, family - Census data, Bureau of Economic Analysis

- Economic trends and projections - Bureau of Economic Analysis, State and regional planning agencies

- Land uses: current and projections - State, regional, local planning offices, field surveys

- Sales: by industry, trade patterns - Bureau of Economic Analysis, State and regional planning agencies

- Planning regulations - State and local agencies

- Input - Output coefficients - State economic and planning agencies, research institutions.

Demographic

- Total population trends - Census data and estimates

- Age, sex, race-ethnicity of population - Census data

- Birth, death, migration trends - Census data, State health department

- Characteristics of families and households - Census data

- Nonresident, temporary population - Local and regional planning agencies, State and Federal park service

- Population by type of urban center - Census data, local and regional planning agencies

- Population density - Census data and local surveys.

Fiscal

- Tax revenues: type and jurisdiction - State revenue department

- Assessed valuation: rate and jurisdiction - State revenue department, local assessor's office

- Federal and State revenue distribution - State revenue department, local and regional planning agencies, local treasurer's office

- Government expenditures: types and trends - State revenue department, local government offices

- Bonding status and capacity - Local governments.

Community Service

- Housing units, type, condition, vacancy - Census of housing, State, and regional planning agencies

- Education: enrollment, school capacity - State department of education, local school districts

- Medical and mental health services - State health departments, department of human resources, National Center for Health Statistics

- Law enforcement - State police, county sheriff, and local police offices

- Fire protection - State fire marshall and local stations

- Water supply, wastewater treatment, and solid waste - Environmental Protection Agency, State health department, and community governments

- Transportation - State transportation department, community government

- Recreation services - State recreation agency, local and regional planning agencies.

Social

- Community organizatons: type and size - Community agencies

- Community leadership - Community sources

- Government organization and activity - Community leaders

- Attitudes, perceptions of community concerning repository development, economic development, community growth and change discussion and interviews with community leaders and citizens

- Local cultural heritage - Local historical society and other agencies

- Social disorganization: types and incidence of crimes - State and local crime reports

- Social services: State department of human resources and local offices.

These activities will occur during the first 2 years of site characterization, and 4 staff persons would be in the site area periodically for 2 weeks at a time. Impact-monitoring activities will also occur throughout site characterization. Impact monitoring involves periodic field visits to collect data and analyze key indicators of local economic and social change. Some indicators that will be analyzed in communities and countries projected to receive new residents include project information and community information.

The kind of project information that will be required during site characterization can be divided into project worker characteristics and project purchases:

1. Project worker characteristics, such as family size, housing needs, number of school-age children present and marital status, changes in the scheduling of the project and worker settlement patterns will be monitored. These factors will affect the number of persons that will be present in any community and affect the demands on community services.

2. Project purchases will be monitored during site characterization. The magnitude of project purchases during site characterization will affect the local economy and be related to the number of secondary jobs created. To obtain this data, project purchase orders could be sorted out by purchase location.

Community information which may be required during site characterization can be divided into indicators of the economic, demographic, land use, community service, social, and fiscal conditions. The factors to be monitored will be keyed to impacts identified in Section 4.2.2. The staff involved in collecting impact data will also participate in the monitoring effort.

Monitoring reports will be prepared for quarterly project reports and semiannual community reports.

If impact mitigation activities are required during site characterization, area visits will be conducted to discuss mitigation measures with project management, State and local officials, and public groups.

4.1.3.3 Land Acquisition

The land within the Davis Canyon site consists of approximately 92 percent Federal land managed by the Bureau of Land Management (BLM), 4 percent private land, and 4 percent State land. No lands owned by the DOE are located in the vicinity of the site.

The DOE expects to commence land acquisition for the site characterization program, following Presidential approval of recommended sites. The exploratory shaft site will require approximately 24 hectares (59 acres). The DOE will enter into a cooperative agreement with the BLM to obtain access for the exploratory shaft facility (ESF) and to conduct field studies on public land. The DOE will purchase or lease private and State-owned land needed to conduct field studies.

Land protection is necessary to prevent uncontrolled human activities which could affect the licensibility of the proposed site as a repository. On a technically conservative basis, a minimum of 4,060 acres was recommended for protection (Chen and Raines, 1985). Because the DOE will not know precisely what and how much land will be needed for a repository site until site characterization studies are completed, and data collected in those studies are evaluated, the DOE plans to protect a larger area. A 2,331 hectare (5,760 acre) sized protected area was uniformly used for all bedded salt sites. (See Section 5.1.1.5). Preliminary analyses indicate that a site area of this size would allow all EPA and NRC repository performance requirements to be met (see Sections 6.3 and 6.4). The DOE will protect private and State-owned land by purchasing or leasing surface and subsurface rights or by acquiring some lesser interest that adequately protects the proposed site. The DOE may grant the surface owner(s) the right to continue their present activities. Some activities on the land would require the prior approval of the DOE. The DOE will protect public land by administrative withdrawal from BLM and cooperative agreement should greater than 2,024 hectares (5,000 acres) require protection. For BLM lands, most surface activities could continue during site characterization.

The DOE expects to conduct some site characterization activities outside the protected area. These activities may include drilling boreholes, conducting seismic surveys, and performing other studies (see Table 4-2). The DOE plans to obtain right-of-way, right-of-entry, and lease or purchase agreements for parcels of State lands, and purchase, lease, or easement agreements for private lands. For Federal land, the DOE would obtain the required use authorizations from the BLM.

In the area immediately surrounding the exploratory shaft facility (ESF), the DOE will conduct intensive activities for a period of more than two years. These activities are described in Section 4.1. Because of the presence in this area of large numbers of drill rigs, other equipment, and personnel, the DOE will establish a buffer area of approximately 120 to 150 meters (400 to 500 feet) beyond the "repository surface facility" area (Figure 4-2). This area, including the ESF and repository surface facility areas, is approximately 200 to 240 hectares (500 to 600 acres), and has been designated as a limited-access area to ensure the safety of project personnel and the general public and to enhance the security of supplies and equipment. The DOE will acquire appropriate interests in this land. The limited-access area will be suitably marked.

Land requirements also include an access roadway. For more information on land requirements see Section 4.1.2.1. During the site characterization phase, only the area encompassed by the exploratory shaft activities will be fully restricted. Access to Canyonlands National Park through Davis Canyon may be inconvenienced but not prohibited. The DOE plans to allow surface-oriented activities such as grazing and surface exploration during site characterization, insofar as those activities do not interfere with the site characterization activities. As the DOE acquires mineral rights, the opportunity for individuals to conduct subsurface explorations will cease.

4.2 EXPECTED EFFECTS OF SITE CHARACTERIZATION

This section describes the environmental, socioeconomic, and public health and safety effects expected to result from the site characterization activities discussed in Section 4.1. These effects were determined by comparing specific site characterization activities with information on local environmental conditions presented in Chapter 3.

This description of site characterization effects is divided into two subsections. Effects on the physical environment are presented in Section 4.2.1. The discussion of the effects for each discipline generally follows the order of the site characterization activities presented in Section 4.1 (i.e., field studies [Section 4.1.1], exploratory shaft facility development [Section 4.1.2], and other activities [Section 4.1.3]). Both beneficial and adverse effects are discussed.

4.2.1 Expected Effects on the Natural Environment

This section describes the expected effects of site characterization activities on various components of the physical environment, including land and mineral resources; terrestrial and aquatic ecosystems; air quality; surface- and ground-water quality and availability; soils; noise; aesthetics; archaeological, cultural, and historical resources; radiological levels; and transportation and utilities.

4.2.1.1 Effects on Land Use and Mineral Resources

The Davis Canyon site and vicinity consists of public, State, and private lands (Section 3.4.1). Principal land uses are cattle grazing, mineral and hydrocarbon exploration, recreation, and other limited agricultural uses. Land acquisition procedures are discussed in Section 4.1.3.3.

The Federal Land Policy and Management Act (FLPMA) (1976, 43 USC Sections 1701-1782) establishes procedures for Federal departments and agencies to use, occupy, and develop public lands administered by the U.S. Department of the Interior (DOI). In using this area, the DOE will cause a change in land use because multiple resource uses be replaced by site characterization activities, and oil, gas, and other mineral leases will be extinguished.

The impacts of these changes will be minimal. The change in land use must be viewed in light of the fact that the area has been classified by BLM for multiple use (BLM, 1982c). Moreover, as discussed below, land impacts will be minimized and the land will be restored to its original condition to the extent feasible. The impacts on mineral and hydrocarbon leaseholders will result in a loss of exploration and development rights. Within the site vicinity there are 24 oil and gas leases on Federal property (WCC, 1985). The impacts of the extinguishing of these leases will be offset through compensation for mineral and oil and gas leases acquired. Procedures for withdrawal of land by the DOE will be made in accordance with FLPMA and corresponding regulations. A summary of the requisite procedure is set out in Section 6.2.1.6 (Table 6-2). Federal Register publication of the withdrawal application will result in the segregation (removal of the area from operation of the public land laws, including mining laws) of this land during site characterization. Granting the withdrawal will result in removal of public land from the jurisdiction of public land laws for the period of characterization; only a small portion of this land would actually be disturbed.

During the site characterization phase, the areas encompassed by the exploratory shaft facility and nearby geotechnical and environmental activities will be restricted. Access to Canyonlands National Park through Davis Canyon may be slightly altered, but not prohibited. The DOE plans to allow surface-oriented activities such as grazing to the extent that these activities do not interfere with site characterization activities. As the DOE acquires mineral rights (Section 4.1.3.3) and oil and gas leases, the opportunity to conduct subsurface explorations will cease.

4.2.1.1.1 Geotechnical Field Studies. Potential land-use effects from field study activities (e.g., drilling deep and shallow boreholes, trenching, and laying seismic lines)

will be short term. The duration of these activities is described in Section 4.1.1.1. Approximately 243 hectares (600 acres) will be disturbed as a result of geotechnical field activities (Table 4-2). The largest amount of land (154 hectares [380 acres]) would be required for three-dimensional seismic reflection study and regional seismic studies. Existing roads and trails will be used where possible. There may be a temporary disruption of grazing adjacent to the lines for 1 or 2 days.

Temporary access roads to the geotechnical sites will be constructed, where necessary (Section 4.1.1, Figure 4-2, Figure 4-3). Standard BLM procedures will be followed to minimize erosion and siltation during access road construction. Access for geological and environmental field studies will be provided, to the extent possible, by existing roads and trails. Ease of access to Newspaper Rock State Historical Monument will be temporarily disrupted to a minor extent. There will be an increase in traffic on Utah 211, as discussed in Section 4.2.1.10. In order to minimize possible traffic congestion around Newspaper Rock State Historical Monument, alternatives such as busing of workers and traffic control will be considered. Another potential alternative measure being considered is the construction of a bypass around the Monument as discussed in Section 4.3.5. Requirements under the National Historic Preservation Act (16 USC Sections 470-470w-6) are addressed in Section 4.2.1.8.

During foundation borehole drilling, a truck-mounted rig will need to drill about 450 locations on a grid in the area prepared for surface facilities. The activities will create surface disturbance over the proposed repository surface facility area. However, little site preparation is required and existing access roads will be used where possible.

Land disturbance during the 2 months of trenching activity (Section 4.1.1.8.) will result from site clearing, mixing excavated material and topsoil, and filling trench. Upon completion of trenching, the trench will be filled, the fill compacted, and the site restored.

Impacts will occur to livestock grazing in the vicinity of drilling and trenching and near the new road corridors. The noise and movement of workers and equipment (at the site, as well as to and from the work site) could be disruptive enough to keep livestock away from the vicinity. Land clearing and disturbances caused by constructing new access roads, drill pads, and a test trench will temporarily disrupt all or most of the forage on these sites. This will eliminate or decrease the use of these sites for livestock grazing until usable forage is reestablished through artificial methods (seeding) or through natural plant succession. Geophysical activity and rehabilitation of the disturbed property will follow procedures established by the BLM for geophysical exploration on public lands in the San Juan Resource Area (Nodine, 1985).

As stated in Section 3.4.1.3, average forage production in Davis Canyon is estimated to be 5.2 hectares (13 acres) of rangeland per animal-unit month (AUM). Assuming this same rate of production for all areas disturbed for the field studies (243 hectares [600 acres]), 37 to 46 AUMs of forage will be temporarily lost. This will represent less than 10 percent of the estimated 500 AUMs in Davis Canyon. Hence, a significant reduction in grazing is not expected. If surface uses of the entire protected area are precluded, grazing would be substantially reduced. Since the Davis Canyon site is located in the BLM grazing allotment, the DOE will review with the BLM, pursuant to the Taylor Grazing Act (43 USC Sections 315-316), any grazing plans in light of site characterization activities.

The field activities with the potential to interfere with mineral resources exploration and development are the engineering design borehole (EDBH), other deep boreholes (Table 4-2), test trenches, test pits, and atmospheric monitoring stations. Nearly every location for these activities is currently under State or Federal leases for oil and gas exploration (BLM, 1982c, p. 67).

Since the BLM Indian Creek-Dry Valley Management Framework Plan (43 CFR Part 1610) is currently being updated (expected completion, 1987, Section 3.4.1.3), the DOE will continue to consult with the BLM regarding site characterization activities on BLM lands. The proposed activities are considered compatible with the San Juan County Master Plan which zones the area for mining, grazing, and recreation (Section 3.4.1). The impacts on the Canyonlands General

Management Plan and the Statement for Management of the National Park Service are discussed in Section 4.2.1.1.3.

4.2.1.1.2 Exploratory Shaft Facility (ESF). As discussed in Section 4.1.2, exploratory shaft drilling will occupy approximately 24 hectares (59 acres). In addition, about 14.2 hectares (35.0 acres) of land will be needed for new access roads.

The primary land-use impact from these activities will be disturbance to livestock grazing in the vicinity of the drilling and testing site. Land clearing and other disturbances will clear all or most of the forage on the site. However, the total land disturbance will be minimal since a relatively small portion of the grazing allotment will be affected. Assuming 5.2 hectares (13 acres) of rangeland per AUM, about 4.5 AUMs per year will be lost. This will represent about 0.9 percent of current grazing use (Section 3.4.1.3.1). Also, as discussed in Section 4.2.1.11.2, wind dispersion of salt is not expected to reduce the grazing potential or productivity of the area. However, road corridor construction will be temporarily disruptive to normal cattle foraging in the immediate area. The roadway will be constructed to minimize unnecessary removal of vegetation (see Section 4.1.2.2.1).

Following site characterization, if the site is not selected for a repository, the DOE intends to restore the exploratory shaft site to near its original natural condition in accordance with BLM procedures. Restoration plans to be developed by the DOE will include soil protection, and specifications on the type and quantity of plant species to be seeded (see Section 4.2.1.5).

Evaluation of mineral resources in the affected area (including interpretation of exploration data and projections of geologic information) indicates that the potential for commercial resource discoveries is relatively low (Section 3.2.8). Uranimum exploration has been limited to small prospects in the Cutler and Chinle Formations, and there is no current commercial production of oil, gas, or potash. This indicates that there will be minimal impact on these activities.

As indicated in Section 4.1.2.4, disposal of nonhazardous solid wastes, composed of residues from the evaporation of fresh water and brine drilling fluids, salt-contaminated runoff, and salt-contaminated and nonsalt-contaminated excavated materials and waste salt, can all be accommodated by existing EPA-approved landfills located at either Grand Junction, Colorado, or Farmington, New Mexico, (Smith, 1984; Downs, 1985; Alkema, 1985; Haun, 1985; Sands, 1984; McCutchen, 1985) (see Section 4.2.1.11).

The effects of disposal of the material to an offsite landfill could include (1) a decrease in the design life of the landfill facility; (2) a potential for land-use conflicts if additional space is required; and (3) concern over long-term integrity of the landfill with respect to erosion, ground-water infiltration and subsequent leaching of salt, and potential surface- and ground-water contamination. While these effects could occur in a poorly sited and designed landfill, operators of the previously mentioned landfills have indicated that their facilities will have the necessary permits and sufficient capacity at the time of disposal to handle the expected types and amounts of solid wastes generated during site characterization (Smith, 1984; Downs, 1985; Alkema, 1985; Haun, 1985; Sands, 1984; McCutchen, 1985). Therefore, potential impacts occurring at the disposal sites are not expected to be of major concern from a land-use and environmental standpoint.

Transport of salt and salt-contaminated materials by truck is not expected to affect land uses along the routes because existing roads will be used and the vehicles will be covered (Section 4.2.1.11).

4.2.1.1.3 Canyonlands National Park Impacts. Site characterization activities such as borehole drilling and trenching will not occur within the boundaries of the Canyonlands National Park.

The objectives of the General Management Plan (NPS, 1978) and the Statement of Management for Canyonlands National Park are described in Section 3.4.1. These documents have as a key

objective the preservation and protection of the natural resources of the Canyonlands National Park in a manner which minimizes the adverse impacts of human activities. In particular, the Needles district, which is adjacent to the Davis Canyon site, is being managed to provide for a wide range of interpretive and recreational activities, focusing principally on hiking and four-wheel drive vehicles. A specific objective of the management plan is to provide efficient access to the park and facilitate circulation within the park via two- and four-wheel drive roads, as well as by other means.

Another potential conflict with the park management plan may occur due to potential increase in the use of park wilderness and recreation areas. This will principally occur within the Needles district of the park. As indicated in Section 4.2.1.1.1, it is impossible to estimate how many visitors to the site or characterization workers and their families will visit the park. As a point of reference (see Section 3.6.2.4) in 1981, 42,100 persons visited the Needles District. During site characterization, it is estimated that 787 individuals will in-migrate to the area (Section 4.2.2). It appears that the potential land-use impact will be insignificant, even if many of the in-migrants visit the park frequently. Another potential conflict may arise from the illegal use of off-road vehicles. This is difficult to accurately predict; however, the impact is expected to be small.

Similar land-use considerations and conclusions are directly relevant to both the Organic Act of the National Park Service and the Wilderness Act (16 USC Sections 1131-1136) (see Table 6-2). Portions of Canyonlands National Park and nearby areas have been proposed as wilderness areas. No disruptive exploratory activities will be conducted within the park, and no direct land-use changes on the park will occur. With regard to indirect impacts, proposed characterization activities are not expected to be significant enough to have adverse impacts on the proposed wilderness areas because they are sufficiently remote that use by project personnel and in-migrants will be minimal. As described above in Section 4.2.1.1 under the Federal Land Policy and Management Act of 1976 (FLPMA), portions of the areas surrounding the park, which is located primarily on BLM land, will experience a change in land status due to proposed site characterization activities.

Additional analyses on the impacts resulting from other factors relating to air quality, noise, aesthetics, ecosystems, and tourism and recreational experiences are discussed in Sections 4.2.1.3, 4.2.1.6, 4.2.1.7, 4.2.1.2, and 4.4.1, respectively. The DOE will continue to consult with the National Park Service to minimize, to the extent possible, any impacts to the park that would conflict with its objectives as stated in the Statement for Management and General Management Plan.

4.2.1.1.4 Environmental Field Studies. Small amounts (less than 1 hectare [2.5 acres]) of land will be used for land-disturbing environmental studies (Section 4.1.3). These studies are expected to have insignificant effects on land use in the area. The environmental field study which will require the largest amount of land is the air quality study. The meteorological tower will require approximately 0.4 hectare (1.0 acre) of land and access of approximately 8 kilometers (5 miles).

4.2.1.1.5 Cumulative and Long-Term Effects on Land Use. No significant cumulative and long-term impacts on land use are expected. All of the impacts due to site characterization will be localized. Furthermore, all disturbed land will be restored as nearly as possible to its original condition, which will be accomplished through the reclamation measures described in Sections 4.1.1, 4.1.2, and 4.2.1.5. The deep-aquifer hydronests (Section 4.1.1) will leave 15 well heads. The DOE will maintain access rights to all deep hydrologic well sites during the site characterization period. This could disrupt some localized land use in the future.

The specific land-use impacts attributable to site characterization include the following:

- Extinguishing of mineral, oil, and gas leases for which appropriate compensation will be provided
- Temporary and localized loss of vegetative cover, which will have a minor impact on grazing

- Temporary inconvenience with respect to access to Canyonlands National Park and Newspaper Rock State Historical Monument.

4.2.1.2 Effects on Terrestrial and Aquatic Ecosystems

The impacts that may occur to local biota (Section 3.4.2; BGI, 1982, ONWI-144; 1983, ONWI-469; BLM, 1982c) due to site characterization activities, which include field studies (Section 4.1.1), exploratory shaft (Section 4.1.2), and other studies (Section 4.1.3), are addressed below.

4.2.1.2.1 Geotechnical Field Studies. Approximately 243 hectares (600 acres) will be disturbed for the field studies (Section 4.1.1). Field studies concerned with geologic and hydrogeologic characterizations and shallow soil and rock profiles will produce varying degrees of surface disturbance for site preparation and site access. Direct impacts to vegetation will result from clearing surface plants and surface grading at borehole test sites, the proposed deep borehole sites, and the test trench. Some limited clearing of vegetation may also occur during seismic surveys. Environmental effects on vegetation would be minimized by using existing roadways wherever possible, by clearing, grading, and filling only to the extent necessary, and by prohibiting indiscriminate driving over the terrain.

Two species of protected plants, listed as endangered (*Echinocereus triglochidiatus* var. *inermis*) and threatened (*Sclerocactus glaucus*) under the Endangered Species Act of 1973 (16 USC Sections 1531-1543), may be present in the vicinity of the field study sites. Site clearance studies at each of the proposed test sites would have to be conducted prior to any site disturbance. If the presence of these species is confirmed, the DOE will continue consultation with the Fish and Wildlife Service (FWS) to establish appropriate measures for avoiding any adverse impacts to the extent possible. Such measures may include moving the site or modifying the proposed activity.

Impacts to wildlife resulting from field studies in Davis Canyon are also not expected to be significant, because only minor and temporary displacement of small mammals and birds from the immediate vicinity of drilling activities would occur. Following the completion of field studies and restoration of all disturbed sites, wildlife would return to the area.

Some of the geologic and other studies performed outside of Davis Canyon may impact some wildlife species during certain seasons. These activities include borehole drilling south of Newspaper Rock State Historical Monument. This site is approximately 1 kilometer (0.6 mile) from a golden eagle nest. However, if a 0.8-kilometer (0.5-mile) buffer was maintained during critical periods (April 15 to June 15), then the nest is not expected to be abandoned by the eagle as a result of this activity (UDWR, 1979, p. 12). A similar buffer can be placed around the golden eagle nest in Lockhart Basin. The nest site, shown on Figure 3-69, is approximately 1.5 kilometers (2.5 miles) from Lockhart Basin geohydrologic hole #1.

A planned deep-aquifer hydro-nest (borehole) drilling operation in Lavender Canyon is located about 2.4 kilometers (1.5 miles) east of a golden eagle nest on Lavender Mesa. Nesting success probably will not be adversely affected because of the 2.4-kilometer (1.5-mile) distance from the disturbance, the height of the nesting cliff, and the tolerance golden eagles have for mining and other industrial activities in the region. Construction of the access road to this drill site may disturb the birds during nesting season; use of the road for well monitoring should not provide any additional level of disturbance. Measures will be developed in consultation with the Department of Interior to minimize adverse impacts pursuant to the Bald and Golden Eagle Protection Act (16 USC Sections 668-668d).

Peregrine falcons, an endangered species protected under the Endangered Species Act of 1973 (16 USC Sections 1531-1543), are known to nest in the region (see Section 3.4.2.3 and Figure 3-69). The nearest known eyrie is approximately 13 kilometers (8 miles) from any proposed field study location. Although it is unlikely that any nesting habitat will be adversely affected, impacts due to project noise or the increased human presence in the region may disturb the birds or affect foraging habitat. The endangered bald eagle is another species that may be affected by project activities. Bald eagles have established winter

roosts which may be disturbed by increased levels of noise or human presence. The nearest roost area is approximately 3 kilometers (2 miles) from any project activity. As indicated above, the DOE will continue consultation with the FWS and establish acceptable measures to avoid adverse impacts to these sensitive species. Scheduling activities which avoid critical times during the species life cycles may prove successful in the cases of the two species.

Low-density, bighorn sheep range is present in Lockhart Basin near the planned locations of two geohydrologic boreholes. Because very few animals would be affected and because drilling operations will be concluded within 12 months, impacts to the area-wide expanding sheep population will not be significant.

Small mammals and reptiles will be subject to limited mortality in all disturbed areas. Secondary impacts to wildlife may result from increases in poaching, harassment, off-road recreational vehicle activities, and other recreational uses of lands in the project area. Noise, lights, and increased human activity in the area may impact some wildlife. The DOE will continue to consult with the BLM, the FWS, and the Utah Division of Fish and Game.

Approximately 180 kilometers (112 miles) of seismic reflection survey lines, 3.2 kilometers (2.0 miles) of refraction survey lines, and a 26-square-kilometer (10-square-mile) grid for three-dimensional seismic survey lines will be established. Truck-mounted vibrators or explosive charges will be the energy source. Surveys will take 8 months to complete, and many of the test sites will be along established roadways. In running the survey lines, some vegetation will be damaged by the use of heavy trucks, particularly if the surveys run in straight lines with little deviation. The survey lines will be walked prior to disturbance to determine the presence of any rare or protected species of plant, such as those discussed above and in Table 3-30. If such plants are found in the vicinity, the DOE will consult with the FWS and establish appropriate measures to avoid impacts to the plants and their habitat.

Impacts to wildlife from all seismic surveys will occur only for the duration of the surveys (expected to be about 11 months). Truck noises and the use of explosives will be disturbing to most species of wildlife. Wildlife will avoid the test areas while crews are present, resulting in a temporary loss of foraging habitat. Surveys will be scheduled in cooperation with the FWS to avoid the loss of migratory birds, their nests, and eggs under the Migratory Bird Treaty Act (16 USC Sections 703-711). Surveys will, if possible, avoid areas frequented by endangered peregrine falcons and bald eagles and important species such as mule deer, pronghorn antelope, and desert bighorn sheep. The DOE will consult with the FWS, the BLM, and the Utah Division of Fish and Game in order to establish optimal times to conduct surveys. Surveys will be conducted so as to avoid habitat destruction, important habitats, and critical times during the species' life cycles.

Following the completion of field studies, all sites not selected for repository development would be decommissioned, restored to pre-existing contours, and revegetated according to BLM specifications. More specific details of site rehabilitation can be found in Section 4.2.1.5, which incorporates the major elements of the BLM specifications.

4.2.1.2.2 Exploratory Shaft Construction and Operation. Approximately 24 hectares (59 acres) would be cleared for the exploratory shaft facility (ESF) (Section 4.1.2). Construction of an ESF in Davis Canyon will result in certain unavoidable impacts to the local desert shrub ecosystem. As described in the following section, these impacts will not be significant, in part because of the low-level disturbances associated with site characterization activity, as well as the low density of important species in the region containing the site (see Section 3.4.2) The affected desert shrub ecosystem is not unique to the area (BNI, 1985a), and Davis Canyon does not contain sensitive wetlands (Johnson, 1984). Designated critical habitat does not exist in the project area (Johnson, 1985).

Direct impacts to the galleta-shadscale plant community will occur in Davis Canyon from clearing and grading activities during site preparation. Clearing and grading will be limited to that which is essential for construction and operation of facility components. Unauthorized off-road traffic will not be permitted. These would cause changes in vegetative cover composition and frequency of plant species. Also certain plant species (e.g., cactus)

within walking distance of highways, roads, and facilities could be selectively removed by collectors.

Wildlife (e.g., highly mobile birds and larger mammals) in the project area and along the access road will shift to adjoining desert shrub habitats during site preparations. Increases in competition for food and cover may occur between emigrating and resident populations, which will result in some mortality if carrying capacities of adjacent habitats are exceeded. If disturbed by the increased noise and human presence, the estimated 10 to 15 overwintering mule deer in Davis Canyon will move to another area. The BLM, however, does not consider Davis Canyon to be a crucial deer winter range (Sandberg and McClure, 1983). Any site characterization activities planned in crucial deer winter ranges outside of Davis Canyon can be scheduled to avoid disturbance to winter herds.

Secondary impacts to wildlife may result from increases in poaching, harassment, off-road recreational vehicle activities, and other recreational uses of lands in the project area. Noise, lights, dust, and increased human presence in the area may also affect some wildlife, particularly sensitive species like raptors and gamebirds. If potential impacts to migratory birds occur, appropriate mitigative measures will be developed in consultation with the DOI pursuant to the Migratory Bird Treaty Act (16 USC Sections 703-711).

Currently, no federally designated threatened or endangered species are known to reside in Davis Canyon, although studies by the project and the FWS show that several threatened or endangered species are known to occur in the Gibson Dome region (BGI, 1983, ONWI-470; England, 1983). In addition, there are no federally designated critical habitats in the Davis Canyon Area. Peregrine falcons currently nest approximately 16 kilometers (10 miles) from the Davis Canyon site, and bald eagles winter along the Colorado River about 24 kilometers (15 miles) from the Davis Canyon site. No disturbance or depletion of endangered bald eagle or peregrine falcon populations is likely to result from the proposed activities, because no known roosts or breeding areas lie within 3.2 kilometers (2 miles) of the Davis Canyon site (BGI, 1982, ONWI-144, p. 126; BLM, 1982a, p. 61). Should future studies produce evidence of threatened and endangered species, the FWS will be consulted under the Endangered Species Act of 1973 (16 USC Sections 1531-1543) to assist the DOE in modifying site activities or locations to avoid adverse impacts.

Some small mammals and reptiles will be destroyed during site clearing. The minor losses in prey populations would not create a problem for raptors, because only a small portion of the total available prey base would be affected by ESF activities.

Fences or cattle guards, which are erected for safety and security of the facility, will also minimize impacts on wildlife and livestock. No firearms will be permitted in contractor vehicles or on site. Hunting or discharge of firearms will be prohibited in the drill areas, and harassment or capture of wildlife and domestic livestock will not be permitted.

Plant stress or reduced productivity both on and off site could result from erosion of soil and from deposition of salt due to onsite handling and storage. Dust suppression, prevention of soil erosion, and soil restoration are discussed in detail in Section 5.2.1.1. These measures will effectively eliminate adverse impacts due to blowing dust.

Section 4.2.1.11.3 addresses the ecological effects of increased salt levels resulting from mining, handling, storing, and transporting excavated salt. Salt in sufficiently high quantities can reduce plant productivity either indirectly from excess accumulation of salt in the soil, or direct from deposition of salt on the foliage. Any reductions to plant productivity result in a subsequent reduction in habitat carrying capacity.

During the ESF program, approximately 137,000 cubic meters (180,000 cubic yards) of salt and salt-contaminated rock will be generated. This will be stored in a 2-hectare (5-acre) pile approximately 9 meters (30 feet) high. Any saline runoff will be contained within a 1.8-hectare (4.4-acre) evaporation and retention pond designed to prevent any runoff from getting into any local drainages. Ditches will convey any saline runoff to a lined evaporation and retention pond. This pond will be designed to contain the runoff generated by a 500-year,

24-hour rainfall event and to take advantage of the high evaporation rates in the region. Any remaining brine will be disposed off site in an acceptable manner.

Control of salt dust and the natural crusting characteristic of piled salt will limit deposition of airborne salt to a maximum of 1.0 kilogram per hectare (0.9 pound per acre) at less than 0.8 kilometer (0.5 mile) from the source. Deposition falls off rapidly from that point. Soils in the area are already fairly alkaline, and the galleta-shadscale vegetation is known to be tolerant to elevated salt concentrations. Since the results of salt deposition modeling discussed in Section 4.2.1.3 indicate that salt concentrations reaching beyond the ESF will be extremely small, salt is not expected to accumulate in soils, vegetation, or herbivores in the immediate area. Any accumulations which may occur during winter or dry months will not elevate current salt concentrations in either the Indian Creek or the Colorado River drainages.

The presence of a 60-meter (197-foot) meteorological tower and a 38-meter (125-foot) ESF shaft headframe may be hazardous to birds during migration or during low-visibility conditions. Collisions may be avoided by the installation of warning devices such as lighting or horns.

4.2.1.2.3 Other Activities. Impacts from environmental baseline studies are expected to be relatively insignificant to ecological resources of the site and surrounding areas. Field studies may require collection of voucher specimens of plants and animals, tissue samples for productivity and radiological critical path studies, and soil sampling. Removal of small numbers of individual organisms will not significantly affect regional populations, and none of these field studies will entail major habitat modifications.

Other environmental field studies will have varying effects on the site ecosystem. Most disturbances will involve field crews conducting soil, noise, or land-use surveys, although it is expected that any effects will be minor and very short term. The construction and operation of a 60-meter (197-foot) meteorological tower will require some site disturbance. The most significant impact of this activity will be the potential for birds to fly into the tower during periods of low visibility. Such impacts could be mitigated by installing warning devices such as lighting and horns.

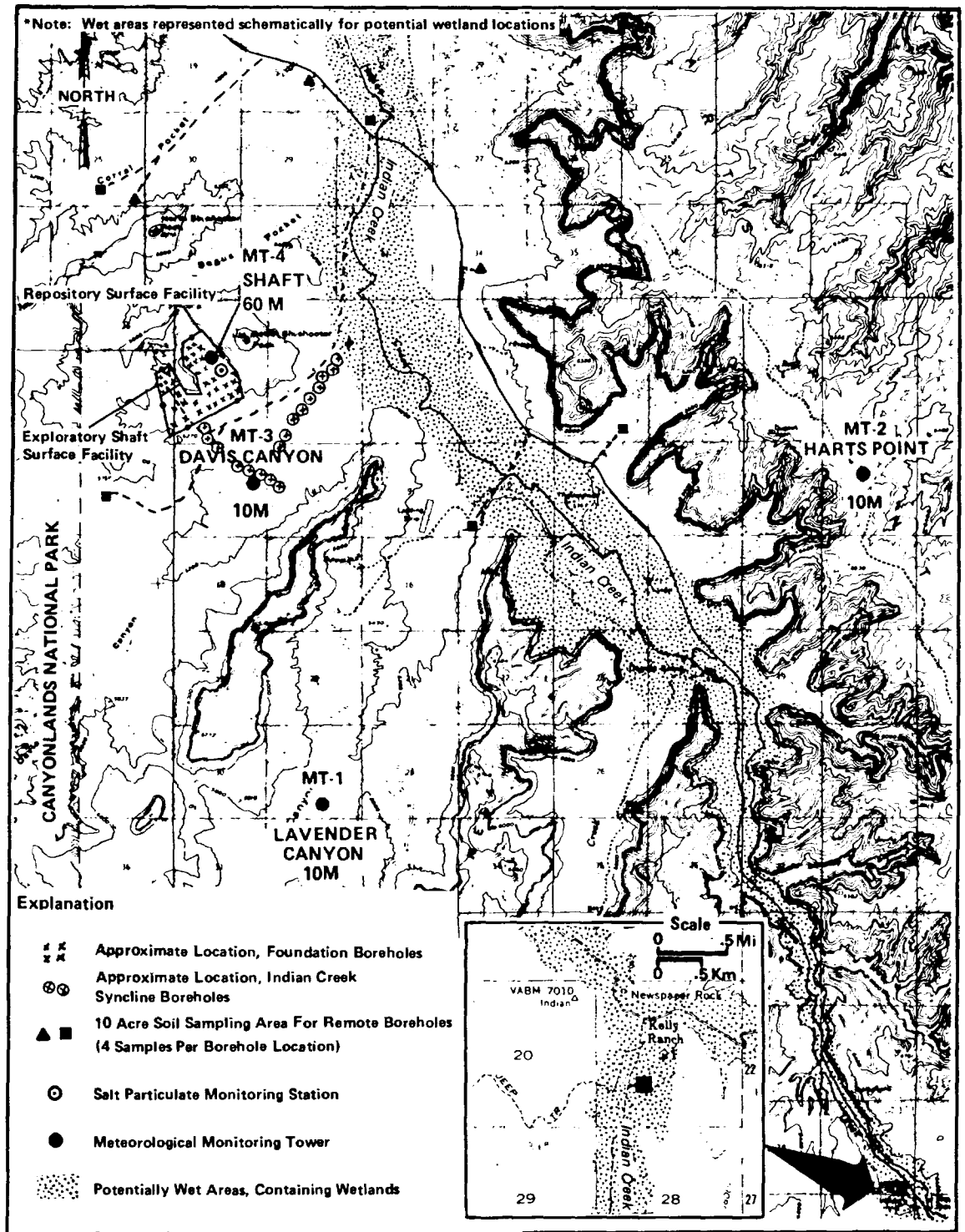
4.2.1.2.4 Effects on Floodplains and Wetlands.

Description of Floodplains and Wetlands. Floodplains in the project area occur as flat lowlands adjoining the larger drainages such as Indian Creek, Cottonwood Creek, and the Colorado River. These are shown as potentially wet areas containing wetlands on Figure 4-22. Flash flooding along Indian and Cottonwood Creeks occurs infrequently in response to local storm events. Vegetation occurring in floodplains in Davis Canyon is typical of the galleta-shadscale plant community (Section 3.4.2.1.1, Table 3-28). Along Indian Creek and the Colorado River riparian vegetation is also present (see below).

Wetlands are not common in the Davis Canyon area, but do occur as narrow riparian zones along Indian Creek, and some upper reaches of various desert washes. These wetlands can be classified under the FWS system (Cowardin et al., 1979) as follows:

- Riverine, upper and lower perennial, rock bottom
- Riverine, lower perennial, sand bottom
- Riverine, intermittent, sand or streambed.

These riparian zones are very important to wildlife in the area, as they supply crucial breeding, foraging, roosting, and cover habitat not found elsewhere in the region (BNI, 1984b). The typical vegetation of these riparian zones includes Fremont cottonwood, sandbar willow, salt cedar, greasewood, big sagebrush, and several other species (BGI, 1983, ONWI-469). Important species of wildlife which frequent riparian zones in the area include mule deer, bighorn sheep, pronghorn antelope, bald eagle, peregrine falcon, and waterfowl. Yellowstone cutthroat trout occur in the upper reaches (above Shay Canyon) of Indian Creek (BNI, 1984b).



Source: Modified from USGS, 1968

Potentially Wet Areas Containing Wetlands, Davis Canyon Site

Figure 4-22

Description of the Proposed Action. The principal land-disturbing activities occurring during site characterization which could impact floodplains and wetlands include: construction and operation of the exploratory shaft facility, multiple-aquifer hydro-nests, access roads, seismic refraction surveys, air quality and meteorological monitoring, and various foundation and other drilling efforts. Descriptions and locations of these activities appear in Section 4.1.1 and 4.1.2. The locations of some borehole and drilling sites and their access roads are somewhat flexible and may be moved within limits, as required. The proposed Shay Graben deep-hydro hole #1 is located about 91 meters (300 feet) from Indian Creek in the Kelly Ranch area. This site will be 1.6 hectares (4 acres) in size and drilling operations will last 6 months. Deep-hydro-nest #5 at the mouth of Lavender Canyon is located approximately 0.4 kilometer (0.25 mile) from Lavender Creek and will require access across Indian Creek. This drilling operation will require 5 hectares (12 acres) and 6 months of operating time. Finally, access to the ESF will run immediately adjacent to the Davis Canyon wash.

Construction and operation of the ESF will generate approximately 137,000 cubic meters (180,000 cubic yards) of salt and salt-contaminated rock. After being mined, the salt will be stockpiled on the surface for the duration of the program. The lined pile is expected to crust by natural means or by wetting. Runoff from the pile will be directed via a system of drainage ditches to a double-lined evaporation and retention pond.

Approximately 276 acre-feet (89.9 million gallons) of water will be required during site characterization and will be obtained from local or regional suppliers.

Effect of the Proposed Actions on Floodplains and Wetlands. The extent of the 100-year floodplain at the Davis Canyon site is shown in Figure 3-51. Access to the main ESF will require some modification of the Davis Canyon wash and floodplain. Road construction and upgrading will be consistent with good engineering and construction practices to ensure the structural integrity of the roadbed and safety of project personnel and equipment. Where necessary to contain potential flash flooding and minimize damage to the roadbed, such drainage control measures as drainage channels, rip rap, gabions, culverts, and levees will be employed. The road and associated drainage control features will be constructed during dry periods to reduce possible sedimentation and turbidity downstream in Indian Creek. Effective erosion control measures including revegetation will also be employed. Access routes across Indian Creek into Lavender Canyon will use similar drainage and erosion control measures, as required.

Impacts to floodplain biota will include the clearing of local vegetation adjacent to Davis Canyon wash and at the Indian Creek crossing point. No impacts to big game or other important species are expected from this limited clearing and construction within the 100-year floodplain. Increased human presence and its associated noise, light, and vibration will cause limited disturbance and displacement of wildlife from adjoining floodplain areas, although no important species are known to concentrate in Davis Canyon (Section 3.4.2). Some local siltation and and sedimentation could occur downstream of the crossing into Lavender Canyon, but no fish are known to occur in these lower reaches of Indian Creek (BLM, 1982b).

Effects on wetlands from site characterization activities should be negligible. Drilling operations planned for Lavender Canyon and near Kelly Ranch will be designed with siltation and sedimentation control structures to ensure protection of nearby riparian zones. All drilling muds, cuttings, and borings will be isolated in diked areas and disposed of off site. Sedimentation basins will be used to avoid contamination of Indian Creek and its important trout fishery (near Kelly Ranch). Salt piles at the ESF in Davis Canyon will be similarly diked, lined, and isolated from general runoff (Section 4.1.2). No measurable increase in the salinity of Indian Creek or the Colorado River will occur from wind drift or runoff of contaminated water (Section 4.2.1.12), so no adverse effects to endangered Colorado squawfish will occur. No loss of opportunity for trout fishing or hunting is expected to result from site characterization activities in floodplains and wetlands.

Mitigation Measures and Alternatives to the Proposed Actions. Mitigation of impacts to aquatic and wetland habitats will be required by the U.S. Army Corps of Engineers. In

accordance with EPA guidelines 404(b)(1) of the Clean Water Act (33 USC Sections 1251-1376), impacts to wetlands and special aquatic sites should be avoided. However, if no practical alternative exists then the development activity should be conducted in the least damaging manner. Losses to wetland and aquatic habitats that still result should be offset by mitigation through the upgrading or development of new wetland or aquatic habitats. Typical types of mitigation requirements for the activities will include the following:

- Moving borehole sites and access roads to alternative sites where wetlands or aquatic habitats do not occur
- Reconfiguration of restricted area, preliminary test shafts, permanent road and railway corridors to avoid aquatic and wetland habitats
- If no practical alternative exists for the various potential site impacts, application of best management practices to minimize impacts in each situation will be required
- If impacts occur, upgrading nearby wetland or aquatic habitats will be considered. Specific kinds and amounts of upgrading will have to be determined by using the FWS habitat evaluation procedure.

4.2.1.2.5 Cumulative and Long-Term Effects. Long-term effects to biota from site characterization activities would include a small decrease in specific vegetation, associated wildlife, and wildlife habitat in Davis Canyon. Some species of biota would be locally and temporarily affected by vegetation clearing.

If the Davis Canyon site proves unacceptable for further development as a repository, the site would be restored according to BLM standards and following consultation with appropriate Federal and State agencies. Design plans minimizing clearing, grading, and the placement of concrete during site preparation would benefit future restoration efforts. Stockpiles of excavated salt and rock would be backfilled into the shaft, and the site graded to its approximate original contour. Disturbed sites would be revegetated in accordance with BLM specifications. The selection of seed mixes, soil amendments, and other measures will depend on site-specific conditions such as elevation, slope, aspect, soil nutrients, and soil moisture. (Site restoration is discussed in detail in Section 4.2.1.5.) The BLM indicates that grasses and forbs can generally be reestablished to predisturbance density and vigor within 2 to 4 years (BLM, 1982c). Natural recovery of the galleta-shadscale plant community would be slow, but through natural reinvasion and succession, recovery should occur within 20 to 100 years (BGI, 1983, ONWI-469, p. 5-1).

4.2.1.3 Air Quality Effects

The analyses presented below are based on geotechnical and engineering data (e.g., schedules, equipment inventories, and specifications) and air and noise source terms (see BNI, 1985b, c).

Site characterization will affect air quality as a result of emissions from vehicles, drilling rigs, earthmoving equipment, turbine-driven generators, and wind-blown dust. The process of determining air quality impacts includes (1) an estimate of emissions from project activities; (2) selection of an air quality model by which air quality concentrations can be estimated from emissions; (3) meteorological data; (4) background air quality concentrations (to which estimated air quality concentrations from proposed activities must be added); and (5) an understanding of how predicted air quality concentrations may affect human health and welfare, as established by the National Ambient Air Quality Standards (NAAQS)(40 CFR Part 50) (see Table 4-18). Project-related emissions analyzed are particulates, oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO) (Emission rates derived from EPA documents such as "AP-42" are used; see BNI, 1985b for details). However, to determine compliance with the appropriate NAAQS, particulate and NO_x emissions and their impacts are examined in detail. Effects on air quality-related values (AQRVs) are also considered. Estimated short-term concentrations of SO_2 and CO, based on very conservative analyses, are

less than the respective NAAQS (BNI, 1985b). Other than their possible effects on AQRVs (Section 4.2.1.3.3), SO_2 and CO are not considered further.

4.2.1.3.1 Activities and Emissions. Site characterization activities that have the potential for producing the most emissions are associated with geologic field studies and exploratory shaft facility (ESF) construction (see Section 4.1).

Geologic Field Studies. Activities during the approximate 42-month period of geologic field studies include drilling of the following:

- Stratigraphic boreholes
- Shallow and deep hydrologic test wells
- Engineering design boreholes
- Shallow foundation boreholes.

Exploratory Shaft Facility. Activities during the approximate 30-month period of ESF construction include the following:

- Access road construction
- Site clearing
- Sinking the two 3.7-meter (12-foot)-diameter shafts
- Final lining* of the shafts (optional)
- Construction of surface facilities*
- Underground excavation.

The primary source of particulate emissions during geologic field studies and ESF construction is due to earthmoving activities (see Table 4-6). Particulate emissions from engine exhausts are included in the earthmoving fugitive dust emission rates. Other sources during ESF construction include operation of a concrete batch plant and mined materials handling. Sources of NO_x emissions include the operation of borehole drilling rigs as well as exhaust emissions (due to fuel combustion) from mobile equipment (Table 4-7).

Maximum daily particulate emissions are 767 pounds per day (see Table 4-19). This maximum is expected to occur during months 6 through 10 of ESF construction. Figure 4-23 presents a plot of the mean monthly particulate emissions for that portion of ESF construction that includes the expected maximum emissions (BNI, 1985b).

Maximum annual particulate emissions are 86 tons per year (see Table 4-19). This maximum is expected to occur during the first twelve months of ESF construction. They include emissions due to access road construction and site clearing activities (see Section 4.1.2), the activities that cause most particulate emissions (see Figure 4-24). This figure presents a plot of the 12-month running total of particulate emissions resulting from all sources connected with ESF construction. Figure 4-24 does not present individual monthly mean emission rates as in Figure 4-23. Running totals for the latter portion of the schedule are represented by a dashed line indicating the decrease of particulate emissions over time (BNI, 1985b).

Particulate emissions due to wind erosion from disturbed areas of the site are not included in Table 4-19 or in Figures 4-23 and 4-24, but are considered in estimating project-related impacts. The determination and application of these emissions is discussed further in Section 4.2.1.3.2.

Excavation of salt does not occur during the periods of maximum daily and annual particulate emissions analyzed here. Sources of particulate salt emissions will include handling of mined salt and transferring it to the salt storage pile, maintaining the pile, and wind

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* These activities require cement mixed at an onsite batch plant. Batch plant emissions are included in the impact analysis (see Section 4.2.1.3.3).

Table 4-18. National and Utah State Ambient Air Quality Standards

Criteria Pollutant	Averaging Time	Primary Standards[a] g/m^3	Secondary Standards[a] g/m^3
Carbon Monoxide (CO)	8-hour [b]	10,000	10,000
	1-hour [b]	40,000	40,000
Nitrogen Dioxide (NO_2)	Annual	100	100
Total Suspended Particulates (TSP)	Annual[c]	75	60[d]
	24-hour [b]	260	150
Sulfur Dioxide (SO_2)	Annual	80	--
	24-hour [b]	365	--
	3-hour [b]	--	1,300

(a) Primary standards are for protection of health; secondary standards are for protection of welfare. Concentration units: g/m^3 = micrograms per cubic meter.

(b) Not to be exceeded more than once per year.

(c) Geometric mean; all other annual standards are arithmetic means.

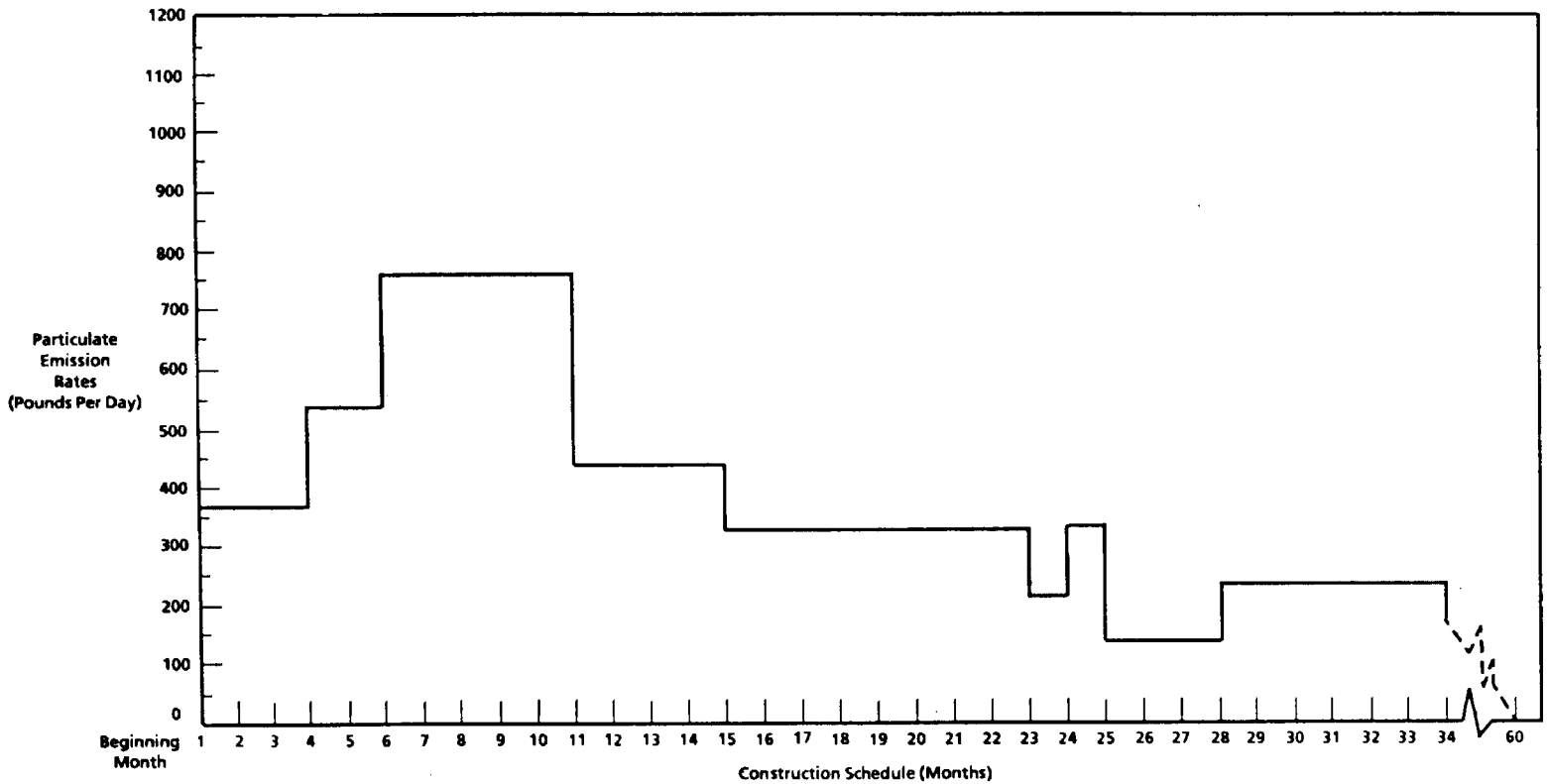
(d) Guideline; not a standard. To be used in assessing implementation plans to achieve the 24-hour standard.

Sources: Clean Air Act (42 USC Sections 7401-7642); 40 CFR Part 50; Air Conservation Act, Utah Code Annotated, Sections 26-13-1 to 26-13-30.

Table 4-19. Emissions from Geologic Field Studies and Exploratory Shaft Construction

Pollutant	Emission Rate	
	Maximum Daily (Pounds per day)	Maximum Annual (Tons per year)
Particulates	767	86
Wind Erosion		120
Total		206
NOx		
Drilling Rigs and Turbines	---	170
Mobile Equipment	---	24
Total	---	194

Source: ONWI, 1986.



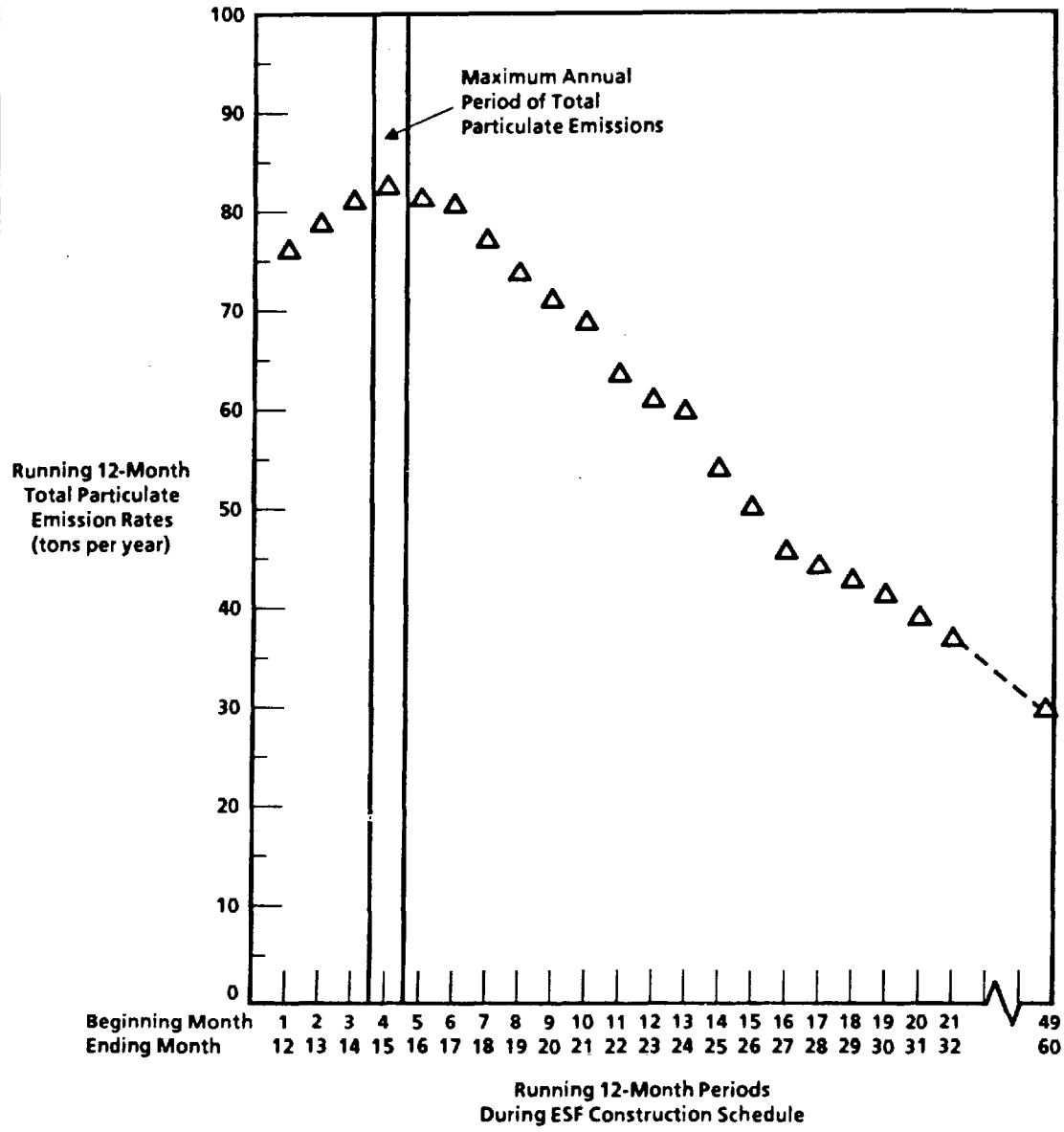
Note: Beginning the 10th Month After Presidential Announcement

Source: BNI, 1985b.

Monthly Particulate Emission Rates Due to ESF Construction and Underground Testing Activities at the Davis Canyon Site

Figure 4-23

Source: BNI, 1985b.



Note: Beginning the 10th Month After Presidential Announcement

Source: BNI, 1985b.

Running 12-Month Total Particulate Emission Rates Due to ESF Construction and Underground Testing Activities at the Davis Canyon Site

Figure 4-24

erosion of the active pile area. Relative to the activities associated with constructing the much larger salt storage pile during the repository phases (see Section 5.2.5), and because the size of the salt pile is much less, fugitive salt emissions expected to be less during site characterization, are not analyzed in this section. Salt deposition impacts during site characterization are discussed relative to repository impacts in Section 4.2.1.11.

Maximum annual NO_x emissions are 129 metric tons (142 tons) per year (see Table 4-19). This period is expected to occur during months 24 through 35 following Presidential approval of a recommended salt site to undergo site characterization. This time schedule differs from that required to identify maximum periods of particulate emissions because a significant amount of the NO_x emissions are due to geologic field studies beginning prior to ESF construction. Geologic field studies and ESF construction begin in months 3 and 9 following the Presidential approval, respectively. Therefore, the maximum annual period includes NO_x emissions due to geologic field studies (borehole drilling) and ESF construction activities (turbines and mobile sources). Borehole drilling and turbine generators represent stationary sources, which account for 113.5 metric tons (125 tons) per year of the maximum. Mobile sources account for the remaining 15.5 metric tons (17 tons) per year (BNI, 1985b).

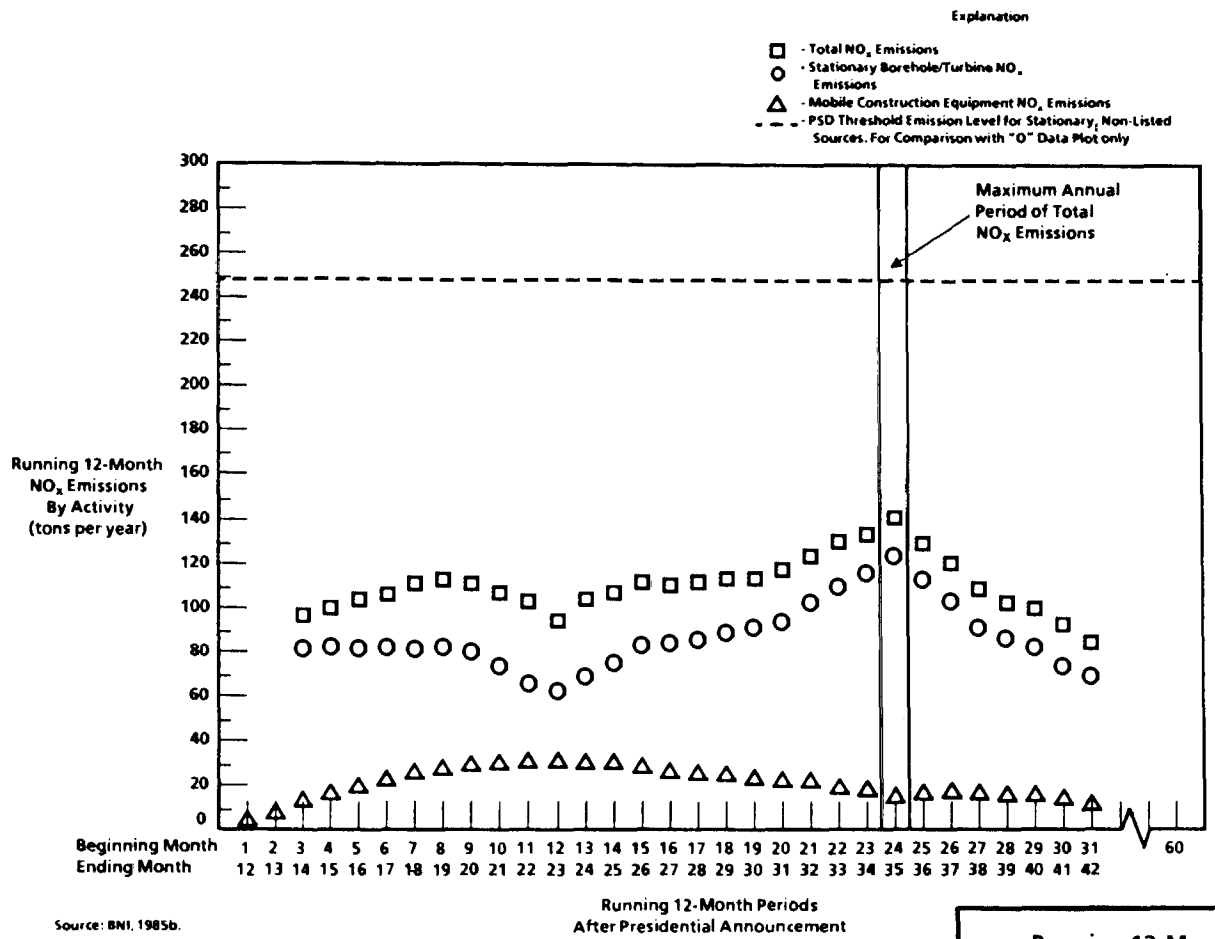
Figure 4-25 presents a plot of the 12-month running total NO_x emissions resulting from stationary and mobile sources and from all sources from the initiation of geologic field studies, through the ESF construction schedule based on Presidential approval. (This figure also indicates the threshold emission level for stationary sources, 250 tons per year, which would trigger prevention of significant deterioration [PSD] requirements.) The plot of emission values resulting from stationary sources indicates that site characterization activities will not be subject to PSD requirements (Section 4.2.1.3.3 contains further discussion).

Mitigation. Numerous air pollution mitigation techniques have been built into the plans for site characterization activities. For example, and as required by Utah air pollution control regulations, best available control technology (BACT) is applied to sources of fugitive emissions. Fugitive dust mitigation planned for the project includes the application of water and chemical suppressants to disturbed areas and haul roads in a carefully designed control program. Cuscino (1984) describes such a program to control fugitive dust from paved and unpaved roads by up to 90 percent. Additional controls which may be applied include speed controls on earthmoving vehicles and haul trucks, minimizing the size of disturbed areas, and covering storage piles. Control efficiencies are dependent on three parameters: (1) application intensity, (2) application frequency, and (3) chemical dilution ratio. By adjustment of these parameters it should be possible to obtain higher (or lower) control efficiencies than those documented in the EPA report. The 90-percent control efficiency (Cuscino, 1984) is for travelled roadways. By applying the same control measures to disturbed areas and then limiting traffic access to them, control efficiencies in excess of 90 percent should be achievable. The control program for the proposed Davis Canyon ESF activities has a goal of 90 percent; the degree of control assumed in the modeling is discussed below.

To protect the environment from any adverse effects which these chemicals might pose, all runoff from the site will be captured and stored in retention ponds. Prior to release to the environment, the runoff will be analyzed to determine if it meets Federal, State, and local standards. If water standards are not met, the collected water will be held in the evaporation pond for later transport to a licensed disposal site.

Mitigative measures are required to reduce the amount of particulate salt emissions associated with the salt storage pile. Water sprays may be used to suppress dust during salt-handling activities. Wind erosion emissions from the salt pile will be reduced due to the natural crusting tendency of salt (Ver Planck, 1958). Crusting may be promoted by daily watering of the pile. Inactive areas of the salt pile will be covered (e.g., with dirt or asphalt) as it is being developed and after it is filled to capacity. Transport vehicles for hauling excess salt to offsite disposal areas will be covered.

Control of NO_x emissions from diesel exhaust will be as required of manufacturers by Federal regulations. Inspection and maintenance of these controls by contractors will be a project requirement.



Source: BNI, 1985b.

Running 12-Month NO_X Emissions Due to Drilling Rig Operations and Mobile Sources at the Davis Canyon Site

Figure 4-25

4.2.1.3.2 Methodology. The choice of an air quality model for the Davis Canyon site considered the following factors:

1. The terrain is complex.

2. Fugitive emissions are at ground level and are best represented by area sources.

3. Emissions vary with time of day and with meteorological conditions.

4. Deposition of particulates is important in predicting offsite ground-level concentrations.

The Valley Model is often used for complex terrain applications. However, it was developed for elevated-source air quality impacts on elevated terrain. In such situations, the maximum concentration occurs at a distant point on elevated terrain from a very stable (Class F) plume. At the Davis Canyon site, most emission sources are at ground level, and maximum concentrations will occur very close to the source. Such considerations preclude the selection of the Valley Model as the appropriate model for the Davis Canyon air quality analysis for site characterization.

The EPA Industrial Source Complex (ISC) Model (Bowers et al., 1979) was selected for estimating air quality impacts of exploratory shaft facility construction, because it best serves the above modeling considerations. Although it is not a complex terrain model, it is often applied in complex terrain situations where the emission sources are at or near ground level and particulate deposition is an important factor.

Precedents for the use of ISC for modeling impacts due to surface emissions in complex terrain have been established. For example, in a PSD case, ISC was used to analyze emissions from the Quartz Seal Project Surface Mine of the U.S. Borax Company in Ketchikan, Alaska. Originally, the permit application used the Valley Model, but the EPA requested a remodeling with ISC. In a non-PSD case, the EPA applied the ISC model at John Henry No. 1 Mine in Black Diamond, Washington (Policastro, 1984). In a third case (Joseph, 1980, p. 3), the EPA used ISC to model emissions from the proposed Alton Surface Coal Mine. The Alton Mine site is located in complex terrain within about 10 kilometers (6.2 miles) of Bryce Canyon National Park.

Based on these technical considerations and EPA precedents in similar cases, the ISC model was chosen to model Davis Canyon air quality impacts. The short-term version of ISC (ISCST) was used to estimate 24-hour average concentrations of particulate, and the long-term version of ISC (ISCLT) was used to estimate annual average concentrations of both particulate and nitrogen dioxide.

Particulate emissions were modeled as area sources based on engineering design information discussed by BNI (1985b). Fugitive particulate emissions generated by earthmoving activities, materials handling, and vehicle movement were apportioned to one of two area sources, depending on the ESF construction activity causing them. Wind erosion emissions were also apportioned to these two area sources. The model requires area sources to be represented by a square. Site-work activities were assumed to occur in an area 364 meters (1,194 feet) on a side (or approximately 13.3 hectares [32.8 acres]). Surface facility construction and shaft activities were assumed to cover an adjacent area 201 meters (659 feet) on a side (approximately 4.05 hectares [10 acres]). Wind erosion emissions were assumed to occur over the entire 24-hectare (59-acre) site area, represented by a square 493 meters (1,618 feet) on a side (BNI, 1985b).

The ISC Model contains an option to consider particle deposition by gravitational settling. This latter phenomenon occurs with a significant fraction of the relatively large particle sizes found in fugitive dust emissions. The model requires a particle size distribution as input in order to use this option. The distribution used in this analysis is adapted from the results of fugitive dust measurements at western surface coal mines and is discussed in BNI (1985b).

Wind erosion emissions from disturbed areas were calculated using a predictive emission factor equation (EPA, 1978). The emissions are a function of surface erodibility, soil silt content, precipitation-evaporation index. They are assumed to occur only when wind speeds are above the threshold value of 12 miles per hour at the eroding surface.

Annual NO_x emissions were modeled as a combination of one area source based on engineering design information and one point source as discussed in BNI (1985b). Emissions from drill rigs at the service and production shafts, were modeled conservatively as one point source, centered in the ESF site area. Diesel emissions from drilling rigs associated with geologic field studies were assumed to occur at this same point. This assumption is conservative in that these drilling rigs will be located throughout the site area and will be stationary for periods of only one-to-six months before relocating (see Section 4.1.1). Maximum annual incremental concentrations from any one or group of these widely separated drilling rigs are much less than the concentration resulting from these modeling assumptions.

One year (1975) of sequential, hourly meteorological data from Salt Wash, Utah, a site approximately 110 kilometers (70 miles) northwest of Davis Canyon, was used in the analysis.

In the absence of site-specific air quality data, common practice uses regional values. For the purposes of this environmental assessment, background values of 21 micrograms per cubic meter (0.595 micrograms per cubic foot) of TSP, and 10 micrograms per cubic meter (0.283 micrograms per cubic foot) of NO_2 were assumed (see Section 3.4.3.1).

4.2.1.3.3 Air Quality Impacts. This section addresses the results of the air quality modeling analyses. Additional details appear in BNI (1985b). Since that time, updates and corrections to the equipment list have been made. Furthermore, a quality assurance check of the computation of the air and noise emission levels has indicated errors in some terms, many of which have a cancelling effect with most of the others, leading to reduced impacts. Also, a review of the methodology employed in the air quality modeling revealed that the maximum 24-hour prediction (instead of the second highest) was the more appropriate value to use considering that 1 year of meteorological data was used. The above changes will affect the airborne concentrations of total suspended particulates (TSP) and NO_x predicted in the air quality modeling as compared to what is presented below. A comparative evaluation has been performed of the expected changes in projected air quality impacts and is documented in "Evaluation of Air Quality and Noise Impact Assessments - Davis Canyon" (ONWI, 1986). This document lists the changes in some detail and presents the results of those changes in terms of revised air quality impacts. The document concludes that small differences in expected impacts result, none of which are large enough to invalidate any of the conclusions presented herein.

Regulatory Review. The primary criterion in determining PSD applicability is whether a facility is a "major source" of criteria air pollutants. The sources of particulate and NOx emissions discussed earlier are not included in the list of 28 major stationary sources subject to an emission limitation of 90.78 metric tons (100 tons) per year. To be considered a major source, project-related stationary-source emissions would have to be greater than 250 tons per year (see Utah Air Conservation Regulations, Section 1.1.75).

Table 4-19 indicates that the maximum annual emission level is 86 tons per year. Particulate emissions are primarily fugitive emissions. For these reasons PSD requirements are not applicable (see 40 CFR 52.21[b][1][iii]).

NO_x emissions are due to both stationary and mobile sources. Borehole drilling rigs are stationary sources operating from 1- to 6-month periods at any one location. On an annual basis, the maximum total NO_x emissions from these aggregate stationary sources are 170 tons per year (see Table 4-19).

For purposes of this EA, the DOE concludes that site characterization is not subject to PSD requirements because stationary-source emissions do not exceed the threshold limit of 250 tons per year.

Utah Air Conservation Regulations (UACR) require the following:

1. The State must be provided with a notice of intent prior to construction of a facility.

2. Because the site is located adjacent to a national park, the Federal Land Manager (FLM) will be provided an opportunity to prepare an analysis of whether the proposed site characterization activities will have an adverse impact on the AQRVs of Canyonlands National Park.

3. The FLM will review the extent, duration, magnitude, and frequency of impacts on AQRVs from project emissions.

4. If the FLM finds adverse impacts from project emissions and the Utah Bureau of Air Quality (UBAQ) agrees, the UBAQ will not issue an Approval Order for the project.

The Davis Canyon site area has been designated by the EPA as "attainment" for particulates. Consequently, all new major sources are subject to a PSD review. This review includes demonstrating that the applicable TSP and SO_2 increments are not exceeded. In the State of Utah, once the baseline for the area has been "triggered," nonmajor sources are also required to demonstrate compliance with the increments. However, the baseline in the Davis Canyon site area has not been triggered, because no approval order for a major source has been issued by the State for this area. Furthermore, the repository project itself is not a major source. In a regulatory sense, project-related particulate concentrations would add to the existing baseline rather than consume increment.

In permit review, the State of Utah does not normally require that construction-related fugitive dust be included in its computation of increment consumption. By excluding construction-related fugitives, the DOE estimates that the 24-hour maximum TSP increase at the park boundary would be much less than the 10 micrograms per cubic meter permitted at the boundary of a Class I area. Consequently, the PSD increment at the park boundary (even if applicable) would not be violated during site characterization.

In the interpretation of the modeling results presented below, air quality impacts are considered to be significant if (1) the NAAQS are exceeded, i.e., those ambient concentrations which "... allowing an adequate margin of safety, are requisite to protect the public health" and those levels which "... are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air" (EPA, 1971), or (2) there are adverse effects on air quality related values, or (3) there are detectable increases in ambient concentrations of criteria pollutants within Canyonlands National Park.

Uncertainties. Prior to discussing modeling results, it is important to point out that there are uncertainties associated with the air quality impact analysis:

- Particulate Emission Rates. Emission factors, particle size distributions, and control factors used to estimate particulate emission rates are drawn from the published literature. While the DOE considers that these data are the best available for use in the impact analysis, the DOE recognizes that there are uncertainties inherent in their use. For example, fugitive dust emission factors are based on limited measurements at other locations and for other types of earth-moving activities where natural soil characteristics such as silt and moisture content are different from those existing at the site. Particle size distributions from studies of western coal mines were used for both fugitive dust and salt emissions. Dust control efficiency values (50 percent using water application and vehicle speed limits, and 90 percent using chemical suppressant

application and vehicle speed limits) can involve errors. The DOE believes the values used herein are achievable with a well designed and carefully conducted mitigation program. Uncertainties inherent in emission rate estimates have not been quantified; they could result in either higher or lower air quality impacts.

- Offsite Meteorological Data. The meteorological data are from offsite, and while the Salt Wash Tower is located in an area similar to that of Davis Canyon, because meteorological conditions are complicated at both locations by different complex terrain, there are limitations to their representativeness. The DOE believes that the Salt Wash Tower data are reasonably representative and the best available for use in the impact analysis. Uncertainties inherent in the use of offsite meteorological data have not been quantified; they could result in either higher or lower air quality impacts.

Estimated Concentrations. The highest and second-highest 24-hour TSP concentrations offsite were estimated. The second-highest offsite values are reported as maximums for comparison with the 24-hour standards, which are not to be exceeded more than once per year. The highest annual offsite concentrations of TSP and NO_2 are also reported. "Offsite" refers to points at or beyond a 243-hectare (600-acre) secured area surrounding the ESF.

Maximum 24-hour TSP, and annual-average TSP and NO_2 concentrations at the site boundary and at the park boundary are summarized in Table 4-20. Values presented include background values identified in Section 3.4.3.1.

Impact on Park AQRVs. The National Park Service, through the FLM, will review the frequency, duration, extent, and magnitude of impacts on AQRVs when evaluating the proposed project (NPS, 1982). AQRVs include: visibility, odor, night sky brightness (skyglow), flora, fauna, soils; archaeological, historical, cultural, geological, and water-quality resources (Shaver, 1985).

A level II visibility analysis has been conducted for the site-clearing phase of repository construction (see Section 5.2.5.3.4), which has much higher TSP and NO_x emissions than the ESF. Results of the analysis show that visibility impairment would be imperceptible during that phase, hence the same conclusion can be applied to the site-characterization phase.

Except for engine exhaust near equipment, no odorous emissions are expected during site characterization.

Night skyglow has been analyzed for the repository, which will be a larger source of light than the ESF. The analysis presented in Section 5.2.5.3.4 concludes that night skyglow from the repository can be mitigated to contribute less than existing sources of background light such as Moab. The same conclusion can thus be applied to the ESF phase.

Impacts from project air emissions on soils and vegetation are expected to be negligible (BNI, 1985b).

Impacts of air emissions to archaeological, historical, cultural and water quality resources are discussed in Sections 4.2.1.8 and 4.2.1.4.

Conclusions. The results indicate that the primary and secondary 24-hour NAAQS for TSP and the annual NAAQS for TSP and NO_2, will be met during site characterization. The primary NAAQS were established to protect the public health with an extra margin for safety. The secondary NAAQS were established to protect the public welfare (e.g., environmental and economic interests, visibility and climate, and personal comfort). There will be some impacts on air quality in the park, such as increased ambient levels of TSP and NO_2, particularly during site clearing. The particulate emissions consist mainly of native soils, and impacts will be temporary. Salt impacts are expected to be negligible. Except for possible temporary impacts from construction lighting, night skyglow from project luminous sources should be no more than that from existing sources.

Table 4-20. Air Quality Impacts During Site Characterization, Davis Canyon

Pollutant	Averaging Time	Location	Maximum Concentration (micrograms per cubic meter)	NAAQS (micrograms per cubic meter)
TSP	24-hour	Limited Access Area Boundary	135	260/150[a]
		Park Boundary	46	260/150[a]
TSP	Annual	Limited Access Area boundary	36	75[b]
		Park boundary	22	75[b]
NO2	Annual	Limited Access Area Boundary	20	100/100[a]
		Park Boundary	11	100/100[a]

Notes: Background TSP value is 21 micrograms per cubic meter.
Background NO_2 value is 10 micrograms per cubic meter.

(a) Primary Standard/Secondary Standard

(b) 60 micrograms per cubic meter is a guideline, not a standard, to be used in assessing implementation plans to achieve the 24-hour standard.

Sources: BNI, 1985b; Clean Air Act (42 USC Sections 7401-7642), 40 CFR Part 50; Air Conservation Act, Utah Code Annotated, Sections 26-13-1 to 26-13-30 (Supp. 1984).

On this basis, the DOE concludes that the repository project will not have a significant impact on air quality in general, but there will be some impacts on air quality in the park.

4.2.1.4 Water Quality Effects

This section discusses the potential impacts of site characterization activities on surface and ground water. It also addresses proposed measures to mitigate any significant adverse impacts.

4.2.1.4.1 Surface Water. The site characterization activities associated with the construction, testing, and final disposition of the ESF and with various field study activities are likely to have impacts on the surface hydrologic conditions of the surrounding area. Because the exploratory shafts would be located above the 100-year flood level (Figures 3-51 and 4-6), the shafts would have minimal effect on the overall management of the 100-year floodplain in this area. Potential impacts on surface-water resources would be the following:

- Minor increase in demand on the region's water resources
- Possible degradation of the water quality of nearby streams and water bodies.

The precise extent and magnitude of impacts will be determined after site-specific engineering design plans have been finalized. Consultation with the Department of Interior and State wildlife agency will continue in compliance with the Fish and Wildlife Coordination Act (16 USC Sections 661-666c), on the disturbance and modification of waterways during site characterization activities.

A summary of freshwater requirements during ESF activities is as follows:

- Construction period - 79 million liters (20.9 million gallons)
- Testing period - 61 million liters (16.0 million gallons)
- Final decommissioning - 201 million liters (53 million gallons)
- Total consumption - 340 million liters (89.9 million gallons).

These figures are consistent with conventional mining techniques for shaft construction. Water would be purchased as existing allotments from nearby municipalities and trucked to the site by licensed transporters. Although this amount of water is small by itself, it would contribute to the increasing demands on the region's sparse water resources.

As a result of site preparation activities, foundation borehole testing, and construction of the access road and exploratory shaft, some local and temporary increase in sediment discharge and turbidity in Indian Creek is expected. However, temporary sedimentation basins would be constructed at strategic locations to mitigate any possible adverse impacts to the surface runoff from disturbed areas, such as cleared land and mined or excavated material (nonsalt) storage areas. They would allow the sediments to settle out before the runoff is released to the environment. The basins would be sized to accommodate rainfall from a 500-year, 24-hour storm. An overflow containment area would be provided to contain a 24-hour storm of a 25-year recurrence interval. Control of fugitive dust from paved and unpaved roads using water or chemical suppressants is discussed in Section 4.2.1.3.1. To protect the environment from any adverse effects of these measures, all onsite runoff will be captured and stored in the retention pond. Any discharges from these sedimentation basins to surface waters will be subject to a National Pollutant Discharge Elimination System (NPDES) permit under Section 402 of the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 USC Sections 1251-1376).

A salt-contaminated runoff retention pond will also be constructed to capture and retain surface runoff from the salt stockpile storage area, and to store water pumped from the shaft pumps, which cannot be released directly to nearby water courses. The current design of the retention pond will include a double liner system with a leakage detection and recovery scheme to prevent seepage of retained water which could possibly contaminate the ground water. Because of the net evaporation rate (i.e., annual evaporation greater than annual precipitation) in the region, the retention pond would function, primarily, as an evaporation pond.

The accumulated water will be removed from the pond by natural evaporation. The capacity of the retention pond will be approximately equal to half the total volume of wastewater generated for the exploratory shafts (i.e., 40.9 million liters [10.8 million gallons]) (Table 5-1). The exact dimensions of the pond will be determined using historic cumulative, maximum monthly rainfall and the minimum evaporation rate. In addition, an overflow area will be provided to accommodate a storm event with a recurrence interval of 500 years. According to the current design, a double liner system will also be constructed, which will underlie the salt stockpile storage area, to minimize any possible contamination of ground water.

On the basis of studies performed for the impact assessment of the repository operation which involves the handling of more than one hundred times the volume of salt than the ESF (Section 5.1.3), the potential degradation of the water quality of the nearby streams and water bodies by wind-blown salt will be small. The majority of the salt emission would be deposited within the ESF site. Runoff from this area will be retained and discharged offsite only it if meets environmental discharge standards. The amount of salt deposited in the adjacent watersheds will be less than 1,800 kilograms (2 tons) per year, equivalent to less than 0.5 percent of the present salt loadings carried in Indian Creek. (The salt load of Indian Creek is estimated to be at least 455,000 kilograms (500 tons) per year from observed flow and water-quality data given in Tables 3-14 and 3-19, respectively.) Based on water quality data collected at the Cisco gaging station, the Colorado River carries a salt loading of about 3.5 billion kilograms (3.8 million tons) per year. The annual salt deposition of less than 1,800 kilograms (2 tons) from exploratory shaft operations in the nearby watershed will not be measurable relative to the large salt load carried in the Colorado River.

Sanitary wastewater and other liquid and solid wastes generated at the site will be temporarily stored at the site for later disposal off site and, thus, are not expected to affect surface waters.

Ponding of surface runoff from the disturbed area may possibly reduce runoff to the adjacent streams. However, because the affected areas are small relative to their watersheds, the overall reduction in runoff is expected to be negligible.

Significant degradation of the water quality in Indian Creek could result from the catastrophic release of contaminated runoff from the temporary sedimentation and salt-pile runoff retention ponds. Such an event could occur if the embankment were breached by storm runoff exceeding the design event. The precise effect this event might have on water quality is not known at this time. However, the likelihood of such an event is very low according to stated design criteria, and the resulting impact will be diminished by the dilution effect of the storm runoff which causes the impact.

If the site proves unsuitable for further development, all excavations would be backfilled with salt and other excavated materials stored in the onsite stock-pile areas. Residues from the retention ponds and all other solid wastes will be disposed of at a licensed landfill within the region (Section 4.2.1.1.2). Reclamation of the material storage areas would be done to minimize any adverse impact on the environment.

Field studies and other activities conducted near drainages will have only minimal impact since they involve the disturbance of about 8 hectares (20 acres) of land dispersed over a number of drainages. These disturbances include selected clearing of small areas of land for drill-pad construction; drilling, trenching and augering for geologic investigations during repository site characterization and along the transportation corridor; the installation of test wells for regional ground-water evaluation; construction of stream gaging stations; and water sampling and discharge measuring efforts. With the exception of tasks related to the surface-water monitoring program, field activities would be conducted away from existing stream channels, water bodies, and the 100-year floodplain. However, one drill pad is to be located near Indian Creek in the vicinity of Kelly Ranch. As a result, minor and temporary increases in turbidity may occur in Indian Creek. The mitigating measures will include the construction of temporary wastewater and runoff retention ponds. Retained wastewater, such as saline water pumped from test wells, will be stored and transported from the site for proper disposition. Because these activities will involve relatively small localized areas, they

will not have any significant adverse effect on the overall management of the 100-year floodplain in the area.

With the use of these control measures, the expected impact on the surface hydrologic system of the area resulting from site characterization activities will be minimal. No measurable increases in the salinity of the Colorado River will result from these activities due to the distances from site activities, employed mitigation measures, and the high existing load being carried in the Colorado River.

4.2.1.4.2 Ground Water. In this section, effects on ground-water resources resulting from site characterization activities are discussed. Potential effects identified relate primarily to ground-water quality and are expected to be mitigated by facility design measures (e.g., retention pond and salt pile liners, and shaft seals). Because water requirements will be met from surface water supplies trucked to the site, no effects on the local ground-water flow regime are expected as a result of water use by the project.

Some recharge to the upper aquifer may occur from discharge of imported water onto the ground's surface. If constant discharge (rather than injection) tests are performed on test wells, the water pumped from test wells will also be a possible source of recharge. The quantity of this recharge is expected to be small due to the high potential evaporation rate, the thick unsaturated zone, the low test pumping rate, and the low head in the sedimentation ponds. Therefore, changes in ground-water level or quality are expected to be minor and temporary.

To evaluate the impact of pumping tests in the Cedar Mesa Formation on water levels in the site area, an analytical calculation was performed, using the Theis Equation for non-equilibrium flow to a pumping well (Freeze and Cherry, 1979, p. 317). Input parameters used for the calculations were 0.14 square meters per day (11 gallons per day per foot) for transmissivity, 82 cubic meters per day (15 gallons per minute) for pumping rate, 7 days for the duration of pumping, and 0.005 for the storativity. This calculation showed that drawdown beyond a radius of 75 meters (246 feet) from the pumped well will be insignificant (less than 0.1 meter) [4 inches], and will not have any effect on local wells.

The excavation methods and design of exploratory shafts and surface facilities (described in Section 4.1.2) will minimize contamination of ground water. No adverse impacts to ground-water quality or flow are expected from excavation of the shafts. Excavated material will be stored on site in salt and rock stockpiles. Water seals and collars would be installed to ensure vertical isolation of all aquifers encountered. The salt pile and runoff retention pond will be underlain by impermeable double liners designed to minimize salt (and other potential contaminants) seepage into the soil and ground water. Diesel fuel for the characterization activities will be stored in an underground fiberglass storage tank.

There is a possibility that the salt pile or runoff retention pond liners or the fiberglass fuel tank may leak, locally affecting the quality of the ground water in the upper aquifer. A monitoring system will be installed around these surface facilities to monitor the performance of the liners and the integrity of the fiberglass fuel tank. The monitoring system will provide early detection of any release of contaminants to the ground-water system. The salt-pile and runoff retention pond will also be equipped with a double liner and underdrain monitoring system, permitting any seepage entering the drainage layer between liners to be detected and pumped out. Liner or tank leaks will be repaired and dewatering will be implemented, as required, to mitigate the impact of contaminant seepage on ground water. Monitoring wells will also be installed near the exploratory shaft, to monitor the performance of shaft lining and seals. If aquifer cross-contamination is detected, remedial measures, such as dewatering, liner repair, and formation grouting, will be implemented.

Changes in ground-water quality due to infiltration of precipitation through soils contaminated by wind-blown salt are expected to be very minor. Modeling studies for repository operation, which involves handling 100 times more salt than for the exploratory shaft facility, show that deposition of salt will be on the order of 1 kilogram per hectare (0.9 pound per acre) per year in the repository area, diminishing to 0.1 kilogram per hectare

(0.09 pound per acre) per year at a distance of 1 to 2 kilometers (0.6 to 1.2 miles). If all of this salt were carried to the water table and distributed in the top 3 meters (10 feet) of the saturated zone, it will represent an annual increase in salinity of 0.01 to 0.1 milligram per liter. Over the life of the ESF, this will amount to less than a 1-milligram-per-liter increase in salinity of shallow ground water within the immediate site area. However, it is unlikely that all wind-deposited salt could reach the water table, as much of it will be transported with storm runoff to the retention ponds. In addition, because the unsaturated zone at the site is very thick, and the annual precipitation is low, the transport of surface salts to ground water is expected to be very slow.

Site characterization activities will include drilling approximately 650 boreholes at up to 626 sites (these numbers include foundation and access road design borings). The drilling procedures are designed to prevent contamination of ground water, and will preclude detrimental effects to ground-water quality and the hydrologic flow regimes. Saline water produced from hydrologic testing of boreholes and wells will be collected in tanks and trucked offsite for disposal. No drilling in Canyonlands National Park is planned.

4.2.1.5 Effects on Soils, Geology, and Paleontology

This section contains discussion on effects on soils, geology, and paleontology resulting from site characterization activities. Site characterization activities at the Davis Canyon site will include field studies and the construction of an exploratory shaft facility.

4.2.1.5.1 Soils. Soils will be affected in several ways: (1) The construction and use of roads and drilling platforms by heavy machinery and vehicles will cause soil compaction and accelerated surface runoff; (2) areas stripped of vegetation will be exposed to accelerated water and wind erosion, and (3) various construction activities will require the removal of topsoil or the mixing of soil horizons. These impacts will be mitigated by the following site restoration activities:

- Ripping and disking compacted soil areas
- Seeding and revegetating disturbed areas to reduce erosion
- Storing and stockpiling topsoil for regrading over areas stripped of soil
- Reduction of slope angles to lower runoff velocity
- Soil ridging, banking, or diking and placement of culverts to channel surface water flow.

As indicated in Section 4.2.1.1.2, solid wastes generated during site characterization will be taken to a licensed landfill for disposal. One or more landfills within the region have the capacity and necessary permits to accept the anticipated wastes, including salt and salt-contaminated materials. For this reason, impact to soil quality at the disposal site is not considered a potential problem.

In addition, control measures will be implemented whenever possible during construction and operation. Impacts on water quality (Section 4.2.1.4), air quality (Section 4.2.1.3), and aquatic biota (Section 4.2.1.2) resulting from soil erosion are addressed in the appropriate sections.

Reclamation may begin sequentially as various areas of site characterization activities are completed and in accordance with procedures specified by regulating agencies. The area directly impacted by geologic, environmental, and exploratory shaft facility (ESF) activities, will be inspected with a hand auger by a soil scientist prior to stripping to determine the depth and thickness of the soil. Topsoil will be stockpiled as required to prevent unnecessary soil degradation. The stockpiles will be planted with suitable (ideally mature) plants appropriate to the material stockpile and mulched until the cover is established to prevent wind and water erosion. All rehabilitated areas will be seeded in accordance with Bureau of Land Management (BLM) seeding specifications.

Few well-established cryptogamic communities (nonvascular plants that grow upon or immediately beneath the soil surface) exist in the project activity areas, since most of the areas have been subject to extensive grazing. Impacts to cryptogamic communities will be minimized by avoidance of them when possible. When cryptogam communities are disturbed, the soil surface may be restored to a condition which will promote the reestablishment of cryptogams. Observations of disturbed areas near the project site indicate that cryptogamic communities may be reestablished within 15 years (Welsh, 1985). Upon completion of project activities, the soil of disturbed communities will be left with a rough surface and protected from further disturbance to facilitate the reestablishment of a cryptogamic crust. Where soil cannot be protected from further disturbance, the DOE plans to stabilize the areas with other types of vegetation in accordance with BLM specifications.

Surface preparation will be aimed to ensure that the seed can be incorporated into the soil to the proper depth at seeding time. Fertilizer application will be based on soil analysis and consideration of the existing climatic conditions. For seeding, plants will be primarily selected which are adapted to the site, control soil erosion, and provide forage for livestock and habitat for wildlife. Seeding will be selected for the first climatically suitable period. For mulching, materials will be used which will protect the surface from erosion and aid in the establishment of vegetation in the harsh climate. The mulch will be anchored to the ground to prevent removal by wind.

Monitoring will record the rate at which new vegetation is established on the disturbed areas. Maintenance will include reseeding, remulching, and application of additional fertilizer (or other agrinomic practices) as needed. Monitoring and maintenance will be continued until a plant cover is established similar to the existing vegetation in quality and density.

Geotechnical Field Studies. Drill pads, access roads, and other geotechnical field activities will disturb approximately 243 hectares (600 acres) of land. Areas disturbed by field activities and the duration of these activities are shown in Table 4-2. If the land areas identified for each activity are disturbed for the entire duration identified in the table, the impact would be approximately 52 hectare-years (128 acre-years). A study performed by BGI (BNI, 1984a) estimated both the present rainfall erosion rates and the potential rates following disturbance of the soil at a number of sites in the affected area. Although all of the specific activity sites have not been evaluated for erosion potential, the rainfall erosion rate for similar sites in the area have been calculated. The average soil loss from rainfall erosion at these sites under disturbed conditions was calculated to be 14.7 metric tons per hectare per year (6.6 tons per acre per year). Based on the average rainfall erosion rate for disturbed sites, total soil loss from field activities will be 763 metric tons (847 tons). The average present erosion rate for the similar sites was calculated to be 2.5 metric tons per hectare per year (1.1 tons per acre per year). Therefore, increased rainfall erosion from field activities could result in the loss of an additional 633 metric tons (706 tons) of soil.

Exploratory Shaft Facility (ESF). Site development activities will disturb 24 hectares (59 acres) of land. Based on field measurements taken at three locations in the vicinity of the ESF, the average present erosion rate is estimated at 1.6 metric tons per hectare per year (0.7 tons per acre per year) (BNI, 1984a). During ESF activities, this rate will increase to approximately 16.4 metric tons per hectare per year (7.3 tons per acre per year) as a result of surface disturbance. These figures indicate that during the construction and suitability phases, 3,267 metric tons (3,600 tons) of soil will be lost to water erosion. This is equivalent to 86 metric tons of soil per hectare (38 tons per acre) or a 0.6 centimeter (0.23 inch) soil layer over the entire area. (For these estimates, soil density was assumed to be 1,500 kilograms per cubic meter, 93 pounds per cubic foot).

Some soil loss will occur during construction due to wind erosion. Wind impacts have been modeled, and the expected effects of wind erosion are included in Section 4.1.2.6.

The drilling mud pit will be reclaimed following removal of the drilling fluids, drill cuttings, and synthetic liner. Waste drilling fluids will be separated into liquid and solid fractions to facilitate disposal. These materials will be disposed of off site as discussed

in Section 4.1.2.6. The mud pit will be backfilled and graded to be nonimpounding, self-draining, and mechanically stable.

Deposition of windblown salt may affect soil in the vicinity of the ESF site. On the basis of salt deposition estimates for repository operations, the annual salt deposition rate is small, about 1 kilogram per hectare (0.9 pound per acre). If it is assumed that the predicted maximum deposition rate remains in the top 0.3 meter (1 foot) of the soil strata, the annual increase in salinity would be less than 0.2 parts per million (ppm). However, salt loading of soil is not expected to be significant because this maximum rate of deposition is restricted to areas where salt is being moved or stored and declines rapidly away from the salt handling facilities (see Section 4.2.1.11).

Environmental Field Studies. Installation of meteorological towers for environmental site investigation involves grading, constructing a concrete footing, and grading access routes. These activities will increase runoff and soil erosion through clearing of vegetation and compaction of surface soil by use of heavy equipment. However, this will affect a small area (0.12 hectare or 0.3 acre), and the site will be reclaimed when studies are complete.

Other environmental studies will have minor and localized soil impacts. Soil and archeological surveys would require scattered shallow diggings that will be backfilled. Other surveys (noise, land-use, ecology) will involve several people walking or driving on the site and vicinity and will have minimal soil impacts.

4.2.1.5.2 Geology. Existing topography will be modified by the construction of roads and drill pads, and by the removal and stockpiling of subsurface salt. This impact will be mitigated by backfilling excavations with the mined salt or soil and by regrading roads, platforms, and trenches to predisturbance contour. Regrading will reestablish normal site drainage and will be conducted using appropriate techniques to reduce erosion and enhance moisture retention. Regrading will be limited to only those disturbed areas; areas not directly affected by construction will be left in their natural state.

Site characterization activities are not expected to affect the geology. Backfilling the underground excavations with salt will fill 65 percent of the void space, thereby lessening any potential impacts of underground failure and surface subsidence. Given the depth expected and limited lateral extent of the underground excavation, extremely little subsidence of the surface is expected.

4.2.1.5.3 Paleontology. No areas of unique or readily accessible fossil occurrence have been identified at the site. If such areas are identified during site characterization field studies, a paleontologist can be consulted prior to and during excavation at the exploratory shaft. The paleontologist may conduct field surveys prior to excavation and may recommend mitigation measures. No significant loss of paleontologic information is expected.

4.2.1.6 Noise Effects

The analyses presented below are based on geotechnical and engineering data (e.g., schedules, equipment inventories, and specifications) and noise source terms (see BNI, 1985c). Since the analyses were completed, updates and corrections to the equipment list have been made. Furthermore, a quality assurance check of the computation of the noise emission levels has indicated errors in some terms, many of which have a cancelling effect with most of the others, leading to reduced impacts. A comparative evaluation has been performed of the expected changes in projected noise impacts and is documented in "Evaluation of Air Quality and Noise Impact Assessments - Davis Canyon" (ONWI, 1986). This document lists the changes in some detail and presents the results of those changes in terms of revised noise impacts. That document concludes that small differences in expected impacts results none of which are large enough to invalidate any of the conclusions presented herein.

Increased noise levels during site characterization will intrude into the normally quiet environment of Davis Canyon. Noise from project activities will be produced from fixed, electrically-powered equipment and mobile, diesel-powered equipment. Infrequent blasting noise will occur during the initial stages of shaft sinking. Additionally, geotechnical activities will occur at a number of locations outside the exploratory shaft facility (ESF) area.

In order to accurately assess noise impacts, computer modeling is employed to predict noise levels during periods of peak activities. The noise criteria used to assess impacts, a description of the model, the results of the predictive modeling as noise isopleths (contours) on topographical maps, an assessment of the predicted impacts, and possible noise mitigation measures are presented. Also included are discussions of impulsive noise and ground vibration from blasting.

4.2.1.6.1 Noise Criteria. The U.S. Environmental Protection Agency (EPA) has not promulgated any community noise regulations pursuant to the Noise Control Act of 1972 as amended by the Quiet Communities Act of 1978 (42 USC Sections 4901-4918) that are applicable to site characterization and repository construction, operation, and closure. The Noise Control Act of 1972 requires Federal agencies to comply with State and local noise regulations. There are no applicable State or local regulations for this site.

Two indicators of environmental noise impact are used as noise criteria. The first criterion is audibility. Audibility has been chosen by DOE as a conservative method to estimate the potential noise impacts upon the quietness of the nearby national park, recreation areas, and wilderness study areas. Project noise, the loudest 1-hour energy equivalent level (L_{eq}), may be considered audible if it exceeds the masking noise. The masking noise is the larger of either the residual sound level or the hearing threshold of humans (Fidell and Horonjeff, 1982; Robinson and Dadsen, 1956; EPA, 1974). In determining the audibility of intrusive sound, the average measured ambient daytime and nighttime 1/3 octave band levels corresponding to the levels exceed 99 percent of the time (L_{99}) were assumed as the residual sound (see Section 3.4.4). The audibility level is the amount by which the intruding noise exceeds the masking sound. The threshold of audibility occurs when the difference between the intruding noise during the hour of peak project activity and masking sound is 0 dB in any 1/3 octave band. At the threshold of audibility, the statistical probability that the occurrence would be detectable by human observer is 0.50.

There are no absolute standards which define unacceptable levels, duration, or qualities of environmental sound. The U.S. Forest Service has established subjective audibility guidelines that they currently use to assess noise impacts for various "recreational opportunities" (Harrison et al., 1980). Recreational opportunities vary from primitive areas where people prefer to hear very little human-related sounds to modern recreational areas where a variety of mechanical and nonmechanical sounds are acceptable. Table 4-21 relates these recreational opportunities to the corresponding acceptable levels above the threshold of audibility.

Where noise levels are below the threshold of audibility, no impact will result from project noise. Where noise levels are audible but less than the level appropriate for the recreational opportunity, project noise will produce an insignificant impact. Various degrees of impact will result where noise levels exceed the level appropriate for the recreational opportunity. Based upon subjective studies and case histories of human reaction to various levels of increased noise, Table 4-22 is offered by DOE as a conservative method. For estimating the relative likelihood that an individual (recreationist or park visitor) would complain about project noise (ISO, 1971; Ver and Anderson, 1977, p. 28).

To evaluate the impact upon the few residents of the area, the DOE offers an indicator of broadband environmental noise impact, which is the energy-equivalent sound level defined in Section 3.4.4. The EPA has identified an energy-equivalent day and night sound level (L_{dn}) of 55 dBA as the level sufficient to protect the public from the effects of environmental noise in normally quiet outdoor areas where people spend varying amounts of time (EPA, 1974).

Table 4-21. Acceptable Levels above Threshold of Audibility for Various Recreational Opportunities

Recreational Opportunities	Acceptable Levels (dB)
Appropriate for primitive recreational areas; intruding noise not detectable.	0
Appropriate for trail camps, will not wake most sleepers; intruding noise normally not detectible.	5
Appropriate for undeveloped roadside camps accessible by 4-wheel drive and all-terrain vehicles.	10
Appropriate for roadside camps accessible by highway vehicles.	20
Appropriate for highly developed campgrounds in a quiet, suburban neighborhood.	40

Source: Harrison et al., 1980.

Table 4-22. Individual Response to Noise

dB Above the Appropriate Acceptable Level[a]	Likelihood of Individual Complaints
0 or less	No
greater than 0 but less than 5	Little
greater than 5 but less than 10	Some
greater than 10	Strong

(a) The appropriate acceptable level for various recreational opportunities is found in Table 4-21.

The L_{dn} is the average energy equivalent level for the entire day, with a 10-dB penalty added to nighttime levels (10:00 p.m. to 7:00 a.m.) to account for increased sensitivity to noise during these hours. The EPA has recommended adoption of an L_{dn} less than or equal to 55 dBA as a goal in project planning for future programs. Although a significant increase in noise over the existing quiet conditions may lower the quality of the environment, no health and welfare effects are expected to occur where levels are 55 dBA or less. The effects on humans for outdoor L_{dn} levels of 55 dBA include (EPA, 1974):

- Slight speech communication interference beyond 1 meter (3 feet) may be noted.
- Less than 3 percent of the population may be highly annoyed, depending on attitude and other nonacoustical factors.

For comparison, the existing L_{dn} levels measured near Davis Canyon average between 28 and 46 dBA with 28 dBA being typical of remote areas and 45 dBA or higher being typical of areas near highways, ranches, and communities (Section 3.4.4).

Cumulative effects have also been addressed by the EPA (1974). The cumulative effects of noise are divided into nonimpulsive and impulsive noise. For nonimpulsive noise, the EPA (1974) has concluded that outdoor noise levels having a yearly average energy equivalent level (L_{eq}) of 70 dBA or less over a 40-year period will protect against hearing loss in the general population.

The EPA (1974) guidelines for limiting exposure to impulsive noise (such as noise from blasting) are expressed in terms of peak pressure level, duration of individual pulses, and number of pulses per day. At an exposure rate of 100 pulses per day of 125 dB peak pressure, the exposed population will not experience noticeable hearing loss.

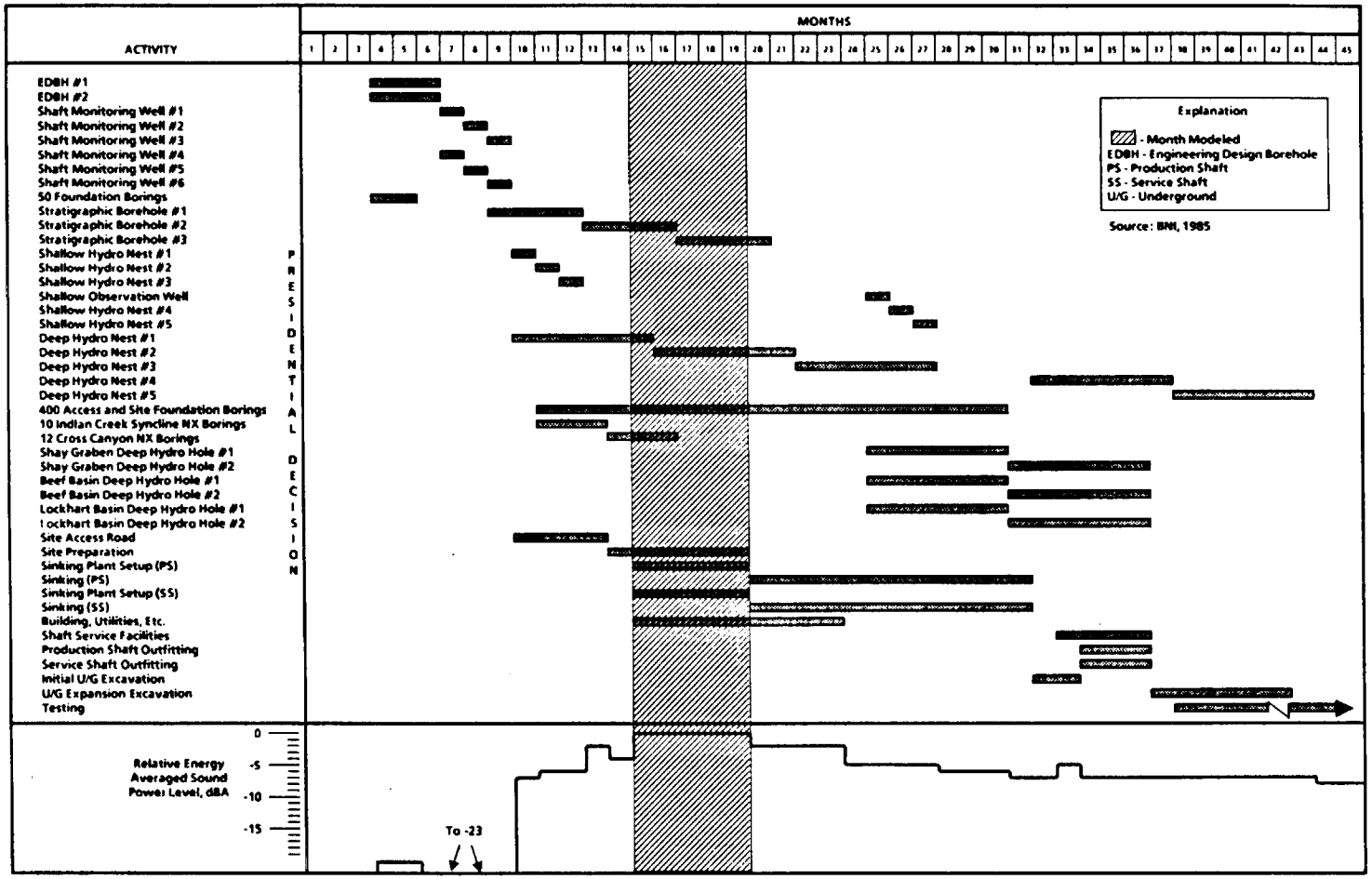
Protection of ruins, antiquities, and geologic structures from ground vibration caused by blasting will be accomplished by a vibration limit of 2 millimeters (0.08 inch) per second particle velocity (Siskind et al., 1980). This magnitude of ground motion is barely perceptable to the average observer. This criterion compares favorably with observations relative to seismic activity in the area (DOE, 1984).

The Occupational Safety and Health Administration (OSHA) regulates exposure to noise in the work place. Noise control measures will be applied as necessary to meet OSHA regulations.

4.2.1.6.2 Geologic Field Studies. Geological and hydrological boreholes will be located both within and outside of the ESF area (see Figure 4-2). The drilling activities will be of varying duration, depending on the type of boring (see Figure 4-26). While the drilling rigs will be in the general area for a period of 40 months, the drilling at each location will last only 1 to 6 months. Field study activities will result in some additional vehicular activity in the area of the boreholes and the site. Increases in sound levels from vehicular activity will be small, localized, and of short duration. Short-term increases in sound levels will result from the operation of truck-mounted generators for conducting geologic resistivity surveys. These generators are small, about the size of the engine-generators on motor homes, and will only produce noticeable increases in sound levels within about 300 meters (1,000 feet) for short periods of time at each survey location.

Noise from other proposed activities would result from vehicular traffic, backhoes, and trucks used for seismic work, however, they would produce considerably less noise than the drilling operations. Generators at the proposed atmospheric monitoring stations would operate for a short period of time and would be audible for only a short distance, as they would be enclosed within an insulated instrument shed.

Noise impacts from these activities are discussed in Section 4.2.1.6.5.



Schedule and Relative Sound Level Site Characterization

Figure 4-26

4.2.1.6.3 Exploratory Shaft Facility. Development of the exploratory shaft facility (ESF) will begin with the drilling of the two engineering design boreholes (EDBH). Additional drilling activities will occur within the ESF area over a 27-month period. In addition to these activities, site preparation, shaft sinking, setup, and facility construction activities will extend over 34 months, followed by underground excavation and testing. If this site is not chosen for the repository, the testing will be followed by decommissioning and reclamation.

Noise impacts from these activities are discussed in Section 4.2.1.6.5.

4.2.1.6.4 Methodology. Potential noise impacts from site characterization, including geological studies, (Section 4.2.1.6.5) were determined by modeling a representative day during the peak activity period (BNI, 1985c). The peak period was determined by summing sound power levels of all equipment during each month of site characterization activities with usage and load factors included and day and night weighting applied. The maximum level occurred during months 15 through 19; however, project noise will remain near this level for about 3 years (see Figure 4-26). Ongoing activities in these months included geotechnical studies of stratigraphic boreholes, deep hydro-nests, access and site foundation borings, and cross-canyon borings (Section 4.1.1). Additional activities include site preparation, sinking plant setup for both the service shaft and production shaft, and building and utility construction. Noise from traffic on the site access road and Utah State Highway 211 (Utah 211) was also modeled.

Computer modeling was based on a one-third octave band analysis and included equipment duty cycles and loading conditions. To minimize the impact of noise in the area adjacent to the Davis Danyon site, the noise source emission terms used in the noise model were based on equipment quieted through the use of proven and available noise control technology. All stationary equipment were assumed to be enclosed to quiet them to the background level at the park boundary. Mobile equipment and drill rigs were assumed to be fitted with engine enclosures and residential grade mufflers. Noise reduction due to these controls range from 5 to 15dB for most equipment. Maximum one-third octave band sound power levels were derived for each equipment item using quieted equipment vendor data or published reports (BNI, 1985c). In cases where sound data were incomplete or unavailable, levels were synthesized from related data, known characteristics of comparable equipment, and published standards. The expected hours of operation (duty cycles) and the percent of time operating near full load (loading conditions) were developed for each equipment item.

The environmental noise prediction model (ENPM) was used to model project-related noise. The computer model determines the one-third octave band sound level as a function of distance from each source using the relationship described by Beranek (1971, pp. 164, 165). The model considers the following:

- The sound power level of the source
- The spatial relationships between noise sources, barriers, and receptors
- Excess attenuation by air absorption (ASA, 1978)
- Anomalous excess attenuation (EEI, 1978, 5-2)
- Attenuation by barriers (Tatge, 1973)
- Duty cycle and loading conditions (used to estimate energy equivalent levels)
- The hearing threshold of humans (Robinson and Dadson, 1956)
- The average daytime and average nighttime residual levels (Section 3.4.4)
- Approximation of the effects of vertical temperature and wind gradients.

The sound contributions of all sources are added to the background residual level to provide a total composite L_{dn} at specified locations on an X-Y-Z grid (BNI, 1985c). The L_{dn} value due to the average daytime and nighttime residual levels is 24 dBA. The 10dB weighting for nighttime noise was employed both in the computation of ambient (Ldn = 24 dBA) as well as for the intrusive noise. Grid intervals are 0.8 kilometer (0.5 mile) apart in the north and south directions and 24 meters (80 feet) apart in the vertical direction. The composite level represents, the effect of all project equipment including borehole drilling (geologic studies) and project related transportation sources. For transportation, the estimated levels at each

receptor considers the shortest distance from the corridor, average vehicle speed, and traffic volume. The audibility analyses considers the hour of peak activity for each source and the L_{dn} calculation considers the temporal fluctuations of project activities throughout the day.

Major terrain variations in the Paradox Basin are represented by barriers in the noise-modeling study. The ENPM considers both noise reflection and noise attenuation due to sound diffraction. The model limits the total barrier attenuation to 24 dB (Tatge, 1973).

Barrier walls also act as reflecting surfaces from which noise will bounce. The model determines the mirror image of a source and adds its noise contribution to the composite level at each receptor location. No reflection is calculated if there are other intervening barriers between the source and the receptor image or between receptor and the source image. Only the first reflection from each barrier source receptor combination is considered.

Refraction of sound is approximated by considering a mixing layer characterized by (1) -1C/100 meter temperature lapse rate (2) mean annual wind speed through the layer (3) an inversion at top of the layer that serves as an oblique reflecting surface. The physical laws of refraction and of reflection are also used (Eshbach and Souders, 1975, p. 1094). Refraction is assumed to be symmetrical about the wind vector in the horizontal plane around the sound source.

Meteorological data are provided from Section 3.4.3. The average temperature of 12 C (53 F) and the average relative humidity of 45 percent were assumed. The annual mean morning mixing height and mean afternoon mixing height were used to predict the additive effects of inversion to the nighttime and daytime sound levels, respectively. The annual mean wind speed of 4.7 mph was conservatively assumed to have a direction from the sound source to the receiver.

Noise impacts resulting from blasting were modeled separately. The audibility estimate was made using a technique described by Fidell and Horonjeff (1982). Blasting noise predictions for Davis Canyon are based on empirical formulas and relationships derived from the open literature spanning the years 1965 to 1985 (BNI, 1985c). Variables and factors which are taken into account in the calculations include the following:

- The charge weight per delay of explosive (12.7 kilograms [27.9 pounds])
- Burial depth of the explosive charge (i.e. overburden) (2.44 meters [8 feet])
- Distance from the source
- Barriers between the source and receiver
- Attenuation due to air absorption
- Meteorological conditions.

Three wind conditions were used in the blasting model: (1) annual mean wind velocity from the source toward the receiver, (2) calm conditions (wind velocity = 0), and (3) annual mean wind velocity from the receiver toward the source. Four vertical temperature gradients were used: (1) large positive (2) small positive, (3) zero, and (4) small negative. Attenuation resulting from distance, anomalous attenuation, air absorption, and canyon walls, which act as noise barriers, were accounted for by the model. The results of this study are discussed in BNI (1985c) and are summarized in Section 4.2.1.6.5 as the extremes of the values obtained. The greatest noise propagation into the park occurs when there is a large positive temperature gradient and the wind blows from the blast site to the park. The least occurs when these is a small negative temperature gradient and the wind blows from the park to the blast site.

Although blasting activity will include parting and breaking shots for site clearing and grading, only the surface blasting associated with shaft sinking, which involves the largest explosive charges, was modeled.

4.2.1.6.5 Uncertainties. It is believed by the DOE that the noise modeling carried out in this section was based on the best available meteorological data, the latest literature on sound emission levels, and the state of the art of noise modeling techniques. However, uncertainties do exist in this modeling and are caused largely by the following:

1. Uncertainties in sound emission levels to approximately ±5 dB.

2. The precise amount of quieting of the equipment to be used. It is estimated that a 2 to 5 dB reduction in noise levels remains possible for some sources.

3. The choice of the degree of conservatism in the noise analysis. The selection of another value for typical intrusive noise [e.g., L(10) instead of L(eq)] would make the predictions more conservative.

4. Consideration of wind and temperature gradient effects on noise propagation. Unfavorable gradients (when occurring) can significantly increase noise propagation into the Park whereas favorable gradients can significantly reduce such impacts.

The accumulated effects of these uncertainties can be large at any point and at any time outside the site boundary.

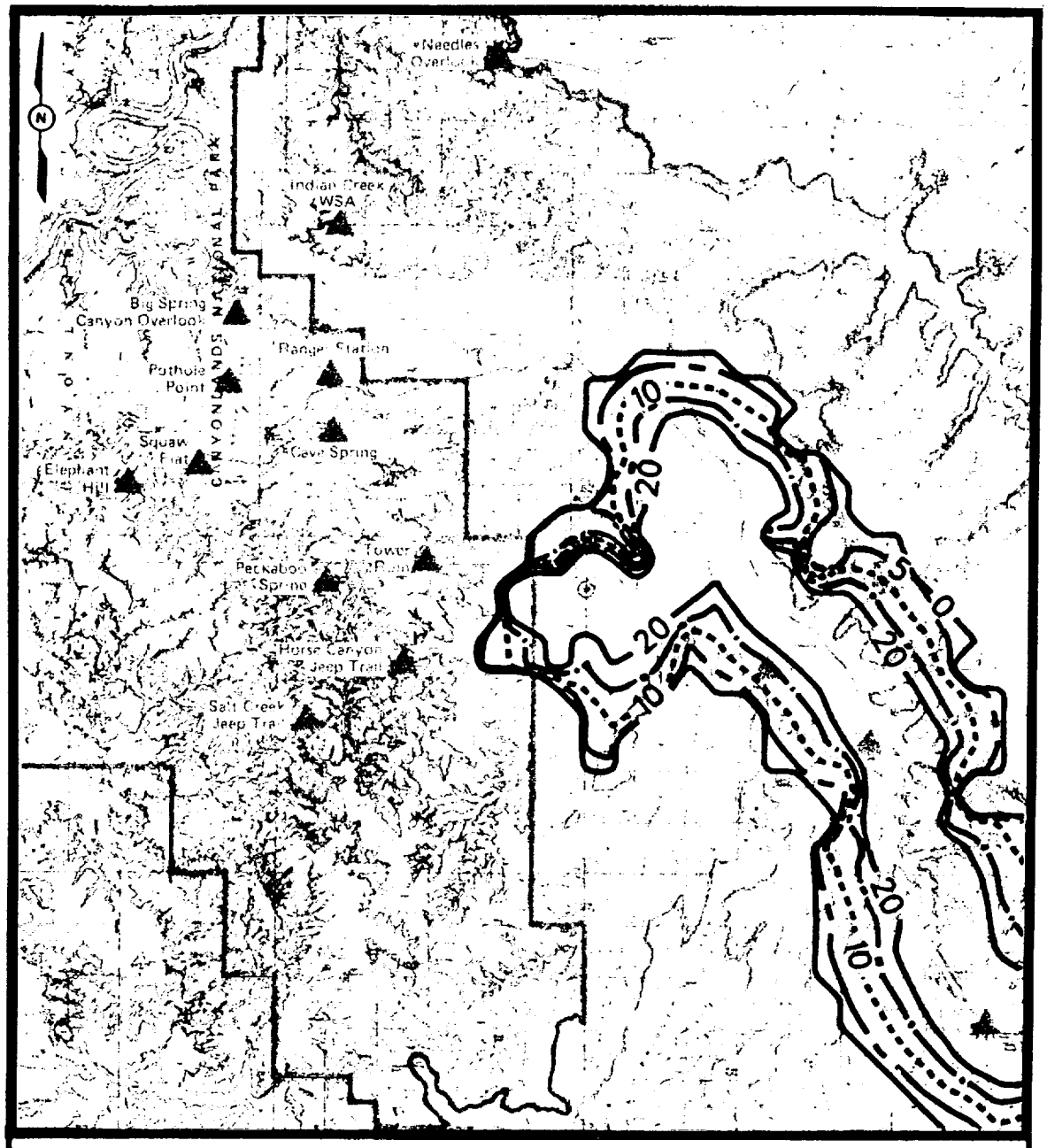
4.2.1.6.6 Noise Impacts. The modeling results for site characterization are presented in Figures 4-27 and 4-28. Figure 4-27 depicts the audibility isopleths (contours) for 0, 5, 10, 15, and 20 dB above the threshold of audibility. The audibility contours represent the maximum one-third octave band difference between the highest hourly project noise and the masking sound. Within the 20 dB isopleth, energy equivalent sound levels (L_{dn}) become a better indicator of noise impacts. Figure 4-28 depicts composite L_{dn} levels with contours shown for 35, 45, and 55 dBA (small closed contour around site). These composite L_{dn} levels represent the energy summation of the hourly L_{eq} levels and the corresponding daytime or nighttime residual level. Measured L_{dn} values ranged from 28 dBA in canyonlands to 46 dBA near dugout ranch.

The potential impacts to sensitive receptors are summarized in Table 4-23 showing predicted and acceptable levels for both audibility and L_{dn}. Acceptable levels appropriate for various recreational opportunities are presented in Table 4-21. No acceptability criteria have been developed for wilderness study areas. However, for the purposes of assessing impacts, it is assumed that these areas correspond to a "primitive" recreational opportunity.

Equipment noise levels resulting from site characterization may be audible 2.0 kilometers (1.3 miles) into Canyonlands National Park during a 5-month period. Lower levels are expected during other periods of site characterization as indicated by the relative sound power levels plotted on the bottom of Figure 4-27.

Of the sixteen sensitive receptors listed on Table 4-23, four will experience audible levels, and twelve will experience no impact from the project. Ten of these twelve receptors are within the park and include primitive and developed campgrounds, as well as areas accessible by both two-wheel and four-wheel drive vehicles. The nearest park boundary is predicted to have an audibility level 20 dB above acceptable levels. This, according to Table 4-22, results in a likelihood of individual complaints. Newspaper Rock State Historical Monument and the most northern extent of Bridger Jack Mesa Wilderness Study Area will experience an increase in noise levels as a result of peak hour traffic on Utah 211. The likelihood of individual complaints at these two receptors is "little" and "strong", respectively. Dugout Ranch is expected to have a composite L_{dn} level of 38 dBA. This is below the EPA guideline of 55 dBA. The L_{dn} of 55 dBA will occur at a distance of less than 0.1 kilometer (0.06 mile) on either side of the highway.

The isopleths (contours) shown in Figures 4-27 and 4-28 reveal that the peak hour traffic noise along Utah 211 and the site access road accounts for a large portion of the noise impacts resulting from site characterization activities. The noise contribution from borehole drilling activities is minor due to the mitigation measures assumed for this equipment.



Explanation

Noise Isopleths in dB Above Masking Level

Sensitive Receptor

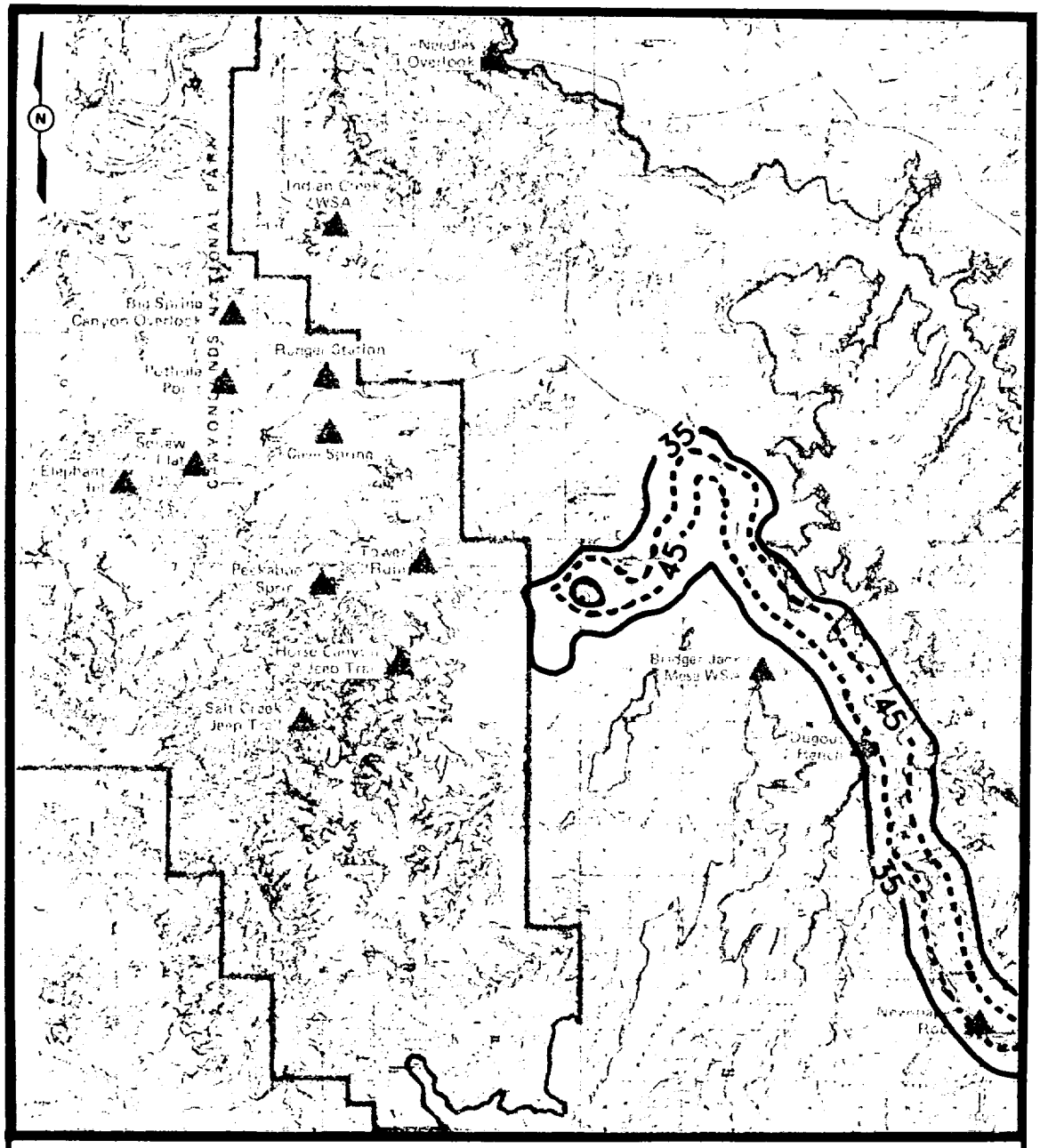
Site

Scale 0 1 2 Mi / 0 1 2 3 4 Km

Source: BNI, 1985c.

Davis Canyon Site Characterization Audibility Contours

Figure 4-27



Explanation

Noise Isopleths in dBA

Sensitive Receptor

Site

Scale
0 1 2 Mi.
0 1 2 3 4 Km

Source: BNI, 1985c.

Davis Canyon
Site Characterization
Day/Night Sound Level

Figure 4-28

Table 4-23.. Noise Impacts to Sensitive Receptors - Davis Canyon, Site Characterization[a]

	Audibility Level		L_{dn} Level[c]	
	Predicted (dB above threshold)[b]	Acceptable (dB above threshold)[e]	Predicted (dBA)[d]	Acceptable (dBA)[e]
Dugout Ranch residence	27	--	38	55
Needles Overlook	na	20	24	--
Newspaper Rock State Historical Monument	21	20	31	--
Indian Creek Wilderness Study Area	na	0	24	--
Bridger Jack Mesa Wilderness Study Area	14	0	28	--
Canyonlands National Park Sites:				
Nearest park boundary	30	10	36	--
Peekaboo Spring Campground	na	5	24	--
Squaw Flat campground	na	10	24	--
Tower Ruin	na	10	24	--
Ranger Station	na	20	24	--
Elephant Hill	na	10	24	--
Pothole Point	na	20	24	--
Big Spring Canyon overlook	na	20	24	--
Horse Canyon Jeep trail	na	10	24	--
Salt Creek Jeep trail	na	10	24	--
Cavespring	na	20	24	--

(a) Although these impacts are estimated for the period of greatest activity, the other periods related to site characterization are expected to have impacts that are not significantly less.

(b) na = not audible (below threshold of audibility).

(c) L_{dn} represents combined project and background noise.

(d) 24 represents the residual level with a 10 dB nighttime weighting.

(e) - = no criteria have been identified.

Shaft blasting will occur in month 20 during shaft sinking. When meteorological condition favorable to sound propagation exists, blasting will be audible 47 kilometers (29 miles) from the blast site. More typical sound propagation conditions (with the wind blowing toward the blast site) would reduce this distance to approximately 24 kilometers (15 miles). Blasting will be scheduled to occur during periods when the wind blows from Canyonlands National Park toward the blast site. As shafts are sunk, blasting is expected to be increasingly muffled by the effects of shaft depth. There are expected to be no more than three blasts per day. Each blast will consist of 10 pulses (charges) separated by 0.5 second. After shafts have reached depths of about 27 meters (90 feet) over a period of 6 to 12 days, a sinking stage will be installed which will muffle the noise, and blasting will no longer be a significant noise source (BNI, 1985c). The park visitor who is exposed to blasting noise will not experience more than three blasts in any 24-hour period, and then only during one of the days when surface blasting is occurring. The highest peak sound pressure level will be below 90 dB at 1.0 kilometer (0.6 mile). These conditions are well below the criteria given in Section 4.2.1.6.1, and cumulative adverse health effects to the general public are not anticipated.

Projections of ground motion due to blasting are below 2 millimeters (0.08 inch) per second at the Canyonlands National Park boundary. The resulting vibration levels are below the threshold of perception for humans. No impacts to the delicate rock formations or ruins in Canyonlands National Park are expected as a result of blasting.

In summary, potential impacts from the ESF activities modeled include the following:

- Equipment noise levels being audible 2.4 kilometers (1.5 miles) into Canyonlands National Park for approximately 3 years
- Noise levels at the nearest park boundary resulting in a strong likelihood of individual complaints throughout the site characterization phase
- Peak hour traffic on Utah 211 and the site access road resulting in increased noise levels at Newspaper Rock State Historical Monument, resulting in little likelihood of individual complaints throughout site characerization
- Peak hour traffic on Utah 211 resulting in strong likelihood of individual complaints at Bridger Jack Mesa Wilderness Study Area
- Blasting being audible up to 24 kilometers (15 miles) west of the blast site three times per day for 12 days during month 20.

As may be inferred from the relative sound power levels at the bottom of Figure 4-26, project related noise levels for other periods of ESF activities may be expected to be no more than those for the period modeled.

The impact of tonal noise from the equipment is more difficult to quantify. Tonal noise may be produced by any equipment, depending on the type and condition (wear) of the equipment. Although typical octave band information exists for the equipment to be used, the specific tonal components and their magnitudes depend on the manufacturer of the equipment. Two factors aid in minimizing tonal noise impacts:

1. The broadband noise caused by equipment such as engines (mobile equipment) tends to mask the tones, reducing the likelihood that the tones would be audible in noise-sensitive areas.
2. Many of these tones (for noise sources such as welding rigs, air compressors) are at high frequencies (greater than 1,000 hertz) and are reduced by atmospheric attenuation.

4.2.1.6.7 Noise Impact Mitigation. The state-of-the-art noise control techniques assumed in the modeling will be a programmatic requirement for all electrical and mechanical equipment during site characterization. Construction contracts will contain provisions requiring contractors to implement the following measures:

- Use and maintain equipment noise controls
- Observe specific shift starting and stopping times so that noise emissions will be limited to less sensitive times of the day
- Use and maintain enclosures, acoustically designed buildings, baffles, exhaust and intake fan silencers, and other noise control features necessary to control noise emissions from stationary equipment to below the threshold of audibility at 1.6 kilometers (1 mile)
- Restrict use of portable saws to enclosed areas
- Limit blasting to times when meteorological conditions are least favorable to noise propagation.

Possible additional mitigation measures to reduce the extent to which audible levels intrude into Canyonlands National Park include the following:

- Implementation of unproven equipment noise controls providing 5 to 10 dB reduction for scrapers, loaders, and graders
- Selection of equipment manufactured to minimize or eliminate any annoying audible tonal components
- Schedule the noisiest 5-month phase (sinking plant setup) to coincide with the period which would impact the fewest park visitors.

If the Davis Canyon site is selected, mitigation measures will be developed based on established need and discussions with appropriate agencies.

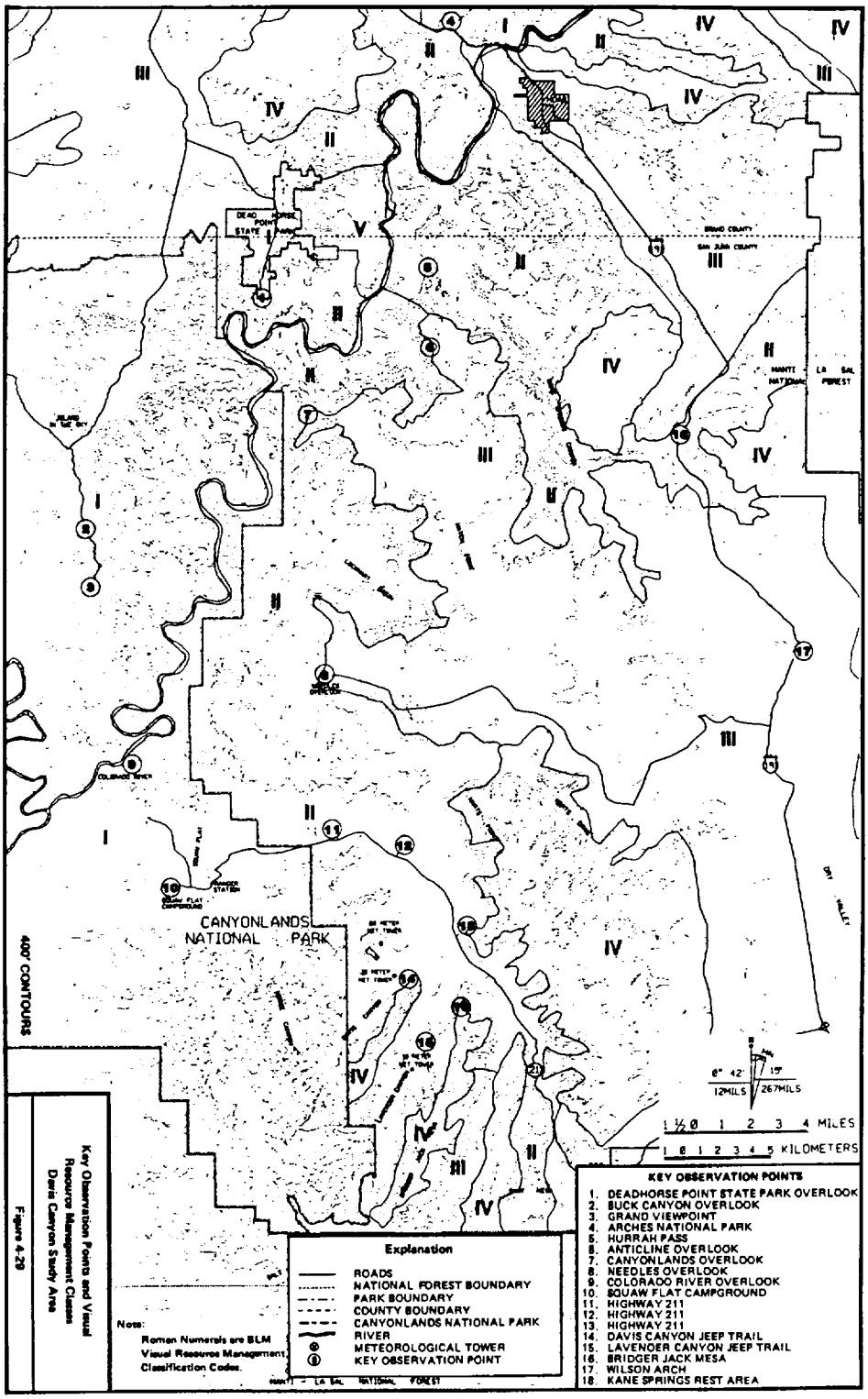
4.2.1.7 Effects on Aesthetic Resources

This section contains a discussion of the potential impacts on the visual character of the landscape from introduction of large structures and associated development into Davis Canyon.

In determining the daytime visual impacts of site characterization activities, Bureau of Land Management (BLM) visual resource management inventory was used to determine the importance of the potentially affected landscape. Then the areas and observation points from which these activities would potentially be seen were identified and mapped. Finally, the degree of contrast with the landscape was evaluated to characterize the visual impacts and developed mitigation techniques to minimize those short and long term visual impacts. Field evaluation for contrast ratings was performed using the methodology described below.

4.2.1.7.1 Methodology. Using the BLM's Visual Resource Management (VRM) program (BLM Manual 8411 "Upland Visual Resource Inventory and Evaluation", August, 1978 and BLM Manual 8431 "Visual Resource Contrast Rating", August, 1978), the impact assessment utilizes existing VRM Classes (Figure 4-29 and Table 4-24). Although Arches National Park, Canyonlands National Park, and Dead Horse Point State Park are not BLM land, they were assigned Class I (the highest VRM Class) in accordance with the VRM criteria.

A larger reproduction of this figure appears at the back of this volume.



Key Observation Points and Visual Resource Management Classes
Davis Canyon Study Area
Figure 4-29

Table 4-24. Summary of VRM Inventory Data for Geologic Field Activities, ESF, and Other Activities

Project Component[a]	Scenic Quality[c] Class	Distance Zone[d]	Sensitivity Level[c]	VRM Class[c]
Drilling Program[b]				
SB #1 - 3	B	FG/MG	High	II
SHN #1 - 5	B	FG/MG	High	II
SHOW	B	FG/MG	High	II
DHN #1 - 5	B	FG/MG	High	II
SGHH #1 - 2	C	FG/MG	High	III
BBHH #1	C	FG/MG	High	III
BBHH #2	C	FG/MG	High	III
LBHH #1 - 2	A	FG/MG	High	II
Champlin	B	FG/MG	High	II
Seismic Reflection Surveys[b]				
3-D Seismic Survey	B	FG/MG	High	II
Exploratory Shaft Facility	B	FG/MG	High	II
Other Activities				
Lavender Canyon Met. Tower	A	FG/MG	High	II
Davis Canyon Met. Tower	B	FG/MG	High	II
60-Meter Met. Tower	B	FG/MG	High	II

(a) Includes access only to the project activity.

(b) See Section 4.1.1 (Geotechnical Field Studies) for description of activity location and explanation of acronyms.

(c) See Section 3.4.5 (Aesthetic Resources) for description of term

(d) Distance Zone

Foreground/Middleground	FG/MG	0 - 5 miles
Background	BG	5 - 15 miles
Seldom Seen	SS	less than 15 miles

Source: Meiiji Resource Consultants, 1980.

VRM classes imply standards by which the visual resources of an area are managed. They are derived from an inventory of the area's scenic quality, distance zone, and sensitivity level.

The scenic quality class indicates the relative visual importance of the rated unit to other units in the physiographic province (Colorado Plateau) in which it is located. Class A areas have landform, water form, and vegetation patterns which are unusual or outstanding; Class B areas have features with variety in form, line, texture, and color but which are not visually outstanding; and Class C areas have little variety and no dominating features.

Distance zones are divided into three categories as well. The foreground (FG) and middleground (MG) is the seen area from a travel route, use area, or other observer position to a distance of 8 kilometers (5 miles), where individual plants no longer have form or texture and landform colors and textures become muted. The background (BG) is the remaining area which can be seen from a major travel route to approximately 24 kilometers (15 miles), where landforms and vegetation are still visible as patterns of light and dark. Seldom seen (SS) areas are either beyond the background distance zone, away from major travel routes or use areas, or seen from low transporation routes only. Whenever the foreground and middleground zone from one travel route overlapped the background from another route, only the foreground and middleground was designated.

Sensitivity levels indicate the relative degree of user interest in visual resources and concern for changes in the existing landscape character. Land use, numbers of viewers and viewers types were all taken into consideration when determining visual sensitivity. Levels of sensitivity range from high to low.

The initial step in the assessment required identification of the viewsheds, or potential visibility, of the site characterization activities by: (1) locating potential observation points within the surrounding landscape, and (2) mapping the potential visibility, or line-of-sight, of the ESF and other activities from those viewing positions. Viewshed mapping was not conducted for the geologic field studies primarily because of the temporary nature of the activities. However, their potential visibility was determined in the field for contrast rating purposes.

Key observation points (KOPs) were selected and included based on viewpoints mentioned in public and agency comments on the draft Environmental Assessment. For the geologic field studies, KOPs were chosen along several nearby jeep trails, along Utah 211 where potential visibility is high, and from within Bridger Jack Mesa Wilderness Study Area, a visually sensitive area. KOPs selected for the ESF and other activities included established viewpoints, designated overlooks, campgrounds, and jeep trails. These KOPs were chosen to represent both the concentration of typical viewers and the general distribution of viewers within the area potentially affected by the ESF.

After KOPs were identified, the land surface from which the ESF and other activities would be visible was mapped using the VIEWIT computer program (Travis et al., 1975). The viewshed analysis was performed using digitized elevation data obtained from the United States Geological Survey (USGS). The USGS assembled the data digitizing 1:250,000 scale maps with a contour interval of 60.8 meters (200 feet). Potential visibility was analyzed and mapped within a 24.1 kilometer (15 mile) radius surrounding the proposed facility, considered by BLM's Visual Resource Management Program to be the approximate limit of the background distance zone, where objects are still distinguishable as forms or outlines. The viewsheds indicate where the ESF would be within the direct line-of-sight at ground level; hence, assuming ideal atmospheric conditions and no vegetative screening, the ESF activities would be potentially visible within these viewsheds.

The computer-generated maps were independently checked by manual cross-sections, overlay examination, and four computer-generated USFS PERSPECTIVE PLOT sketches (from KOP #8, #10, #13, and #14). Also, the vertical reliability of the terrain data was further tested for meaningful differences in the potential visibility of the ESF by simulating the raising and lowering the height of the tallest meterological tower by 15.2 meters (50 feet), plotting each viewshed, and comparing these with the viewshed run at the designated height. Significant differences in visibility did not appear, so that magnitude of variability inherent in the terrain data interpretated at 60.8 meter (200 feet) contour interval was determined to be acceptable for this analysis.

To measure the degree of contrast between the proposed activities and the existing landscape character, the landscape was first separated into major features (land or water surface, vegetation, structures) and each feature, in turn, into its basic elements (form, line, color, texture). Each element was assigned a weighted value based on its significance in the landscape (form = 4, most important, to texture = 1, least important). The contrast rating was used to compare the proposed activity with existing conditions element by element, feature by feature, according to the degree of contrast (strong = 3, moderate = 2, weak - 1, none -0). The element value was multiplied by the degree of contrast, indicating the magnitude of visual impact and revealing which existing features and their respective elements would be subject to the greatest visual impact. This scope was then compared with the allowable levels of contrast for the appropriate VRM class to determine if mitigation would be required to reduce visual impacts.

The significance of the impact from an activity is assessed according to the degree of the visual contrast between it and the existing landscape. The contrast is influenced by the observer's position and distance from the activity. Impacts were considered "insignificant" if the contrast ratings scores were below the requirements shown in Table 4-25 or "significant" if they exceeded them. Impacts were considered insignificant only if they met the VRM class objectives listed in Table 4-25.

Generally, impacts evaluated as "insignificant" are those in which the contrasts may be seen but would not attract attention. "Significant" impacts are those in which the contrasts would be evident and attract attention.

Several other factors influenced the degree of impact: elevation of the observer relative to the activity being viewed and the distance between the observer and that activity. Of the three positions utilized for this study, observer inferior (below activity), observer normal (level with activity), and observer superior (above activity), the latter usually has the greatest influence on visual impact. More importantly, as the viewing distance decreases, the contrasts created by activities become more visible and thus more critical. Distances between the observer and activity were divided into the same three zones utilized for the VRM inventory described earlier in this section. Whenever distance zones overlapped, the most critical or closest distance zone was employed for analyzing degree of impact.

The amount of time it takes for an area to successfully revegetate is typically 2 to 4 years (BLM, 1982c). Few projects would be expected to meet the VRM class objectives immediately upon completion. Therefore, impacts for this study were considered short term (less than 4 years), or long term (greater than 4 years), so that differences in the impacts over time could be separately evaluated.

Table 4-25. Requirements Used to Determine Significance of Visual Impact

VRM Class	Element[a] Score	Contrast Rating Score	VRM Class Objectives
I	less than 1 (week)	less than 10	Visual contrasts may be seen but should not attract attention
II	less than 2 (moderate)	less than 12	Visual contrasts may be seen but should not attract attention; changes in any of the basic elements should not be evident.
III	less than 2 (moderate)	less than 16	Visual contrasts may begin to attract attention but changes should be subordinate to existing landscape character.
IV	No element score used	less than 20	Visual contrast may attract attention and dominate, but should repeat the basic landscape elements.
V[b]			

(a) Form, line, color, texture.

(b) This class is a temporary one for area requiring rehabilitation to meet desirable VRM class objectives.

4.2.1.7.2 Geologic Field Studies. Geologic field studies will involve constructing access roads, clearing and grading land, erecting drill rigs, and moving equipment. Taller drill rigs will be visible but operation will be short-term lasting 6 months or less. When boreholes are completed, rigs will be removed. Well heads for stratigraphic and deep hydrologic wells will be capped and protrude 1 to 2 feet above the ground. These wellheads would be removed if the site is not selected for repository development.

The visual impacts of the Davis Canyon drilling programs, and 3-D seismic survey were evaluated using the visual contrast methodology described above. The location and description of these geologic activities are presented in Section 4.1.1. Table 4-24 summarizes the VRM inventory data for the sites on which these activities are proposed.

Drilling Program. As described above, the visual contrast of the drilling program was determined from five KOPs: Utah 211, at South Six Shooter Peak, Davis Canyon Jeep Trail, Lavender Canyon Jeep Trail, Beef Basin Jeep Trail, and Bridger Jack Mesa. Twenty-one drilling locations were evaluated for visual impact in Davis Canyon (Table 4-26). LB#1 and 2, and SG#1, and 2 are not visible from any KOP. As shown in Table 4-26, DHN 5 is visible from the most KOPs, three, while DHN 1, SHOW and SHN 3 are visible from two KOPs. The remaining drilling locations are potentially visible from only one KOP.

Table 4-27 summarizes the potential visual impacts of the drilling program. Of the 17 sites visible from the five KOP's studied, 12 would create a significant short term impact and 6 a significant long term impact. Significant short term impacts are generally defined as the visibility of the entire operation (i.e., rig, trailers, vehicles, etc.) which is readily noticeable, and long term impacts as the readily noticeable visibility of either the well pad, monitoring road or the success of revegetation. Therefore, a single location can have both short and long term significant impacts.

Seismic Program. The 3-D seismic survey planned for the Davis Canyon site was evaluated from five KOPs: Utah 211 at South Six-Shooter Peak, Davis Canyon Jeep Trail, Lavender Canyon Jeep Trail, Beef Basin Jeep Trail, and Bridger Jack Mesa. Seismic activity can be seen from two KOPs. A summary of the visual resource management impacts of these seismic activities is presented in Table 4-27.

4.2.1.7.3 Exploratory Shaft Facility

Viewshed Analysis. Location of the selected KOP's and the VRM Class in which they are located are listed in Table 4-28 and shown on Figure 4-29.

Viewshed mapping incorporated the full range of vertical structures and horizontal area covered by the ESF and included the following:

- 38.1 meter (125 feet) Service Shaft Headframe
- 38.1 meter (125 feet) Production Shaft Headframe
- 9.1 meter (30 feet) Salt Stockpile
- ESF Ground Level Activities.

These viewsheds are shown in Figure 4-30 (Composite Viewshed, Service and Production Shaft Headframes), Figure 4-31 (Viewshed: Salt Stockpile), and Figure 4-32 (Viewshed: ESF Ground Level Activities).

Overall Visibility from Key Observation Points. The ESF is potentially visible from four KOPs: Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16). As discussed below, individual ESF activities are visible only from those areas within Canyonlands National Park that receive little visitor use since they do not contain designated hiking or jeep trails. Table 4-29 shows the specific ESF activities visible from these KOPs.

Table 4-26. Geologic Field Studies Visibility Summary

Geologic Studies[a]	Key Observation Points[b]				
	Utah 211	Davis Canyon Jeep Trail	Lavender Canyon Jeep Trail	Beef Basin Jeep Trail	Bridger Jack Mesa
Drilling Program					
SB1	X				
SB2	X				
SB3	X				
DHN1	X	X			
DHN2	X				
DHN3	X				
DHN4	X				
DHN5	X		X		X
SHOW	X	X			
SHN1		X			
SHN2		X			
SHN3	X	X			
SHN4		X			
SHN5		X			
LB1					
LB2					
BB1				X	
BB2				X	
SG1					
SG2					
Champlin				X	
Seismic Program					
3-D Seismic Survey		X	X		

Note: X = Activity is visible from that KOP; all other activities are not visible.

(a) See Section 4.1.1 (Geotechnical Field Studies) for detailed descriptions of activity locations and explanation of acronyms.

(b) KOPs for the geologic field studies are not necessarily the same as those used in the viewshed analysis (Figure 4-28). The KOPs in this table represent a series of point within the general vicinity.

Table 4-27. Summary of VRM Impacts of Geologic Field Activities, ESF, and Other Activities[a]

Project Component[b]	Observer Position	Distance[c]	Impacts[d] Short Term	Long Term	Comments
PART A: From Utah 211 at South Six-Shooter Peak KOP					
Drilling Program					
SB #1	Normal	1.75 Miles	Sig.	Insig.	Entire drilling operation visible for extended period of time from scenic pull-out, as well as along Utah 211.
SB #2	Normal	0.33 Mile	Sig.	Sig.	Highly visible location for both west and east bound Utah 211 traffic.
SB #3	Inferior	1,500 Feet	Sig.	Sig.	Entire drilling operation is visible, primarily by eastbound Utah 211 traffic monitoring well pad visible also.
SHN #3	Normal	2.5 Miles	Sig.	Insig.	
SHOW	Normal	3.25 Miles	Sig.	Insig.	
DHN #1	Inferior	1 Mile	Sig.	Insig.	Limited viewing of drill tower, long term monitoring well pad not visible.
DHN #2	Normal	2 Miles	Sig.	Insig.	Entire drilling operation visible for extended period of time from scenic pullout, as well as along Utah 211.
DHN #3	Inferior	3,000 Feet	Sig.	Sig.	Visible location for both west and east bound Utah 211 traffic.
DHN #4	Superior	700 Feet	Sig.	Sig.	Entire drilling operation visible for extended period of time from scenic pullout, as well as along Utah 211.
DHN #5	Normal	1 Mile	Sig.	Insig.	Entire drilling operation would be visible, primarily by eastbound Utah 211 traffic. Flat site could be reclaimed easily.
Seismic Reflection Lines					
Exploratory Shaft Facility	Normal	3.5 Miles	Sig.	Insig.	Salt pile color and road will be highly noticeable.
Other Activities					
Lavender Canyon Met. Tower	Normal	3.5 Miles	Insig.	Insig.	Distance would render the lattice type tower almost invisible.
Davis Canyon Met. Tower	Normal	1 Mile	Insig.	Insig.	Inherent size of cross members painted an environmental color would render negligible contrast.
PART B: From Davis Canyon Jeep Trail KOP					
Drilling Program					
DHN #1	Inferior	1 Mile	Insig.	Insig.	Limited visibility of the drill tower, long term monitoring well pad would not be visible.

Table 4-27. Summary of VRM Impacts of Geologic Field Activities, ESF, and Other Activities[a]
(Page 2 of 3)

Project Component[b]	Observer Position	Distance[c]	Impacts[d] Short Term	Impacts[d] Long Term	Comments
PART B: From Davis Canyon Jeep Trail KOP (Con't)					
SHN #1	Inferior	1.75 Miles	Insig.	Insig.	Limited visibility of the drill tower, long term monitoring well pad would not be visible.
SHN #2	Inferior	1.5 Miles	Sig.	Insig.	Entire drilling operation visible, long term monitoring well pad visible.
SHN #3	Inferior	0.75 Mile	Sig.	Sig.	Full visibility of entire drilling operation, long term monitoring well pad visible.
SHN #4	Inferior	1.75 Miles	Insig.	Insig.	Limited visibility of drill tower, long term monitoring well pad would not be visible.
SHN #5	Inferior	1 Mile	Sig.	Insig.	Limited visibility of drill tower, long term monitoring well pad would not be visible.
SHOW	Inferior	1.25 Miles	Sig.	Sig.	Full visibility of entire drilling operations, long term monitoring well pad visible.
Seismic Reflection Lines					
3-D Seismic Survey	Inferior	0 - 1.5 Miles	Sig.	Sig.	Clearing of vegetation for access would create noticeable line contrasts.
Exploratory Shaft Facility	Inferior	1.5 Miles	Sig.	Sig.	Entire facility highly noticeable with many different building forms and colors, and salt stockpile form and color.
Other Activities					
Davis Canyon Met. Tower	Normal	0.5 Mile	Sig.	Sig.	Close proximity to trail allows complete visibility.
60 Meter Met. Tower	Inferior		Insig.	Insig.	The painted lattice tower would have a backdrop against the cliff and would create low line contrasts.
PART C: From Lavender Canyon Jeep Trail					
Seismic Reflection Lines					
Exploratory Shaft Facility	Inferior	1.5 Miles	Sig.	Sig.	Entire facility highly noticeable with many different building forms and colors, and salt stockpile form and color.
Other Activities					
Lavender Canyon Met. Tower	Normal	500 Feet	Sig.	Sig.	Close proximity to trail allows complete visibility.

Table 4-27. Summary of VRM Impacts of Geologic Field Activities, ESF, and Other Activities[a]
(Page 3 of 3)

Project Component[b]	Observer Position	Distance[c]	Impacts[d] Short Term	Impacts[d] Long Term	Comments
PART D: From Beef Basin Jeep Trail KOP					
Drilling Program					
BB #1	Normal	0.5 Mile	Sig.	Insig.	Entire drilling operation visible from trail, relatively flat site as well as increased rainfall will enhance reclamation or revegetation.
BB #2	Normal	0.5 Mile	Sig.	Insig.	Entire drilling operation visible from trail, relatively flat site as well as increased rainfall will enhance reclamation or revegetation.
Champlin	Normal	500 Feet	Sig.	Insig.	Entire drilling operation visible from trail, previous reclamation or revegetation attempts have proven successful.
Seismic Reflection Line					
Line #2	Normal	500 Feet	Insig.	Insig.	Little additional disturbance would result from this activity.
PART E: From Bridger Jack Mesa KOP					
Drilling Program					
DHM #5 (Davis)	Superior	0.6 Mile	Sig.	Sig.	Entire drilling operation visible for extended period of time from mesa top.
Other Activities					
Lavender Canyon Met. Tower	Superior	1.5 Miles	Insig.	Insig.	Distance would render the lattice type tower almost invisible.

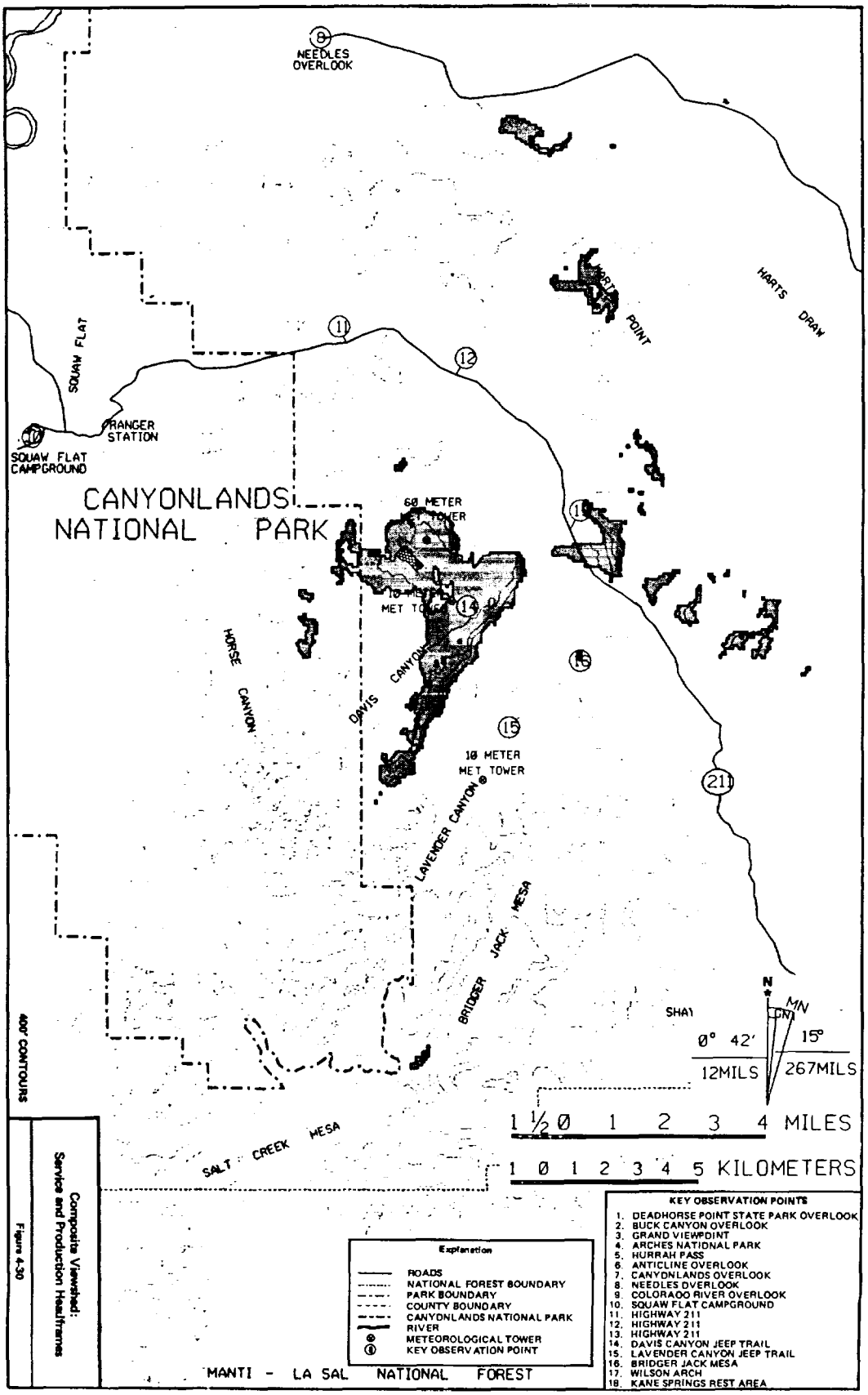
(a) This table presents VRM impacts only for those activities which are visible from that KOP.
(b) Includes access only leading to the project activity.
(c) Includes distance from key observation point to activity.
(d) Impacts are short term (project life plus 2 years, or 4 years total) and long term (greater than 4 years).

Source: BLM, 1985.

Table 4-28. Key Observation Points, Davis Canyon Study Area

	Key Observation Point	Jursidiction	VRM Class
1.	Dead Horse Point Overlook	Dead Horse Point State Park	I
2.	Buck Canyon Overlook	Canyonlands National Park	I
3.	Grand View Point Overlook	Canyonlands National Park	I
4.	Arches National Park Visitors Center	Arches National Park	I
5.	Hurrah Pass	Bureau of Land Management	II
6.	Anticline Overlook	Bureau of Land Management	II
7.	Canyonlands Overlook	Bureau of Land Management	III
8.	Needles Overlook	Bureau of Land Management	III
9.	Colorado River Overlook	Canyonlands National Park	I
10.	Squaw Flat Campground	Canyonlands National Park	I
11.	Utah 211 at Canyonlands National Park	Bureau of Land Management	II
12.	Utah 211 at Corral Pocket	Bureau of Land Management	II
13.	Utah 211 at South Six-Shooter Peak	Bureau of Land Management	II
14.	Davis Canyon Jeep Trail	Bureau of Land Management	II
15.	Lavender Canyon Jeep Trail	Bureau of Land Management	II
16.	Bridger Jack Mesa	Bureau of Land Management	IV
17.	Wilson Arch Viewpoint	State of Utah	III
18.	Kane Springs Rest Area	State of Utah	II

A larger reproduction of this figure appears at the back of this volume.



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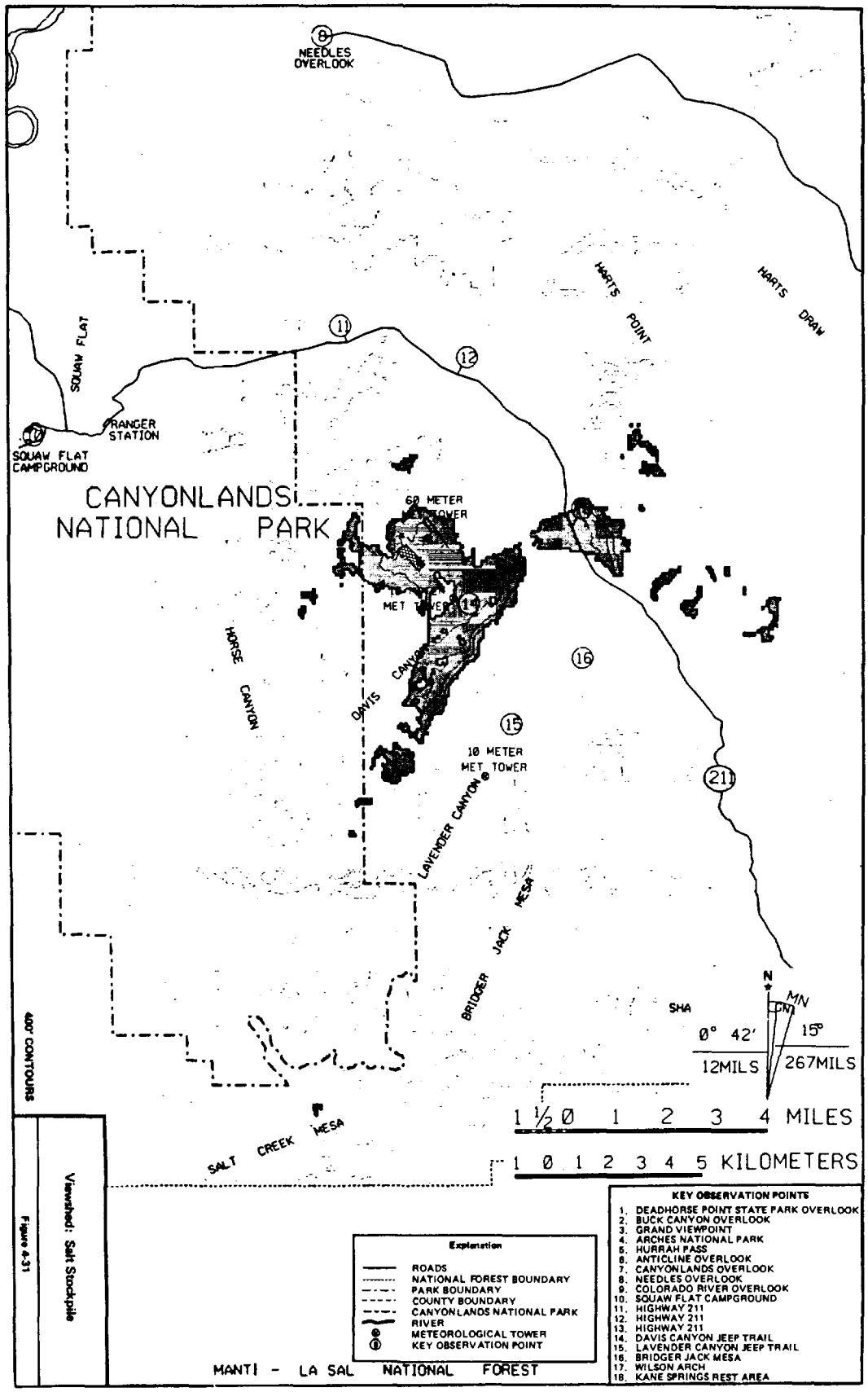

Figure 4-31 Viewshed: Salt Stockpile

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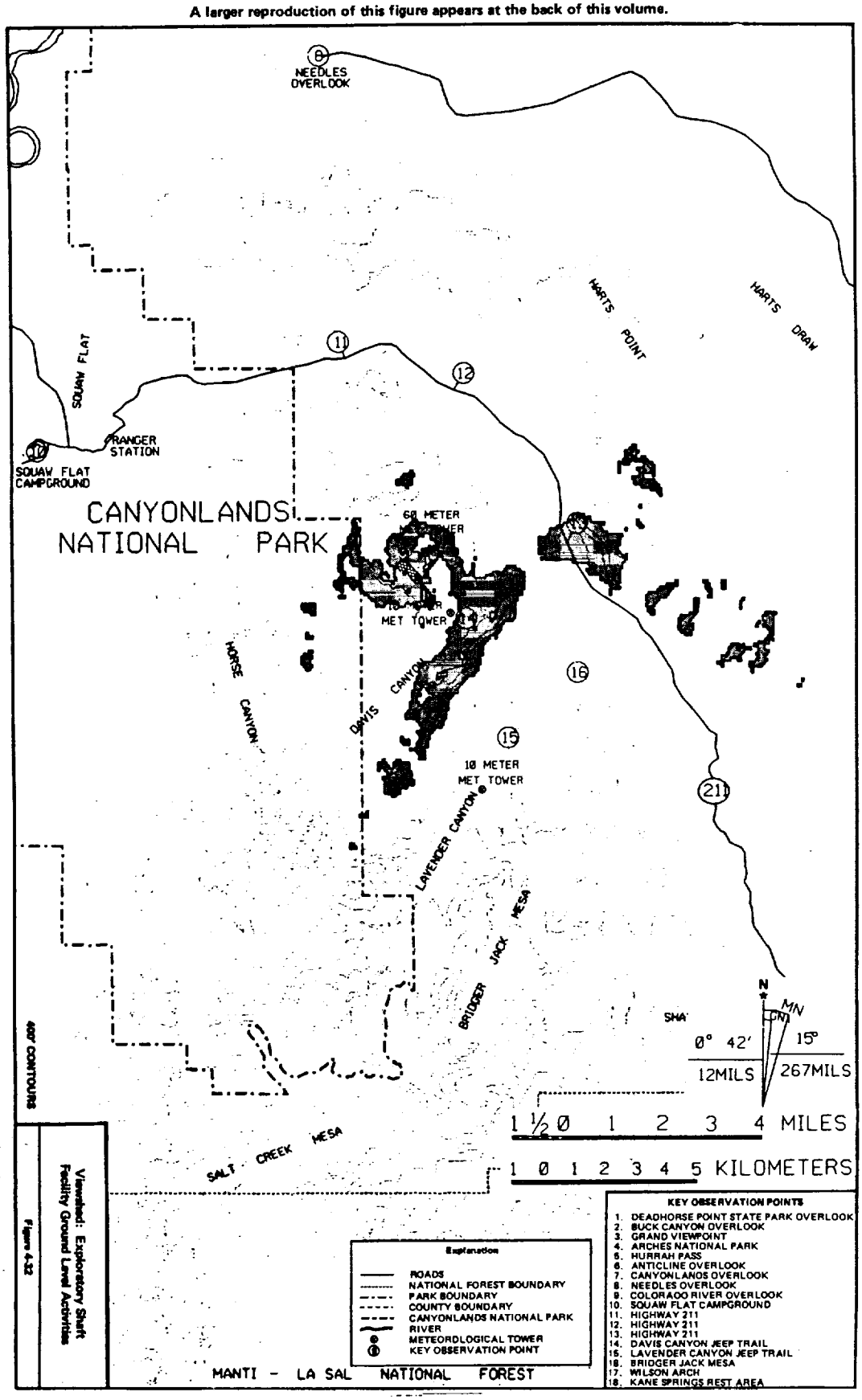

Figure 4-32

Viewshed: Exploratory Shaft Facility Ground Level Activities

The service shaft headframe will be potentially visible from a total area of 22.7 square kilometers (8.8 square miles); the production shaft headframe from 21.3 square kilometers (8.2 square miles) (Table 4-30 and Figure 4-30). These areas of visibility include the Davis Canyon Jeep Trail (KOP #14), the northern tip of Bridger Jack Mesa (KOP #16), scattered portions of the western and southwestern edge of Harts Point, and one isolated area of high ground within Canyonlands National Park (around the head of the north fork of the creek running through Davis Canyon southwest of the site) where visitor use is minimal.

The 97.5-by-185.9-by-9.1 meter (320-by-610-by-30 feet) salt stockpile will be potentially visible from a total area of 22.8 square kilometers (8.8 square miles) (Table 4-30 and Figure 4-31), including: the Davis Canyon Jeep Trail (KOP #14), small areas along the western and southwestern rim of Harts Point, 1.3 kilometers (0.8 miles) of Utah 211 including KOP #13, and a small area of Canyonlands National Park, running for 3.2 kilometers (2 miles) along the eastern park boundary, just west of South Six-Shooter Peak where visitor use is slight.

The ground plane of the entire ESF activity compound will be potentially visible from a total area of 21.2 square kilometers (8.2 square miles) (Table 4-30, Figure 4-32), including: the Davis Canyon Jeep Trail (KOP #14); scattered portions of the western and southwestern edge of Harts Point, 1.2 kilometers (0.7 mile) of Utah 211, including KOP #13, and several small areas scattered inside the eastern boundary of Canyonlands National Park where visitation is low.

Visibility From Roads. No ESF activity will be potentially visible from the jeep trails or other roads within Canyonlands National Park, but all activities will be visible for short distances along Utah 211 in the vicinity of KOP #13 (Table 4-31). The ESF will be visible from sections of jeep trails through Davis and Lavender Canyons and the Harts Point area, all of which are outside of the park.

Visual Contrast Ratings. Visual contrast evaluations were completed for those features of the ESF activities (headframe, salt pile, and facility site) included in the viewshed analysis. However, separate contrast ratings were not computed for each individual activity, but rather for the entire facility.

The visual contrast of the ESF was evaluated from Utah 211 at South Six-Shooter Peak (KOP #13) and Davis Canyon Jeep Trail (KOP #14). Although the top of the headframes are potentially seen from Bridger Jack Mesa at KOP #16, contrast ratings were not calculated for this isolated location. As shown on Table 4-27, the ESF will potentially result in significant short term visual impacts from KOP #13 and significant short and long term effects from KOP #14. Visual contrast of the ESF was also evaluated from the eastern boundary of Canyonlands National Park, one mile west of the proposed facility where the ESF is within view and from a superior observer position. At this location, the ESF will potentially create significant short and long term impacts, but this is an area of isolated highground where visitation is very low.

4.2.1.7.4 Other Activities. The ESF viewshed analysis described previously (Section 4.2.1.7.2) was also performed for the 60 meter (196.85 feet) meteorological tower, the Davis Canyon 10 meter (32.8 feet) meterological tower, and the Lavender Canyon 10 meter (32.8 feet) meteorological tower. Figures 4-33 and 4-34 show the viewsheds for the 60-meter (196.9-foot) meteorological tower and the composite viewshed for the two 10-meter (32.8-foot) meteorological towers. The visibility of these structures from KOPs were shown in Table 4-29, and the total area of visibility was shown in Table 4-30.

The 60-meter (197-foot) meteorological tower located southwest of South Six-Shooter Peak will be potentially visible from a total area of 29.9 square kilometers (11.6 square miles) (Table 4-30 and Figures 4-33), including the Davis Canyon Jeep Trail (KOP #14); near Bridger Jack Mesa (KOP #16); scattered portions of the southwestern edge of Harts Point; a section of the southwest edge of the high ground between Harts Draw and Lockhart Basin, including approximately 3.0 kilometers (1.9 miles) of the road leading to Needles District of Canyonlands National Park. None of Utah 211 is within the viewshed of this structure, as it is apparently shielded by South Six-Shooter Peak and the mesa between Davis and Lavender Canyons.

Table 4-29. Potential Visibility of Exploratory Shaft Facilities and Other Activities from KOPs

KOP No.	KOP Name	Service Shaft Headframe	Production Shaft Headframe	Salt Stockpile	Ground Level Activities	60 m. Met. Tower	Davis Canyon Tower	Lavender Canyon Tower
1	Dead Horse Point Overlook							
2	Buck Canyon Overlook (CNP)							
3	Grand View Point Overlook (CNP)							
4	Arches N.P. Visitor Center							
5	Hurrah Pass							
6	Anticline Overlook							
7	Canyonlands Overlook							
8	Needles Overlook							
9	Colorado River Overlook							
10	Squaw Flat Campground (CNP)							
11	Utah 211 at Canyonlands N.P.							
12	Utah 211 at Corral Pocket							
13	Utah 211 at So. Six-Shooter Peak			X	X			
14	Davis Canyon Jeep Trail	X	X	X	X	X	X	
15	Lavender Canyon Jeep Trail							X
16	Bridger Jack Mesa	X	X			X		X
17	Wilson Arch Viewpoint							
18	Kane Springs Rest Area							

Note: X = Activity is visible from that KOP; all other activities are not visible.

Table 4-30. Potential Visibility by Area

ESF Activities	Total Sq. Km. (Sq. Mi.) From Which This Activity Is Potentially Seen		Total Sq. Km. (Sq. Mi.) From Which This Activity Is Potentially Seen From Canyonlands National Park	
Service shaft headframe	22.7	(8.8)	1.21	(0.5)
Production shaft headframe	21.3	(8.2)	1.3	(0.5)
Salt stockpile	22.8	(8.8)	1.3	(0.5)
ESF ground-level activities	21.2	(8.2)	1.5	(0.6)
Other Activities				
60-meter meteorological tower	29.9	(11.6)	3.32	(1.3)
Davis Canyon meteorological tower	25.7	(9.9)	3.9	(1.5)
Lavender Canyon meteorological tower	25.8	(9.96)	2.9	(1.1)

Note: Individual ESF and other activities are potentially visible within limited areas of Canyonland National Park; however, these areas receive limited visitor use.

Table 4-31. Potential Visibility from Utah 211

ESF Activities	Total Road Kilometers (Miles) From Which This Activity Is Potentially Seen
Service shaft headframe	0.3 (0.2)
Production shaft headframe	0.8 (0.5)
Salt stockpile	1.3 (0.8)
ESF ground-level activities	1.2 (0.7)
<u>Other Activities</u>	
60-meter meteorological tower	Not Seen from Utah 211
Davis Canyon meteorological tower	0.9 (0.6)
Lavender Canyon meteorological tower	0.7 (0.4)

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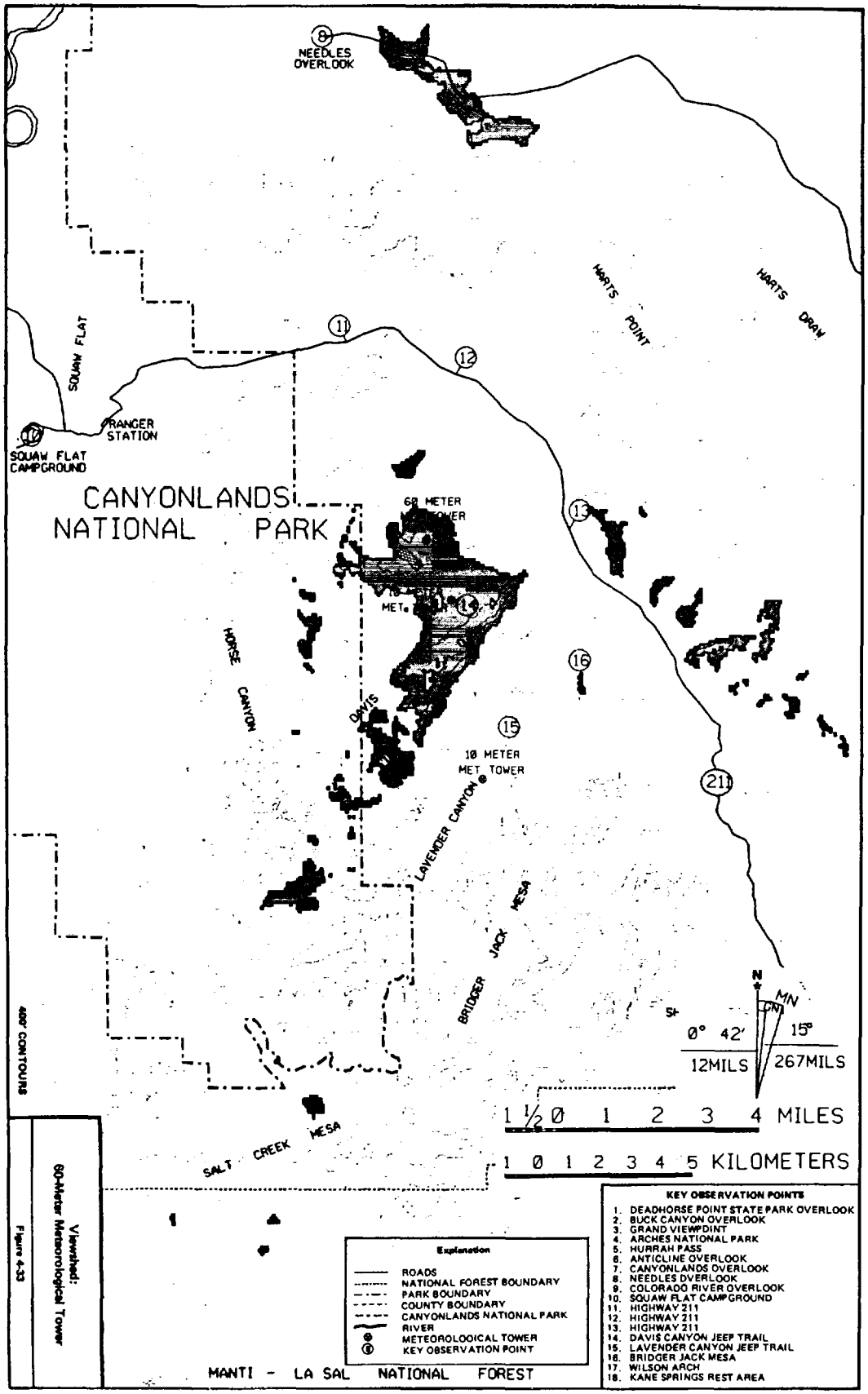

Figure 4-33 Viewshed: 60-Meter Meteorological Tower

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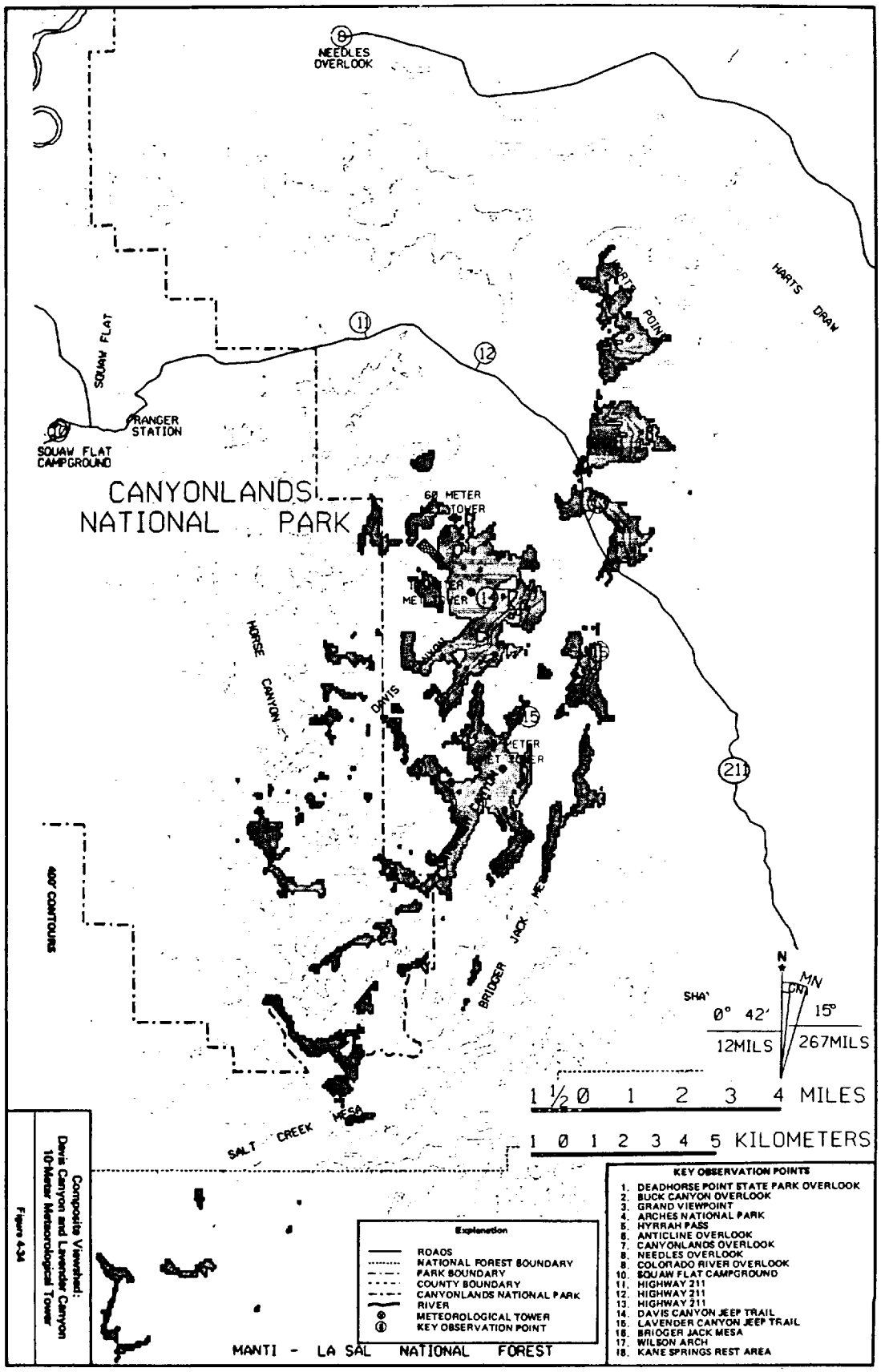


Composite Viewshed: Davis Canyon and Lavender Canyon 10-Meter Meteorological Tower

Figure 4-34

The Davis Canyon 10-meter meteorological tower will be potentially visible from a total area of 25.72 square kilometers (9.9 square miles) (Table 4-30 and Figure 4-34), including: the Davis Canyon Jeep Trail (KOP #14), 0.90 kilometers (0.6 miles) of Utah 211 near KOP #13; portions of the northwestern edge of Harts Point; and isolated high ground where visitation is low within the Needles District of Canyonlands National Park.

The Lavender Canyon 10-meter meteorological tower will be potentially visible from a total area of 25.8 square kilometers (9.96 square miles) (Table 4-30 and Figure 4-34), including: The Lavender Canyon Jeep Trail (KOP #15); Bridger Jack Mesa (KOP #16); 0.7 kilometer (0.4 mile) of Utah 211 near KOP #13; small portions of the northwestern edge of Harts Point; and isolated high ground which receives little visitor use within the Needles District of Canyonlands National Park (near Cleft Arch).

Neither the 60-meter tower nor the Davis Canyon or Lavender Canyon 10-meter meteorological tower will be potentially visible from the jeep trails or other roads inside the Canyonlands National Park.

Visual Contrast Ratings. Visual contrast ratings of the 60-meter meteorological tower, the Davis Canyon 10-meter meteorological tower, and the Lavender Canyon 10-meter meteorological tower were completed from four KOPs: Utah 211 at South Six-Shooter Peak (KOP #13), Davis Canyon Jeep Trail (KOP #14), Lavender Canyon Jeep Trail (KOP #15), and Bridger Jack Mesa (KOP #16). The towers were not potentially visible from any of the other KOPs.

As shown in Table 4-27, the Davis and Lavender Canyon meteorological towers were found to have significant short term and long term impacts because of their close proximity to Davis and Lavender Canyon jeep trails. There are no significant impacts from Bridger Jack Mesa for these two towers. The 60-meter meteorological tower will not create significant impacts from Davis Canyon jeep trail.

4.2.1.7.5 Mitigation Techniques. The contrast rating revealed the elements and features that would cause the greatest visual impact. It thus acted as a guide to the most effective method of reducing the visual impact of a proposed activity. Mitigation measures were developed for those contrast rating scores which exceeded the requirements for the assigned VRM class as well as those which met the class but could be reduced further. Mitigation measures may be used to significantly reduce visual impacts.

In developing mitigation, three basic principles are used: (1) the concepts of strategic location (in less visible and less sensitive areas), (2) minimizing disturbance, and (3) repetition of the basic landscape elements (form, line, color, texture).

The mitigation techniques listed below have been separated into two categories: (1) general, which are basic for all sites of each identified activity; and (2) site-specific, which are limited in application to one site. Implementation of any of the migitation measures listed below would be made in consultation with BLM.

General

1. All rock cuts could be sprayed with a product to simulate desert varnish.

2. End sections of culverts for roads could either be cut to match embankment slopes, painted, or sprayed to reduce color contrasts.

3. For all drilling activities, the boundaries of construction clearing could be curved, not straight. Drill pads should be designed with the corners rounded off and irregularly shaped.

4. For long-term monitoring wells, all areas not required for well access and testing could be reclaimed or revegetated.

5. All cut and fill slopes could be rounded to break the sharp, unnuatural edges formed by the junction of a constant-pitch cut slope with natural rounded land form.

6. All drilling operations to a depth greater than 305 meters (1,000 feet) could use water mist or mud circulating drilling equipment.

7. The placement of a dry hole marker (if required) could be waived on all hydrologic and geologic holes.

8. All exposed concrete (i.e., tunnel portals, buildings, and tower foundations, etc.) could either be tinted or sprayed to match the existing soil color.

9. All permanent structures (i.e., buildings, meteorological towers, fences, bridges, etc.) could be painted a uniform, noncontrasting (flat or semigloss) environmental color. Actual color selection could be specified by the land managing agency before the time of construction.

10. The use of gravel on temporary access roads could be eliminated.

11. Where possible, drilling activities which are visible from Utah 211 could be drilled during the fall and winter season (during low visitor-use periods).

12. For 3-D seismic surveys and seismic reflection lines where no jeep trails exist, helicopter portable drills, surface blasting, driving over uncleared vegetation, or clearing only at drainage crossings could be used. If their data reliability is not compatible with program requirements, then a buggy mount vibroseis shall be used.

Site-Specific:

Drilling Program

1. SB #1. The borehole could be relocated off sandstone bench into grassy area 1,000 feet north to eliminate irreversible damage to the sandstone from road construction, and facilitate more effective reclamation and revegetation.

2. SB#2. This borehole could be relocated behind topographic features 457 meters (1,500 feet) southwest to limit visibility from Utah 211 to east bound traffic only.

3. SB #3. This borehole could be relocated on a flat bench 1,036 meters (3,400 feet) east where less disturbances from pad construction would be required, long-term monitoring well pad would not be visible, and revegetation would be more successful. The tradeoff would be additional road upgrading along an existing trail.

4. DHN #3. This borehole could be relocated out of low, rolling hills to a flat bench 305 meters (1,000 feet) northwest.

5. DHN #4. This borehole could be relocated 2,000 feet southwest where only the drill tower would be visible and the monitoring well pad would not be visible from Utah 211.

Meteorological Towers. All fencing, buildings, and structures could be painted a flat environmental color.

Exploratory Shaft Facility. All fences, buildings, and structures could be painted a brick red or dark brown color.

4.2.1.7.6 Summary. The ESF is located in a side canyon of Davis Canyon where it is screened by the bulk of South Six-Shooter Peak and other high ground. Therefore, ESF and other activities are potentially visible from a total area of 71.3 square kilometers (27.5 square miles). Of this sum, only 9.58 square kilometers (3.7 square miles) are

scattered within the eastern boundary of the Needles District of Canyonlands National Park where visitation is very low, primarily because of the lack of access.

Potentially, the drilling program would produce primarily short term impacts, but also long term significant impacts within the Davis Canyon and along a 6-mile stretch of Utah 211 near the Canyon. The ESF will potentially create significant short-term effects from only KOPs #13 and #14 and long-term effects from KOP #14. The 10-meter Davis and Lavender Canyon meteorological towers would create significant short term and long term impacts from only KOP #14 and #15, respectively. The 60-meter meteorological tower would not create any significant impacts from any KOP. Because none of these activities are visible from KOP's within CNP, there are no short- or long-term impacts on the park other than along short sections of the eastern boundary.

After applying proposed mitigation, the severity of the visual impacts can be reduced at both the short and long term levels. In some cases, the degree of impact can be shifted from the significant to the insignificant category. For example, if borehole DHN #4 were relocated as suggested, the significant long term impact from Utah 211 would be eliminated completely. For the seismic program, all significant visual impacts could be fully mitigated if alternative techniques such as helicopter portable drilling were employed. Mitigation (e.g., provide a color finish that blends in with the surrounding landscape), will help further minimize ESF (including meteorological towers) impacts, but not substantially.

The primary residual impact which will remain after applicaton of mitigation is degradation of the scenic quality from a high class B to a low class B because of day-time visibility of the proposed project. However, it is projected that the VRM class would not be lowered by the project.

In conclusion, overall cumulative visual impacts will not be significant except possibly within the immediate vicinity of the proposed activities, which are outside of Canyonlands National Park. Impacts on the Bridger Jack Mesa are insignificant primarily because of limited visibility. From the closest point in Canyonlands National Park to the proposed project, the visual impact is significant but because this area receives so little visitor use and is not a KOP, it is relatively unimportant. Not one analyzed KOP within Canyonlands National Park will be visually impacted because the activities are not visible from any of these KOPs.

4.2.1.8 Effects on Archaeological, Cultural, and Historical Resources

This section describes direct and indirect impacts of site characterization activities on cultural resources. Impacts of the geologic field studies described in Section 4.1.1 and the exploratory shaft facility (ESF) described in Section 4.1.2 on the site vicinity, including Salt Creek Archaeological District and Newspaper Rock State Historical Monument, are discussed along with impact mitigation measures.

Proposed site characterization activities that may cause such impacts include construction of an ESF and drilling of boreholes within the proposed 2,331-hectare (5,760-acre) site; also, various geologic, hydrologic, and seismic field studies both on and off site may also cause impacts. Primary access to the site for site characterization activities will be along Utah 211, past Newspaper Rock State Historical Monument. Where possible, off-highway access for field studies will include use of existing roads and jeep trails. Some upgrading of roads and new road construction will be required.

All proposed ground-disturbing field activities have the potential to directly affect cultural resources located within the area of construction. Impacts include damage to or loss of cultural resources as a result of grading, drilling, vibration, or vehicular traffic. To manage the discovery, study, and impacts on cultural resources pursuant to the National Historic Preservation Act of 1966 (16 USC Sections 470-470w-6), the DOE will enter into a programmatic memorandum of agreement (PMOA) with the Advisory Council on Historic Preservation and the Utah State Historic Preservation Officer (SHPO) (DOE, 1985a). The implementation of the PMOA would avoid or satisfactorially mitigate the potentially adverse effects of this

project on historic and cultural properties. If required by the PMOA, the DOE would implement the following:

- Initiate a worker awareness program for archaeological and historic resources
- In consultation with the Utah SHPO, develop and implement a research design to guide archaeological survey and data recovery during site characterization
- Ensure completion of archaeological surveys of a unit of land prior to its disturbance; these surveys will address areas which are subject to direct and indirect project effects
- Make every effort to design project activities to avoid damage to any historic or archaeological property; if avoidance is not possible, the DOE will develop and implement a data recovery plan in consultation with the Utah SHPO
- Consult with the National Park Service (NPS), the Moab District of the Bureau of Land Management (BLM), and other appropriate Federal agencies to ensure their concerns are addressed

4.2.1.8.1 Geotechnical Field Studies. To further identify the cultural resource base in and around the site, the DOE has conducted several cultural resource studies, described in Table 4-32. Some of these studies also relate to railroad route corridors discussed in Chapter 5.

Various types of geologic and hydrologic field studies associated with site characterization could result in direct and indirect impacts on cultural resources, as shown in Section 4.1.1. Cultural resource field surveys have been completed for several potential activity areas (Table 4-32). However, subsequent changes in project planning have occurred. The DOE will ensure completion of archaeological surveys of areas to be disturbed prior to their disturbance, and make every effort to design project activities to avoid damage to any historic or archaeological property. It is anticipated that the adverse effects can be avoided through relocation of field study areas. If avoidance is not possible, the DOE will develop and implement a data recovery procedure to mitigate the potential loss of cultural resource information.

4.2.1.8.2 Exploratory Shaft Facility (ESF). The proposed access road corridor from the NPS extension of Utah 211 to the proposed ESF location has been subjected to intensive (100 percent) archaeological survey by archaeologists permitted by the BLM (BGI, 1983, ONWI-468). No cultural resource sites were observed within the corridor, as shown in Section 4.1.2, although an isolated artifact was recorded. There are several known prehistoric sites immediately adjacent to the corridor, but these sites would not be directly affected by upgrading or utilization of the existing access road. Indirect impacts could be expected due to increased visitation. The SHPO and the Keeper of the Register have not yet made a determination of eligibility for these sites, and the DOE intends to seek such a determination prior to initiating site characterization activities.

Several site-specific surveys have been performed at the ESF location and in the immediate vicinity. Numerous cultural resource sites outside of areas of direct impact were also examined (BGI, 1983, ONWI-468). An area of approximately 259 hectares (640 acres) surrounding the ESF location was intensively (100 percent) examined for cultural resources (Nickens and Associates, 1984a). This area is shown in Section 3.4.6. Two prehistoric lithic scatters were recorded within the survey boundary, neither of which was recommended as significant according to National Register of Historic Places (NRHP) criteria. Also included within the survey boundary was a cultural feature designated as site 42SA11244. This site is an isolated hearth. No surface artifacts were present, but carbon recovered from the hearth was dated to about 2,860 years BP (before present) (Beta Analytic, 1982). This date is important in the regional research context because of its antiquity. Although the hearth appears to be an isolated cultural occurrence and, therefore, not eligible for NRHP (i.e., it would not yield

Table 4-32. Archaeological Studies Conducted for the Davis Canyon Site

Archaeological Study	Date/Duration	Reports/Publications
A. Class I literature search for San Juan and Grand Counties	September 1979	----
B. Class III cultural resource survey of the following project features: • 3 primary borehole locations • 8 meteorological monitoring stations • 5 meteorological tower locations • 11 drill hole locations • 2 test trench locations • 9 test pit locations • 13 tiltmeter stations • approximately 76 kilometers (47 miles) of seismic reflection line or access road	November 2 to April 14, 1982	Summary Report on Cultural Resource Investigations in Northwest San Juan County and Addenda prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (1984a).[a] (BGI, 1983, ONWI-468)
C. Test excavation of a fire-hearth at an archaeological site; hearth found during a survey of a primary borehole location and its access road	August 10-11, 1982	Excavation of a Firehearth of 42SA 11244, Davis Canyon, Northern San Juan County, Utah, prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (1984a).[b] (BGI, 1983, ONWI-468)

Table 4-32. Archaeological Studies Conducted for the Davis Canyon Site
(Page 2 of 3)

Archaeological Study	Date/Duration	Reports/Publications
D. Class III cultural resource survey of the following project features: 2 reroutes of the Davis Canyon Road, the Hatch Point Meteorological Station, the relocation of Borehole GD-4B, and the restaking of 6 Boreholes. Work also done included the examination of the extent of an archaeological site at Borehole GD-3B and the evaluation of 9 prehistoric sites located by amateur archaeologists	May 10-12 & May 19-21, 1982	Further Archaeological Investigations in the Gibson Dome Study Area of Southeastern Utah, prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (1984a).(a, b) (BGI, 1983, ONWI-468)
E. Class II cultural resource survey of a sample of a rectangular track of land (39,536 hectares [16,000 acres]) in lower Davis and Lavender Canyons surrounding a proposed waste repository location, and survey of a sample of an area along Indian Creek (11,860 hectares [4,800 acres]) that will be subject to heavy secondary project impacts	April 1983	Gibson Dome Class II: A Sample-Oriented Cultural Resource Inventory of hectares (20,800 acres) in Northwestern San Juan County, Utah, prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (BGI, 1983a).
F. Class III cultural resource survey of 1,581 hectares (640 acres) in Davis Canyon encompassing the repository site, 7 alluvial well locations, 1 trench, and 1 borehole location	April 1983	A Class III Cultural Resource Inventory of a 1,581-hectare (640-acre) Tract and Nine Isolated Features in the Gibson Dome Project Area, San Juan County, Utah, prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (BGI, 1983b).

Table 4-32. Archaeological Studies Conducted for the Davis Canyon Site
(Page 3 of 3)

Archaeological Study	Date/Duration	Reports/Publications
G. Class III cultural resource survey of the following project features: new location of 4 alluvial wells, 2 meteorological tower locations, 2 borehole locations and meteorological station #2, alternative 2	April 1983	Addendum to a Class III Cultural Resource Inventory of a 640-Acre Tract and Nine Isolated Features in the Gibson Dome Project Area, San Juan County, Utah, prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado, 1983 (BNI, 1984c)
H. Class III cultural resource survey of archaeological sites 42SA10695 and 42SA10692, Davis Canyon, Utah	January 1984	Additional Recording of Archaeological Sites 42SA10695 and 42SA10692, Davis Canyon, Utah. Prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (BNI, 1984c)
I. Cultural resource site file search for Gibson Dome Area	February 1984 August 1985	A Cultural Resource Site File Search for Proposed Railroad, Utility and Water Pipeline Corridors for the Paradox Basin NWTS Project, Southeastern Utah. Prepared for Bechtel Group, Inc. by Nickens and Associates, Montrose, Colorado (Nickens Associates, Inc., 1984b)

(a) Total area surveyed around each location varied depending on the nature and extent of geotechnical activities: 4 acres were examined around each proposed primary borehole; 5 acres around each proposed drillhole; an area 30 meters in diameter around each proposed test pit, meteorological tower and monitoring station, and tiltmeter station; and a 35 meter wide corridor along all proposed test trenches, seismic reflection lines and access roads.

(b) These reports have been included in a single ONWI publication entitled Cultural Resource Investigations, Gibson Dome Location, Paradox Basin, Utah (BGI, 1983, ONWI-468).

additional data important to regional prehistory), ground-disturbing activities associated with site characterization in the vicinity of this site will be monitored by a qualified archaeologist.

The SHPO and the Keeper of the Register have not yet made a determination of eligibility of these three prehistoric sites located within the ESF area, and the DOE intends to seek such a determination prior to initiating site characterization activities.

In addition to the project-sponsored cultural resource investigations described above and listed in Table 4-32, local individuals and archaeologists from the NPS have recorded numerous sites in the proposed ESF area over the past 2 years. Approximately 25 sites have been recorded in the lower Davis Canyon area, and several dozen additional sites have been recorded in upper Davis Canyon, on both BLM and NPS lands. The sites are of various types; none has been evaluated for NRHP eligibility by the SHPO or the Keeper of the Register (BGI, 1983, ONWI-468; Manning, 1983).

Based on the 100-percent surveys (described above) of the ESF and access road locations, no direct impacts on cultural resources are expected in these areas. Although the potential exists for indirect effects to the area's rock art as a result of increased air emissions during site characterization activities, such impacts are not expected to occur since reasonably conservative air quality projections (Section 4.2.1.3) are all well below the air quality standards (National Primary and Secondary Ambient Air Quality Standards [40 CFR Part 50]).

Sites identified within the Salt Creek Archaeological District in Canyonlands National Park are being considered for inclusion in the NRHP because they are within the archaeological district. The Salt Creek Archaeological District is located in the southeastern corner of Canyonlands National Park, and includes portions of both Davis and Lavender Canyons. Indirect impacts (i.e., illegal artifact collecting, vandalism, and off-road vehicle use) disturbing or damaging to archaeological resources within this part of the archaeological district could result from increased access and interest in the area as a result of site characterization. These indirect impacts can be expected to be roughly proportional to the combined fluctuation in numbers of visitors and project personnel in the Canyonlands National Park area. Because park visitations fluctuate by thousands of people per year and the site characterization will introduce only several hundred people, indirect impacts attributable to site characterization would be small. While activities detrimental to cultural resources cannot be totally eliminated, the DOE believes that, based on NPS experience, they can be reduced through education, prevention, and conservation measures (Griffin, 1984).

The primary access route for site characterization activities is Utah 211. Newspaper Rock State Historical Monument, a National Register site, is located immediately adjacent to Utah 211. No direct impacts resulting from road improvements are expected at this site. The Advisory Council on Historical Preservation procedures for the Protection of Historic and Cultural Properties (36 CFR Part 800) establishes "criteria of effect and adverse effect (36 CFR 800.3) for those sites included or eligible for inclusion in the National Register of Historic Places." According to these criteria, the increased traffic (Section 4.2.1.10) on Utah 211 would potentially adversely affect the quality of Newspaper Rock because the increased traffic (including truck traffic) would result in the "introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting,..." (36 CFR 800.3[b][3]). This potential impact would be temporary, limited to the period of site characterization, and either reversible or of no lasting impact.

4.2.1.8.3 Impact Mitigation. Indirect impacts could be mitigated through management control by the DOE (to minimize vandalism by workers), restricting offsite and unauthorized off-road vehicle use, and implementing a worker awareness program designed to instill an appreciation for the heritage value of cultural resource sites and a sensitivity to their preservation. Increased resource protection efforts on the part of the area's land-managing Federal agencies (National Park Service, Bureau of Land Management, and United States Forest Service) could also be necessary. However, no mitigation program can ensure that no cultural resource data would be lost due to indirect effects from site characterization activities.

Should previously unidentified cultural resources be encountered during construction or proposed field testing activities, the work will cease until evaluation and consultation with the BLM and the SHPO is undertaken and a procedure to mitigate potential adverse impacts to the resource is implemented.

4.2.1.8.4 Cumulative and Long-Term Effects. The ESF and the new access road to it are not expected to result in direct impacts to significant cultural resources because site surveys have not identified such resources in the areas to be disturbed. Other direct impacts can be minimized, because other geologic field activities generally can be moved to avoid cultural resources that may be found. Indirect impacts can be expected to occur from increases in the numbers of people in the area; these increases, however, could be expected to occur even without the project if park visitation were to increase. The DOE expects that impact mitigation programs will be effective in mitigating indirect effects to cultural resources.

4.2.1.9 Effects on Radiological Levels

No radiological impacts are expected as a result of site characterization activities. No radioactive wastes are planned for use in testing.

Some of the tests performed during detailed site characterization use instrumentation procedures that involve small amounts of radioactivity. These tests include the following:

- Measurement of soil density
- Measurement of soil moisture
- Nondestructive testing of welds.

The measurement of soil density would be made as a downhole well logging procedure. A cesium-137 source of 1.5-curie strength, creating a field of 0.33 roentgen per hour per curie at 1 meter (3.3 feet) when unshielded, would be slowly lowered down a borehole. Its gamma emissions are reflected back from the soil to an appropriate detector and recorder; the intensity of the reflected signal is proportional to the density of the reflecting medium. When the measurement is completed, the source is withdrawn from the hole into a shield that reduces the radiation field to about 2 milliroentgen per hour. This dose rate allows continuous occupational exposure of personnel without exceeding the applicable 5 rem per year limit. The cesium-137, as contained in this instrument, is a short, solid metallic rod encapsulated in another metallic sheath. When the source is withdrawn, no residual radioactivity remains behind.

The soil moisture measurement is similarly made. The radioactive source used emits neutrons. This source is an intimate mixture of americium-241 and beryllium of 16-curie strength, emitting 2.7 million neutrons per second per curie. As the source is lowered down the hole, the neutrons reflect back from water molecules in the soil into an appropriate detector. The signal from the detector is recorded, with the signal being proportional to the moisture content. As with the soil density source, this neutron device is encapsulated and shielded when not in use to approximately 2 millirad per hour. During the passage of the neutron source past the geologic materials, some activation may occur. Because of the short duration of the exposure and the low probabilities of activation, the radioactivity of these activated materials would be at an extremely low level and of short duration.

One technique used to nondestructively test welds made on site would be gamma radiography. This technique is similar to the same procedure using X-rays but uses instead the more energetic gamma rays from radionuclides. The nuclides most commonly used in industrial radiography are cesium-137, cobalt-60, and iridium-192. Bare sources of these materials yield radiation fields of 0.33, 1.32, and 0.48 roentgen per hour, respectively, at 1 meter (3.3 feet) per curie. Physically, these sources are identical to the cesium-137 source described for the soil density measurement. When not in use they are shielded as described earlier. During use (generally above ground) personnel protection is achieved by maintaining a minimum source-to-personnel distance. No radiation or radioactivity remains following termination of the exposure.

Routine releases of naturally occurring radioactivity will take place during the sinking of the exploratory shaft. This radioactivity will consist of radon and its daughter products contained in soil, rock, and to a lesser extent, in salt. However, the impact of these radioactive elements on the environment will be insignificant. As discussed in Section 3.4.7, it is estimated that the background (ambient) whole body dose rate at the Davis Canyon site is approximately 113 millirem per year. An evaluation of the amount of radon and daughter products likely to be contained in excavated overburden and salt from exploratory shaft development (Waite et al., 1985, BMI/ONWI-541, Rev. 1) indicates that up to 0.01 curie of radioactivity could be released to the environment, equivalent to a whole body dose rate of about 1 mrem per year or about 1.0 percent of ambient. Consideration of this information, plus other individual and population dose estimates given in the literature (BPNL, 1979, DOE/ET-0029, Vol. 1; DOE, 1980, EIS-0046F, Vol. 1), indicates that increases in radioactivity due to exploratory shaft development will be so small as to be considered negligible.

4.2.1.10 Effects on Transportation and Utilities

This section describes the impacts of site characterization activities on existing transportation networks (Figures 3-76 and 3-77) and utilities serving the study area (Figure 3-80).

Site characterization starts with field activities, which include geologic, environmental, engineering, and other data acquisition activities. The start of exploratory shaft construction will overlap the field activities. At the end of site characterization, if the Davis Canyon site is not selected for a repository, the site will be decommissioned, requiring the transport of excess salt and salt-laden rock offsite for disposal.

Section 4.2.1.10.1 discusses projected traffic volumes, traffic increases on area highways, trucking activities, accident increases, and disposal of excess salt if the site is not selected for a repository.

Section 4.2.1.10.2 discusses potential impacts on utilities in the area. Short-term and long-term impacts are described in Section 4.2.1.10.3 and mitigation of these impacts is described in Section 4.2.1.10.4.

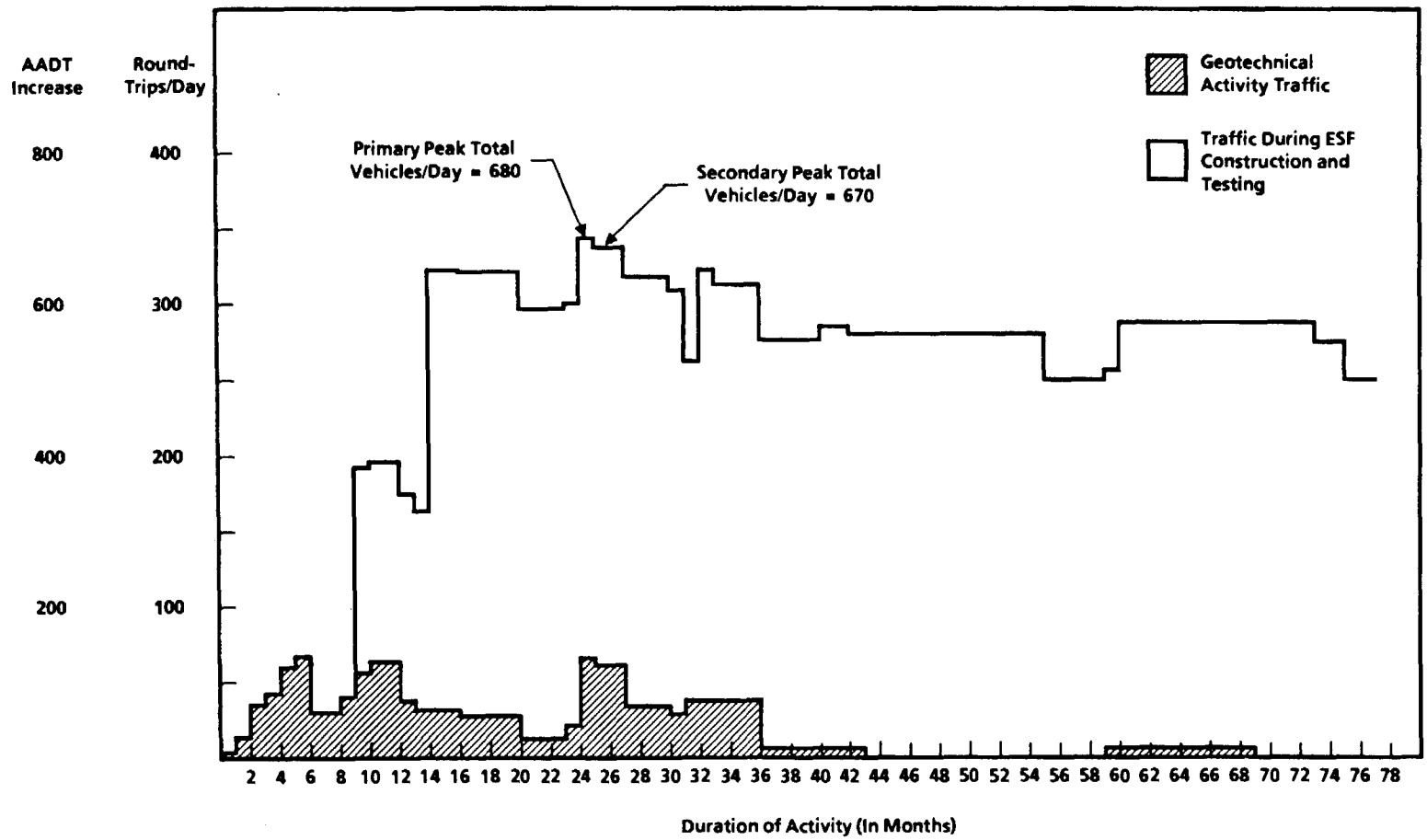
The impacts of the activities described in this section are increased traffic volumes and, therefore, increased congestion, additional traffic accidents, and accelerated highway deterioriation.

4.2.1.10.1 Transportation. The major impact on transportation facilities will result from workers travelling to and from the site and, to a lesser extent, from hauling supplies and equipment during construction of the exploratory shaft.

Access to the site will be on existing roads wherever possible. As described in Section 4.1.2, there will be a need to develop an 8.2-kilometer (5.1-mile) access road into Davis Canyon to the ESF. This access road would extend from the National Park Service (NPS) extension of Utah 211 approximately 10 kilometers (6 miles) from where the park road leaves Utah 211.

During site characterization, field activities and ESF construction will be ongoing simultaneously for a period of approximately 33 months. The cumulative traffic resulting from these site characterization activities is shown in Figure 4-35. This figure shows that traffic increases peak at 680 one-way (340 round-trips) per day. Traffic increases for both private vehicles and truck round trips expected to result from site characterization activities are shown in Table 4-33.

Work-force distribution between cities in the area will determine commuting patterns. Using in-migration information (see Table 4-38) as representative of worker domiciles, 42 percent can be expected to originate in Moab, 32 percent in Monticello, and 23 percent in Blanding. The remaining 3 percent will originate in rural, unincorporated areas. For purposes of traffic impact assessment it has been assumed that the rural 3 percent is equally distributed among the three cities identified above.



Notes:

- The numbers shown for geotechnical activities and ESF construction are combined to give the top line representing monthly peak totals
- Geotechnical traffic distribution from Table 4-2 and Figure 4-1
- ESF traffic distribution from Table 4-9 and Figure 4-8

Davis Canyon Site Characterization
Vehicular Traffic

Figure 4-35

Table 4-33. Traffic Increases During Shaft Construction and Testing, Davis Canyon

Activity	Daily Passenger Vehicle Round-Trips	Monthly Truck Round-Trips
Site preparation	120	490
Shaft and surface facility construction	270	220
Shaft outfitting	270	40
Initial underground excavation	220	115
Expanded underground excavation	250	55
Testing	260	120
Decommissioning	90	550

Note: When scheduled activities overlap (see Figure 4-8), truck traffic is additive; passenger vehicle traffic is not.

Source: Table 4-9.

During peak project activities existing traffic volumes will be increased by 680 vehicle counts* per day. Of this 292 will use United States Highway 191 (U.S. 191) between Moab and Utah 211, which represents a 10 percent increase over current traffic levels. U.S. 191 between Monticello and Utah 211 will experience an 11 percent increase. The segment of U.S. 191 between Blanding and Monticello will experience a 5 percent increase.

Utah 211 and the portion of the NPS extension to be used by project traffic will experience the largest increase in traffic. The existing Utah 211 annual average daily traffic volume of 45 vehicle counts per day will be increased by an average of 506 vehicle counts per day over the entire site characterization period, and by as much as 680 vehicle counts during the peak activity period. As stated in Section 3.5, the NPS estimated that 1,020 vehicles entered the park area on Memorial Day in 1985. This would tend to indicate that Utah 211 can accommodate site characterization activity peaks as well as overall average traffic flows.

Since project operations are generally equally divided between three shifts, traffic increases on area highways during shift changes would be as follows during peak project activities:

Utah 211 = 227 (680/3 = 227 per shift)
U.S. 191 (Between Moab and Utah 211) = 97
U.S. 191 (Between Monticello and Utah 211) = 130**
U.S. 191 (Between Blanding and Monticello) = 55.

Project traffic, especially truck traffic, will accelerate road deterioration during project activities. Through the site characterization period approximately 15,000 truck round-trips are predicted. Should the site not be selected for a repository, approximately 2,900 additional round-trips would be required to dispose of the excess salt and salt-ladened rock. Thus as many as 18,000 round-trips might be required over the life of the project.

Another result of increased traffic volumes will be an increase in traffic accidents on area highways. As discussed in Section 3.5, the 1983 accident rate on U.S. 191 between Monticello and Helper was 0.83 accidents per million vehicle miles and 1.24 fatal accidents per 100 million vehicle miles. The corresponding national rates were 4.1 and 2.7 (see Table 4-34). Table 4-35 provides a comparison of predicted accident increases over the life of the project using national and U.S. 191 rates.

At completion of site characterization, if Davis Canyon is not selected for a repository, it will be necessary to dispose of the salt and salt-laden rock remaining after shafts are backfilled. Trucks will be used to haul the salt to a site near the Bonneville Salt Flats (approximately 640 kilometers (400 miles) from the site).

Approximately 3,800 truck loads of salt, salt-laden rock, and excavated material will be transported from the site to the disposal area over a 12 to 18 month period. Using national statistics, the number of accidents would increase by 9 and the number of fatal accidents by 0.05 between the site and the disposal area during this period. Impacts of salt which might escape from the truck in the event of an accident are discussed in Section 4.2.1.11.1.

There will be no rail access to the site during site characterization. Some supplies may be delivered by rail to Grand Junction for transshipment to the site by truck. This additional traffic is expected to be minor and should have no significant impact on the rail system. Traffic during decommissioning is shown in Table 4-33.

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* 2 vehicle counts = 1 round trip.

** Includes the 55 vehicles from Blanding.

Table 4-34. National Motor Vehicle Accident and Fatality Rates, 1983

U.S. vehicle accidents (reported to police)	6,769,100
U.S. traffic fatalities	44,600
U.S. total vehicle miles (million)	1,651,000
Accident rate per million vehicle miles	4.1
Fatality rate per 100 million vehicle miles	2.7

Source: National Safety Council, 1984

Table 4-35. Projected Accident Increases on U.S. 191 During Project Activities

	Number of Additional Accidents		Number of Additional Fatal Accidents	
	Using 1983 National Rate	Using 1983 U.S. 191 Rate	Using 1983 National Rate	Using 1983 U.S. 191 Rate
Moab, Utah 211	80	16	0.5	0.2
Monticello, Utah 211	37	8	0.3	0.1
Blanding-Monticello	28	6	0.2	0.1
Utah 211, Junction to Site[a]	115	23	0.8	0.4
Total Increase	260	53	1.8	0.8
Yearly Increase	43	9	0.3	0.13
1983 Actual on U.S. 191	55		1	

(a) No accidents occurred on Utah 211 in 1983. For a regional rate, U.S. 191 rates were used.

4.2.1.10.2 Utilities. Electricity will be generated on site and, therefore, will have no impact on local supplies. Natural gas, other than possibly bottled gas, will not be used on site during characterization and, therefore, will not impact local supplies. Rubbish (non-hazardous) will be trucked to a permitted landfill. For other waste and disposal methods, see Table 4-17, Section 4.1.2.

4.2.1.10.3 Short-Term and Long-Term Impacts. Highway Utah 211 has a 3.2-kilometer (2.0-mile) section east of Newspaper Rock State Historical Monument with reduced capacity because of steep grades and sharp "S" turns. This section, the most limiting on Utah 211, has a capacity of 482 vehicles per hour at level of service E. With the mitigation measures to be used, the speed on this section will be reduced from 48 to 32 kilometers per hour (30 to 20 miles per hour), and the capacity will be reduced to 321 vehicles per hour. At shift changes, a peak of 227 vehicles per hour may use this section travelling in both directions, which indicates that level of service D (or better) would be achieved, i.e., reduced speeds but no stoppages (see Table 4-36). This section, as it is, could become congested during shift changes.

Another impact will be accelerated deterioration of area highways as a result of increased automobile and truck traffic. The rate of deterioration will depend, in part, on the size and weight of the trucks. Based on Utah Department of Transportation data for 1983, the pavement and subgrade of Utah 211 are strong, and its estimated life to fatigue is 17 to 19 years, based on 238 current 18,000-pound-equivalent axle loads per year (Martinez, 1985). Project-related activity, even though at a peak several times greater than current levels, will not significantly reduce this fatigue life estimate, provided that regular maintenance is carried out to repair cracks, ruts, pop outs, and pot holes that result from weather and temperature changes. During periods of peak traffic, traffic flow near the S-curves could be impeded due to the need to reduce speed and because of the mitigative measures necessary to assure that current road safety levels are maintained. All required maintenance can be conducted without disruption to access to Canyonlands National Park. DOE, in consultation with State and local authorities, will determine what financial assistance is needed and legally allowable to construct network improvements and mitigate potential road damage.

4.2.1.10.4 Mitigative Measures. Traffic congestion on Utah 211 and U.S. 191 will be studied (see Section 4.1.3.1.10) to determine if any improvements are required on those sections where capacity is reduced. Mitigation could include upgrading those sections or possibly busing of workers to reduce automobile traffic volume or upgrading those sections. Improvements to U.S. 191 or busing of workers will tend to reduce accident increases on area highways during site characterization.

Improvements to Utah 211 were considered to reduce the potential for traffic congestion and to improve safety. The benefits of improving Utah 211 to reduce congestion and improve traffic flow during site characterization appear to be outweighed by the adverse impacts that the improvements would have (Section 4.3.5).

The following mitigation measures will be implemented at the intersection of U.S. 191 and Utah 211, at the "S" curves east of Newspaper Rock, and in the Newspaper Rock Area, which will eliminate any safety concerns associated with project-related traffic.

Utah 211/U.S. 191 Intersection. Widening Utah 211 and U.S. 191 as the intersection is approached will make it possible to add turning lanes and through-traffic passing lanes. This would allow traffic turning onto Utah 211 to slowdown without interfering with regular traffic flows. Traffic signals and warning signs advising that a traffic signal is ahead will also be provided to improve safety.

Utah 211 "S" Curves. Additional visual warning signs, audible warning devices (corrugated pavement) and guard rails will reduce the possibility of accidents. Flagmen and escort vehicles will be provided to control traffic when large trucks are in this section of Utah 211. The movement of large trucks will be restricted to daylight, off-peak, hours to reduce the potential for accidents.

Table 4-36. Comparison of Levels of Service

Level A:	Free flow: Speed controlled by driver's desires, speed limits, or physical roadway conditions.
Level B:	Stable flow: Operating speeds beginning to be restricted. Little or no restrictions on maneuverability from other vehicles.
Level C:	Stable flow: Speeds and maneuverability more closely restricted.
Level D:	Approaches unstable flow: Tolerable speeds can be maintained, but temporary restrictions to flow cause substantial drops in speed. Little freedom to maneuver. Comfort and convenience low.
Level E:	Volumes near capacity: Speed typically in neighborhood of 30 mph. Flow unstable. Stoppages of momentary duration.
Level F:	Forced flow, low-operating speeds, volumes above capacity. Queues formed.

Source: Oglesby, 1975.

Newspaper Rock and Campground. To prevent traffic from approaching the area at unsafe speeds, measures similar to those proposed for the "S" curves will be adopted.

Westbound truck traffic will need to swing out around overhanging rock immediately east of Newspaper Rock. Flagmen and possibly escort vehicles will be provided to prevent accidents. Movement of large trucks will be restricted to daylight, off-peak, hours to reduce the probability of accidents. A pedestrian overpass will be constructed for tourists who cross the road from the campground to the monument.

4.2.1.11 Effects of Salt Management and Disposal

This section summarizes the potential environmental impacts associated with the management of salt and salt-ladened rock during site characterization and measures for mitigating those impacts. The discussion is presented in three parts. First, the management practices are briefly described in the context of their potential for releasing salt to the environment. Secondly, measures for mitigating the impacts from these sources are discussed and the basis for assessing the impacts is described. Finally, the options for permanently disposing of the excess salt, if the site is not selected for the development of a repository, and the basis for selecting one option are presented.

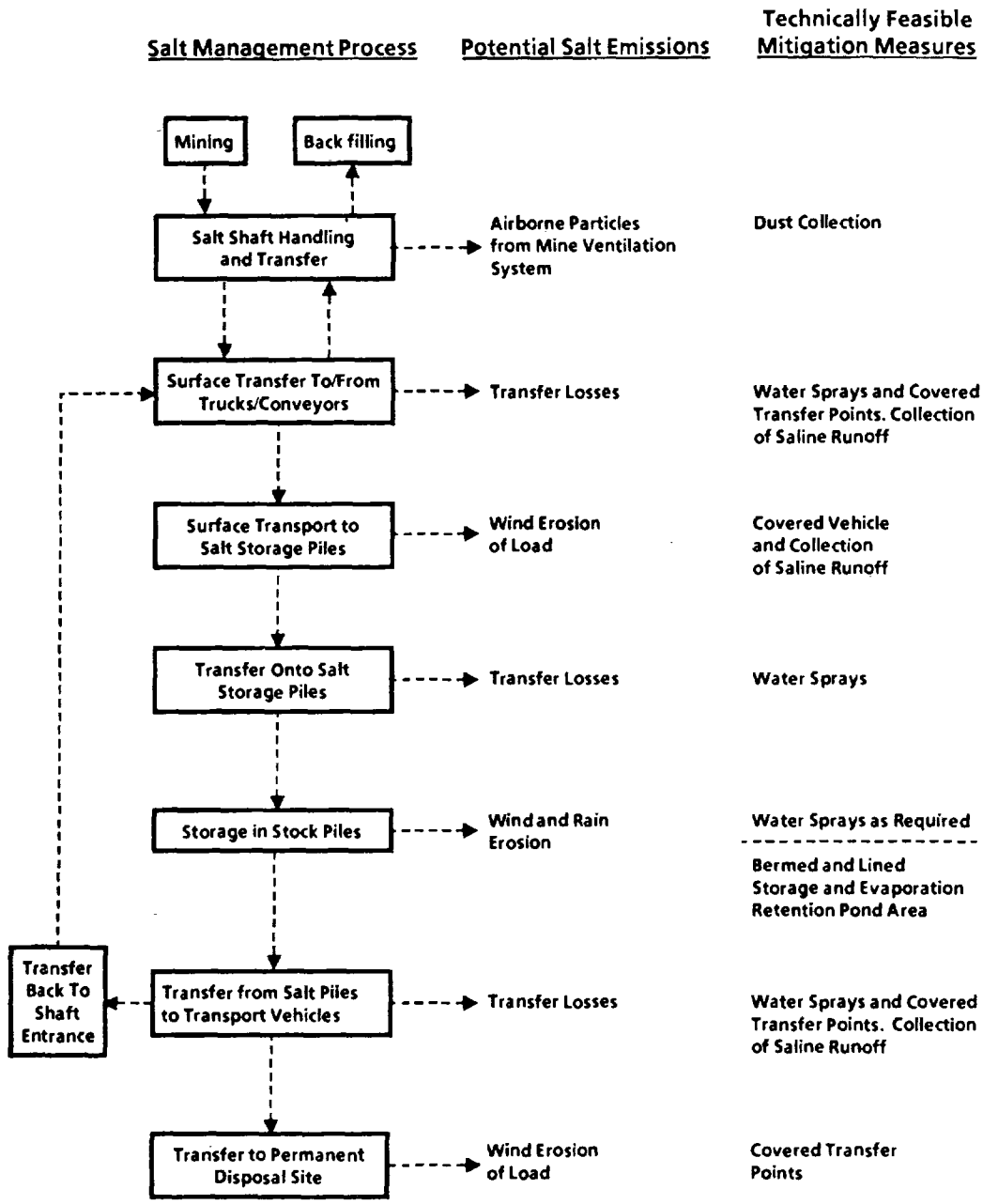
4.2.1.11.1 Salt Management and Control. The exploratory shaft facility (ESF) will involve mining, handling, transporting, and disposing of salt and salt-ladened rock. The discrete elements of this salt-management process are illustrated in Figure 4-36, along with each element's potential contribution to overall salt emission and likely mitigation measures for each source point.

Mined salt is lifted to the surface by a skip and transferred to covered haul trucks for transfer to the salt storage pile. Emissions of salt to the atmosphere occur at the outlet of the mine ventilation system and at the point of transfer of the mined salt to the surface transport vehicle. These emissions can be minimized by the use of dust collection devices at the mine-exhaust facility, and by using a covered transfer device and water sprays at the point where subsurface salt is transferred to the surface haulage vehicle. Saline water from either the salt control devices or storm runoff will be collected and conveyed to the evaporation and retention pond.

When salt is exposed to the weather or another source of moisture, a hard surface crust forms in a few days which tends to shed rainwater (Ver Planck, 1958; DOE, 1984). According to the experience of the salt industry, stockpiled salt is not a source of windblown particles, and crusting can be accelerated by wetting the pile. Freshly deposited material will be wetted, after spreading and compacting, to mitigate any wind effects (Section 4.1.2) (Parsons-Redpath, 1984). The salt storage pile will be kept moist, as required, to accelerate crust formation.

Possible leachage of brine from the evaporation and retention pond into the ground will be prevented by using double liners. These can be made of natural clays or synthetic materials (polyvinyl chloride, polyethylene, or polypropylene). A leachate collection system will be installed between the liners to monitor the integrity of the liner and to remove any leaked effluent. The existing topsoil overburden will be stripped before emplacement of the liners and an engineered sound subbase established. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner so that it can accommodate heavy equipment.

Saline runoff from the shafts area, haul roads, and mined-material stockpiles will be collected by a system of lined drainage ditches which gravity-flow to an evaporation and retention pond. In addition, water collected in the shaft sumps will be periodically pumped to the ditch system for collection in the evaporation and retention pond. The drainage ditches will be designed to convey the runoff from a 500-year storm of a duration and intensity based on time of concentration of the local watershed. This will provide the capability



Salt Management Flow Diagram

Figure 4-36

to convey the runoff from duration storms which produce higher peak flows than a 24-hour rainfall event. The evaporation and retention pond will be designed for an operational volume equivalent to 100 percent of the rainfall volume from a 500-year, 24-hour storm, falling on the areas which drain to the evaporation pond. The maximum volume of the pond will include an additional 61 centimeters (2 feet) of freeboard above the operational level (Section 4.1.2). Due to the greater volume available per unit depth in the top of a pond, the freeboard volume available will be almost equivalent to a second 500-year 24-hour storm volume.

Project GNOME and the Waste Isolation Pilot Plant (WIPP) involved salt management practices similar to those to be employed at the ESF. Activities associated with the December 1961, Project GNOME underground nuclear test resulted in a substantial volume of sodium chloride (salt) being excavated and stored on the site. The storage facility for the salt was an area of approximately 3.6 hectares (3 acres), enclosed by a dike and fence. The salt pile was stored inside the dike and fence but was otherwise open and exposed to the elements of the environment. The project GNOME test site is located approximately 48.3 kilometers (30 miles) southeast of Carlsbad, New Mexico. Soil samples and ecology surveys indicate that insignificant wind erosion and dispersion is occurring at the Project GNOME salt pile, and that there is little, if any, attendant adverse impact on the immediate environment due to salt dispersion by wind (INTERA, 1978).

The WIPP facility presently under construction approximately 40.2 kilometers (25 miles) east of Carlsbad, New Mexico, will test the feasibility of storing nuclear defense wastes in salt. Excavated salt has been stored in an uncovered, unlined pile holding about 136,080 metric tons (150,000 tons) of salt. The pile is surrounded by a bermed ditch which collects and evaporates the precipitation which falls on the pile (average rainfall: 22.9 centimeters [9 inches] per year). The salt is crusted over, and rainfall does not penetrate the pile. No problems with wind dispersion of the stored salt have been experienced (Reith et al., 1985).

4.2.1.11.2 Impact of Salt Management. Soil productivity, water quality, ecosystems, and land use can be impacted by salt transported through air and water pathways. Assessment of the potential impacts requires identification and quantification of the various factors involved. For example, airborne salt can impact crop productivity through root uptake by the plants and foliar deposition. In these cases, not only must deposition rates be estimated, but irrigation rates, rainfall patterns, etc., must be taken into account. The salt deposition rates for site characterization are expected to be less than those for the repository. Repository deposition rates are predicted to be 1.0 kilogram per hectare (0.9 pound per acre) per year at 0.8 kilometer (0.5 mile), diminishing to 0.1 kilogram per hectare (0.09 pound per acre) per year between 1 and 2 kilometers (0.6 and 1.2 miles) from the salt storage pile (Section 5.2.5). Use of these values for assessing the impact of site characterization activities is considered conservative because of the much smaller quantity of salt to be mined during ESF activities. Factors are identified in the following sections for each category of impact, and numerical values are provided to the degree that current information allows.

Effects on Soils. In preparation for the salt pile and associated retention pond facilities, topsoil will be removed and stored for reuse during reclamation. Proper lining and salt management activities should preclude contamination of soils under and adjacent to these facilities.

On the basis of the deposition of wind-blown salt estimated for repository operations, the annual salt deposition rate during ESF activities is small, less than 1 kilogram per hectare (0.9 pound per acre) per year. The deposition decreases with distance; most of the deposition occurs within fenced areas. Deposition is estimated to be 0.1 kilogram per hectare (0.09 pound per acre) at 1 to 2 kilometers (0.6 to 1.2 miles) from the site. This deposition rate will result in an incremental increase in salt concentration in the upper 0.3 meter (1 foot) of the soil strata and is estimated to be 0.2 part per million for a soil with a density of approximately 1,600 kilograms per cubic meter (100 pounds per cubic foot).

Accidental salt spills could adversely affect soils in a limited area by altering cation ratios that could produce sodic conditions. This would lead to dispersion of soil aggregates

and loss of soil permeability. Reclamation would consist of containing the area within a berm and flooding with water to which amendments such as calcium chloride have been added (Hoffman and Meyer, 1982; Rhoades, 1982). The amendment would restore permeability as the water penetrated the soil and the leachate would be collected by drains and disposed of properly.

Effects on Surface Water Quality. Runoff from the region around the salt pile and adjacent to the shaft will be collected and channeled into the evaporation and retention pond. In the Davis Canyon area, the precipitation is lower than the evaporation; therefore, there should not be excess saline water for offsite disposal. If, during operation, it becomes evident that an acceptable evaporation rate of the water cannot be achieved due to area or depth constraints of the pond, the water would be peroidocally removed for transport to an acceptable, off-site disposal facility (Section 4.1.2.4.6).

On the basis of predicted salt deposition rates for repository operation the potential degradation of the water quality of the adjacent streams and water bodies by windblown salt would be small. The majority of the salt emission would be deposited within the ESF boundary; runoff from this area will be retained in the evaporation and retention pond. The amount of salt deposited in the adjacent watersheds will be less than 1,800 kilograms (2 tons) per year, equivalent to less than 0.5 percent of the present salt loadings carried in Indian Creek. The salt load of Indian Creek is estimated to be at least 454,000 kilograms (500 tons) per year from observed flow, and water-quality data in Tables 3-14 and 3-19. Based on water-quality data collected at the Cisco gaging station, the Colorado River carries a salt loading of 3.5 billion kilograms (3.8 million tons) per year. The annual salt deposition of less than 1,800 kilograms (2 tons) from ESF operations in the nearby watershed will amount to less than 5 one-hundred-thousandths of a percent of the total salt burden of the Colorado River. The probability of a tornado strike to the salt is addressed in Section 5.2.5.

Effects on Ground Water. Any area that is used for storage and handling of salt-contaminated material will be constructed with salt-resistant liners to minimize impacts to ground water. Salt concentrations between the liners will be monitored at various points around the site as an early warning system for possible salt contamination. Should salt be detected, appropriate measures will be taken to restore the integrity of the liners, remove leaked effluents from between the liners, and pump leachate back to the surface.

Changes in ground-water quality due to infiltration of precipitation through soils contaminated by windblown salt will be minor. Modeling studies of repository operation show that deposition of salt for the ESF will be less than 1 kilogram per hectare (0.9 pound per acre) per year in the site area, diminishing to 0.1 kilogram per hectare (0.09 pound per acre) per year at 1 to 2 kilometers (0.6 to 1.2 miles) away. If all of this salt were carried to the water table and distributed in the top 3 meters (10 feet) of the saturated zone, it would represent an annual increase in salinity of 0.01 to 0.1 part per million. Over the life of the ESF, this would amount to an increase of less than 1 part per million in salinity groundwater within the immediate site area. However, that all wind-deposited salt could reach the water table is unlikely, as much of it will be transported with storm runoff to the retention ponds. In addition, because the unsaturated zone at the site is very thick and the annual precipitation is low, the transport of surface salts to ground water is expected to be slow.

Effects on Ecosystems. Impacts on terrestrial and aquatic biota resulting from site characterization activities were discussed in Section 4.2.1.2. The discussion below focuses on impacts from salt management.

Sodium, chlorine, and the ions present in common salt are universal components of plant materials; however, excessive amounts of these ions deposited on vegetation or present in the soil are harmful to plant growth. The major toxic effect is osmotic inhibition of water absorption; a common symptom is leaf-tip burn. Salinity levels (generally expressed as electrical conductivity) at which a definite productivity reduction occurs in the yield of many crops have been reported (Wadleigh and Sherman, 1978; Bernstein and Howard, 1958). Since forage crops and native grasses are considered less susceptible to salt impacts than annual crops (Hart, 1983), the salt deposition impacts on native terrestrial ecosystems are expected to be insignificant.

Based on soil deposition and accumulation, no significant impacts to natural vegetation are expected to occur outside of the controlled area. As determined from air dispersion analysis, less than 0.1 kilogram per hectare (0.09 pound per acre) per year of windblown salt is expected to be deposited at 1 to 2 kilometers (0.6 to 1.2 miles) from the ESF site. Most of the salt deposition, therefore, is expected to occur within the fenced controlled area.

Runoff from the controlled area and salt pile will be collected and directed to evaporation and retention ponds. Runoff outside the controlled area will contribute less than 0.5 percent increase in the salt loading of Indian Creek and an immeasurable amount to the Colorado River. Hence, no impacts to aquatic biota in Indian Creek or the Colorado River will occur.

Because the evaporation and retention ponds will contain water only intermittently, they will not be a source of attraction for raptors or water fowl.

Site clearing and rehabilitation will result in some loss of habitat, and a small number of mammals and reptiles will die as a result. Such losses, although unavoidable, will result in small and localized impacts to the total ecosystem.

Effects on Land Use. Deposition of windblown salt from the salt stockpile will not significantly affect plant growth and, consequently, land use for grazing activities at the Davis Canyon site. The impact will be minimal because predicted salt deposition rates are low. In addition, deposition rate decreases with increasing distance from the site, and most deposition will be confined within the ESF area. The control measures discussed in Section 4.2.1.11.1 will minimize the potential for soil and vegetative impacts that would affect land uses in the Davis Canyon site.

The onsite area will be restored following site characterization if the site is not selected for the repository (Sections 4.2.1.1.2 and 4.1.2.4).

4.2.1.11.3 Salt Disposal and Impacts. If the ESF site is not chosen for the development of a repository, about 35 percent of excavated salt and salt contaminated rock, which consists of 46,600 cubic meters (61,000 cubic yards) will require permanent disposal. This section summarizes the basis for choosing a preferred option from among the candidate options and examines the environmental impacts associated with that option.

Disposal Options. In addition to the preferred disposal method of offsite landfill, four alternative methods for disposal of the waste salt are available (Section 4.3.4.2):

- Onsite landfill
- Disposal in existing, unused salt mines or flats
- Deep-well brine injection
- Offshore disposal
- Transfer, gift, or sale of salt to Federal, State, or private parties.

For site characterization, all of the alternatives have greater potential for environmental impacts than disposal in a landfill that is licensed, bermed, and double-lined with leak monitors. An investigation of a candidate landfill was conducted at Bonneville Salt Flats, Utah (McCutchen, 1985). The facility has the capability to handle the waste salt from site characterization (McCutchen, 1985) and will be considered for use along with other candidate landfills, subsequently identified. The dust generated during transportation and disposal operations will be controlled by use of covered trucks and water sprays. Leachate collection will control leakage from the landfill.

Impacts of Disposal. Because the potential for environmental impact is negligible once the excess salt is emplaced in a licensed landfill, the only other potential impacts to be assessed are those associated with transporting salt off site, from the ESF to the landfill.

The excess salt and salt-laden rock will be disposed of over a 12 to 18 month period. A total of approximately 2,900 truck loads of salt and salt-laden rock will be transported off-site for disposal. Each truck will contain approximately 16 cubic meters (21 cubic yards) of material. One of the possible disposal options is to transport these materials to a licensed landfill near the Bonneville Salt Flats, Utah. The proposed route from Davis Canyon to the disposal site is approximately 640 kilometers (400 miles). The highway routes are Utah 211 west to U.S. 191 north, U.S. 191 to Crescent Junction, I-70 west to U.S. 191/6, U.S. 191/6 north to I-15, I-15 to Salt Lake City and I-80, then I-80 west to the Bonneville Speedway exit.

Environmental impacts of salt transportation under normal conditions are expected to be negligible because existing routes will be used and trucks transporting the salt will be covered to minimize wind dispersal.

In the event of an accidental spillage of salt during transport, the potential impacts will depend on several factors:

- Location and quantities involved in the spill
- Proximity to water bodies
- Cleanup response time
- Weather conditions during that period.

Impacts resulting from accidental transportation spills on land will be localized and short-term. Spills occurring during precipitation could lead to infiltration of saline runoff. During dry conditions, a small plume of dust would be generated at the accident site, settling out within a short distance. Some vegetation that is not crushed or broken by either the vehicle or its load may show symptoms of salt stress after prolonged exposure to salt drift or runoff if the site is not rapidly cleaned up. Procedures have been established to reload the salt into another vehicle, test soils for elevated salt concentrations, and remove and replace soil or vegetation, as necessary.

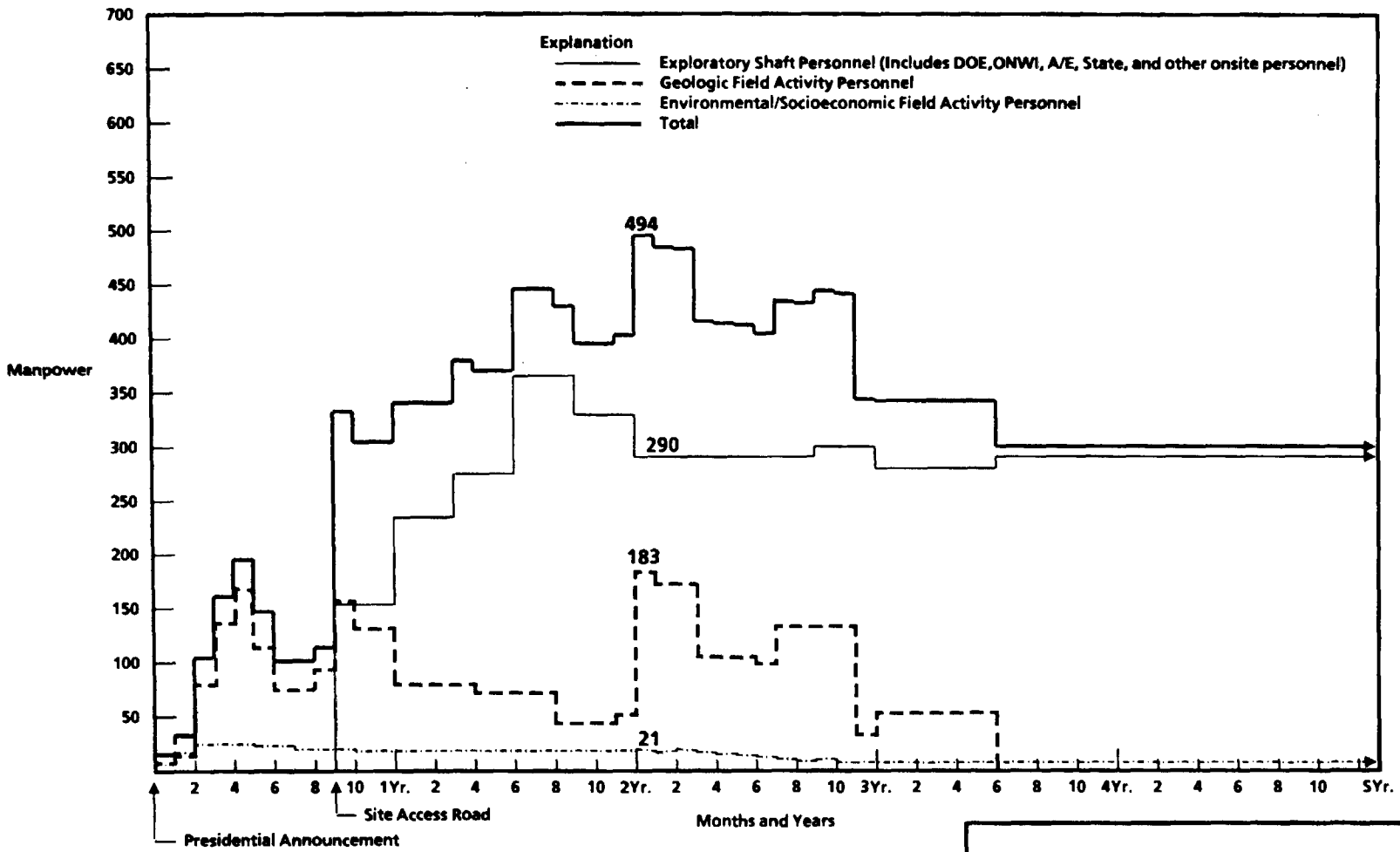
There is a lower probability that accidental spillage into a body of water could occur. In that event, mitigation action would be more difficult and time dependent. If effective mitigation is not feasible, precautions will be taken that will lower the probability even further (e.g., route selection and vehicle speed control).

4.2.2 Expected Socioeconomic Effects

The magnitude of socioeconomic impacts that may affect surrounding communities depends upon several major factors: characterization work-force requirements, in-migration worker profiles, the location preferences of the workers, and the number of local residents that can be employed for characterization activities.

Even though there are a number of local residents available to take jobs as carpenters, welders, plumbers, electricians, drillers, miners, heavy equipment operators, laborers, etc., the number of local residents hired will depend in part on whether local or outside business concerns are awarded site characterization contracts. Experience at other projects of this magnitude with numerous short-term activities suggests that the minimal percentage of local hires might be 10 percent of the 494 peak number of characterization workers (see Figure 4-37). Although it is possible that a higher percentage of local hires would be employed during characterization, the 10 percent estimate is used in this analysis because it represents a realistic conservative case for socioeconomic impacts (Parsons-Redpath, 1984).

The duration of each worker's stay in the site area will vary with scheduled tasks. Some tasks will require workers to be in the area periodically for two weeks (e.g., socioeconomic data collection), while other tasks will require workers to be in the area for the entire site characterization period (e.g., project management activities). The various schedules of activities are presented in Section 4.1 for engineering, geologic, environmental, and socioeconomic activities. Workers associated with the shorter term tasks will occupy



Cumulative Site Characterization Work Force

Figure 4-37

available temporary housing and will have few effects on community services. The peak work-force number used for the following analysis is a short-term peak lasting for 1 month (see Figure 4-37) but represents a conservative case. As site activities change, specific workers used will vary, thus reducing the number of workers living in the site area for the entire site characterization period. Because many of the workers are temporary, the accompanying demand for services can sometimes be met by intensive use of services over the short duration of the peak. Peak project demand is used in this analysis, however, to identify the maximum requirements which could occur.

The population in-migration model (Goldsmith, 1984) was used to project the number of people who would be in the area as a result of site characterization work activities (engineering, geologic, environmental, and socioeconomic). The percentages and multiplier inputs to the model for site characterization are shown in Table 4-37. A logic diagram and discussion of the model are contained in Section 5.4. On this basis, 445 in-migrating workers would be in the area, for a total of 965 in-migrants, including families.

The indirect work force related to site characterization activities is estimated to be 150 people. Given the high local unemployment rate, a large number of existing residents should be available for these positions. The spouses of in-migrating site characterization workers will also be available for newly created jobs in the local economy. Demand which cannot be met from these two sources of labor will encourage some in-migration. It is assumed that local residents and worker spouses would secure almost all of the new indirect jobs.

The projected in-migrants were distributed to Moab, Monticello, Blanding, and the rural unincorporated areas using a population allocation (gravity) model (see Section 5.4). The distributions were based upon the 1984 population estimates for these communities and their distance from the site. Moab, 122 highway-kilometers (76 highway-miles) from the site, had an estimated baseline population of 6,620 (including Spanish Valley). Monticello's estimated 1984 population was 1,980 persons; it is located 77 highway-kilometers (48 highway-miles) from the site. Blanding had an estimated population of 3,210 persons, and it was located 114 highway-kilometers (71 highway-miles) from the site. The population of the rural unincorporated areas within commuting distance of the site was estimated at 450, and the average distance of these communities from the site is 112 highway-kilometers (70 highway-miles). Using this information, the allocation of in-migrants assumes that Moab would receive 42 percent, 32 percent would locate in Monticello, Blanding would capture 23 percent of the in-migrants, and the rural area would receive 3 percent of the total.

Table 4-38 provides a description of the total number of in-migrants expected, the number of school-aged children, single workers in-migrating (including married workers who do not relocate with their families), and married in-migrating workers with family present in Moab, Monticello, and Blanding under these distribution assumptions. Table 4-39 presents the additional baseline growth expected for 1987. Both baseline growth and in-migration will be used to assess the impact on local housing and services.

The site characterization program is estimated to cost $250 million (1985 dollars) for ESF construction and $225 million (1985 dollars) primarily for geologic activities. Of this amount, 70 percent will be used for materials and 30 percent for wages. Although a much smaller portion of this amount would be spent locally for materials and project-worker wages, considerable economic activity could result. The fact that the site characterization project would be the largest employer in southeastern Utah suggests that action may be needed to prevent an economic bust upon completion of the project. It may be necessary to slowly phase down activities.

Economic impacts within the communities are not the only potential economic impacts. For example, withdrawing the shaft site, access road, and geologic drill sites from private use will result in a slight reduction in the amount of land available for grazing in the Davis Canyon area (see Section 4.2.1.1). Approximately 24 hectares (59 acres) of land will be required at the exploratory shaft facility site. The land required for geologic activities

Table 4-37. Inputs for the Population In-Migration Model for Site Characterization

Direct In-Migration	
Percent of work force in-migrating (Parsons-Redpath, 1984)	90.0
Percent of in-migrating workers with family members present (Murdock and Leistritz, 1979)	45.0
Family size multiplier (Department of Energy, 1978)	3.6
Percent of children who are school age (Bureau of Census, 1982)	65.0
Indirect In-Migration	
Indirect employment multipliers (Murdock and Leistritz, 1979)	0.3

Table 4-38. Peak Site Characterization In-Migration Distribution to Moab, Monticello, and Blanding

Characteristic	Moab	Monticello	Blanding	Rural (unincorporated)
Percent of total in-migrants	42	32	23	3
Number of total in-migrants	405	309	222	29
Number of single in-migrating workers including married without family present	103	78	57	7
Number of married in-migrating workers with family present	84	64	46	6
Number of married in-migrating workers and number of family members present	302	230	166	22
Number of in-migrating school-age children	87	67	48	6

Source: Hines, 1986.

Table 4-39. Additional Baseline Growth Present at the Peak of In-Migration for Moab, Monticello, and Blanding (1984-1987)

Characteristic	Moab	Monticello	Blanding
Additional baseline growth (number of persons)[a]	190	165	557
Number of additional households[b]	66	48	141
Number of additional school-age children[c]	49	43	145

(a) Interpolated from county projections made by the State of Utah (Prall and Teuscher, 1984)

(b) Moab's 1980 persons-per-household size was 2.89.
Monticello's 1980 persons-per-household size was 3.44.
Blanding's 1980 persons-per-household size was 3.96.
(BGI, 1984, ONWI-471).

(c) Based on 1980 school children per population in Moab--26 percent (Bureau of the Census, 1982).

will range from 0.4 to 5 hectares (1 to 12 acres) per activity. Future private mining, drilling, and extraction or injection of water and other liquids by lessors of subsurface rights will not be permitted in the larger controlled area (approximately 2,332 hectares [5,760 acres]). Leasees of mineral rights that are within the protected area will be compensated as allowed by law. This concludes the analysis of site characterization economic impacts. A discussion of site characterization impacts on tourist sales in the local retail and service sectors appears in Section 4.4.1.

For this assessment of impacts on community services, the baseline growth demand and the additional demand created by peak in-migration related to site characterization are summarized in Table 4-40. The data in Table 4-40 are compared with the capacities listed in Section 3.6.3 to determine what services could be adversely affected. Peak project demand does not represent average yearly demand. Peak demand can sometimes be met by a more intense use of a service over the short duration of the peak. Peak project demand is more suitable for planning purposes in that it identifies maximum requirements.

If it is assumed that every in-migrating employee would need a housing unit, and that in-migrants will seek to locate in the area as projected by the gravity model, then the demand for rental, single-family, and mobile-home spaces could not be satisfied in Monticello or Blanding. Moab would have enough housing capacity to meet the demand projected by the gravity model and still have some additional housing available. However, this excess housing could not satisfy all of the additional demands or housing preferences of the newcomers projected to locate in Monticello or Blanding.

Because Moab has extra housing, school capacity, and service capacity, it might be possible to alleviate some initial housing demand problems by providing new hires with information on the availability of housing, schools, and other amenities. It might be necessary for the site contractor to develop mobile home spaces in Moab and Monticello. It might also be possible for the contractor to lease vacant housing or mobile home spaces to provide temporary workers an alternative to short-term stays in area hotel or motel rooms. Spaces could also be provided for weekly commuters that may wish to bring recreational vehicles to the area.

Other measures which could be effective include programs or policies to hire as many local residents as possible, and scheduling characterization activities in a manner that would lower peak work-force requirements. This would reduce the number of workers and families relocating to the area. Increasing local employment opportunities would reduce the number of workers who would be spending a substantial portion of their wages outside the region, providing greater economic benefit to the region. The DOE could also provide technical assistance to aid in local planning efforts. Finally, as noted in Section 4.1.3.2, a monitoring program will be established during site characterization so that appropriate mitigation measures can be established.

Any increased community expenditures associated with the project could also be offset by using a variety of additional revenue sources. For example, the DOE is authorized to make annual grant payments under Section 116(c)(3) of the Nuclear Waste Policy Act of 1982 (NWPA) (10 CFR Part 960) to states and units of general local government where a site has been recommended for characterization. These payments will be made in amounts equal to the taxes that states and units of general local government would have received were they authorized to tax site characterization and repository development activities as they tax other real property and industrial activities occurring within their jurisdictions. Payments are to be made each fiscal year until activities at the site are terminated.

The major types of taxes imposed by the State of Utah and its units of general local government on real property and industrial activities occurring within their jurisdictions include:

- Real property tax
- Personal property tax
- Corporate income tax
- Franchise tax

Table 4-40. Projected Baseline and Project-Related Service Requirements for the Peak of Site Characterization Activities, Davis Canyon

Service	Moab		Monticello		Blanding	
	1987 Baseline	1987 Project-Related	1987 Baseline	1987 Project-Related	1987 Baseline	1987 Project-Related
Population increase	190[f]	405	165	309	557	222
Additional households	70	187	50	142	140	103
Education						
Number of additional students	49	87	43	67	145	48
Additional teachers required (student/teacher ratio 19:1)[a]	3	5	2	4	8	3
Protective services						
Additional municipal police officers required/population (2:1000)[b]	0	0	0	0	0	0
Additional fire service personnel required/dwelling units (2:1000)[c]	0	0	0	0	0	0
Health						
Additional physicians required/population (1:1000)[d]	0	0	0	0	0	0
Additional hospital beds required/population (5:1000)[d]	1	2	1	2	3	1

Table 4-40. Projected Baseline and Project-Related Service Requirements for the Peak of Site Characterization Activities, Davis Canyon (Page 2 of 2)

Service	Moab		Monticello		Blanding	
	1987 Baseline	1987 Project-Related	1987 Baseline	1987 Project-Related	1987 Baseline	1987 Project-Related
Water						
Additional municipal water needs in gpd (150 GPCD)[e]	28,500	60,750	24,750	46,350	83,550	33,300
Sewage						
Additional effluent (100 GPCD)[e] in gpd	19,000	40,500	16,500	30,500	55,700	22,200
Recreation						
Additional developed acres required (1 acre/600 children - playground)[e]	0	0	0	0	0	0
(1 acre/1000 population - neighborhood parks)[e]	0	0	0	0	1	0
Solid Waste in pounds						
6.25 pounds/capita/day	1,190	2,531	1,030	1,931	3,480	1,388

Note: All service numbers are rounded.

Sources: (a) National Center for Education Statistics, 1983
(b) Federal Bureau of Investigation, 1984. This includes local law enforcement, state police, and highway patrol officers.
(c) Stenehjem and Metzger, 1976
(d) National Center for Health Statistics, 1983
(e) International City Management Association, 1979

- Severance tax
- Sales and use taxes
- Other excise taxes.

Some of these taxes might be applied to site characterization and repository development if such activities were taxed in a manner similar to the way in which other real property and industrial activities are taxed. One of the important considerations involved in calculating the annual grant-equal-to-tax payment is establishing which taxes might be applicable. Other considerations include jurisdictional eligibility and grant administration.

Grant-equal-to-tax payments will begin during site characterization and continue throughout repository construction and operation. The NWPA provision indicates that these funds are to be paid to states and units of general local government where a site is located.

This fund is not designated as a mitigation grant, as are those payments described in Section 116(c)(2)(A) of the NWPA. Therefore, jurisdictions receiving grant-equal-to-tax payments will not necessarily correspond to jurisdictions affected by project-related activities. For example, San Juan County is eligible for grant-equal-to-tax payments, but Grand County and other affected communities in the region may not be eligible.

The DOE is looking at alternative ways to assist communities that require mitigation assistance during site characterization. The Mission Plan (DOE, 1985, DOE/RW-0005, Vol. II, p. 88) states that "before site characterization, the DOE will review requests for impact mitigation assistance on a case by case basis."

The NWPA also provides grants to states for a variety of other activities. States having an approved candidate site are eligible for grants under Section 116(c)(1)(B). These grants will be made available to eligible states for, among others, the purposes of (1) reviewing site characterization activities and determining socioeconomic, public health and safety, and environmental impacts; (2) developing a request for repository impact assistance; and (3) monitoring site characterization activities. The grants are also available for several other activities not specifically related to socioeconomics.

In developing a request for repository impact assistance, the states and local governments will need to identify impacts and associated mitigation measures. This activity will involve community planning during the site characterization phase. Funds for planning activities related to the project can be provided through this provision of the NWPA.

School districts in the area affected by increased Federal activities could apply for funds through the "School Assistance in Federally Affected Areas for School Construction and Operation" (Office of Management and Budget, 1983). New county and community revenues would also be generated from user fees and sales taxes paid by project workers.

In addition to the various forms of revenue available to the State of Utah and the local governments, the DOE can also provide technical assistance to aid local planning efforts. This assistance could be used to develop job training for Native Americans and other local residents. It could be used for worker transportation, housing or any other mitigation measures which require coordination between the DOE, the State, affected tribal governments, and the local governments. DOE technical assistance could also be used to help local governments form an impact management committee and in the development and implementation of a comprehensive community impact monitoring program.

Impacts on most services would probably be limited to a need for additional equipment and part-time staff. However, additional solid waste created by baseline and site characterization in-migrants could be a problem because of the limited life span of the existing community landfills.

Impacts on social structure and quality of life are related largely to the population change in the community. The population change due to site characterization for Moab during the peak will be approximately 7 percent, Monticello's population change will be 14 percent,

and Blanding's will be 6 percent. The area has experience in hosting seasonal populations and should not be overwhelmed by the in-migrating site characterization workers. However, some social problems related to the differences between worker and local lifestyles may occur. It has been noted that the traditions and religious values of the current residents are likely to be different from the values of newcomers. Some of the current energy boom towns are occurring in predominantly rural or Mormon areas. The construction workers' need for recreation is likely to find outlets which are not appreciated by current residents. Another group with values which may be in conflict with the values of many project workers are the Native Americans (Finsterbusch, 1980). These factors could create a need for additional law enforcement in the communities. Although social problems could occur, the number of in-migrants compared to the number of current local residents and the short time that these in-migrants would be present will probably not be enough to significantly alter the social structure of the nearby communities.

The project may do little to foster community cohesiveness, given the local controversy that has surrounded its development (see Section 3.6.4). Some people will continue to perceive the project as a threat to their livelihood and even their life style. Others will perceive it as a boon to both the local economy and themselves.

4.3 ALTERNATIVE SITE CHARACTERIZATION ACTIVITIES

This section discusses some alternative methods and approaches to site characterization. Some of these could be used to avoid adverse impacts; however, they may not be feasible because of unavailable technology, costs, or secondary effects.

Site characterization involves two major groups of activities:

1. The collection of geological, hydrological, and environmental data uses standard readily available procedures, such as seismic surveys and the drilling of 15-centimeter (6-inch) boreholes. These activities cause only local and temporary disturbances to the physical environment which can be mitigated to acceptable levels (Section 4.2). No alternative test procedures causing less environmental impact are available; however, the location of these tests could, in many cases, be moved to accommodate the existence of any newly discovered archaeological or other environmentally sensitive finds.

2. The construction of an exploratory shaft facility permits in situ testing of thermomechanical and other properties of the host rock. This activity is required to verify site suitability and fulfill data needs for the repository, and cannot be replaced by alternate procedures. However, various aspects of the construction and operation of the exploratory shaft facility can be carried out using alternate procedures of varying impact; some of these alternatives are described below.

4.3.1 Alternative Exploratory Shaft Locations

The location of the exploratory shaft facility (ESF) was selected relative to a conceptual repository layout for one of seven reference locations for a salt repository. These locations were selected using scientific, engineering, environmental, and nontechnical (such as land use) criteria. The favorableness of a particular location as a potential repository site will be verified through geologic mapping and geological, environmental, and engineering surveys during site characterization. Alternate ESF locations, apart from those given in these environmental assessments, will be considered if investigations indicate that location changes are necessary to avoid such problems as destruction of significant archaeological resources or severe impacts on sensitive biological communities. However, the location of alternate ESF sites would remain within a limited area around each reference location, because of the physical constraints imposed by the canyon walls.

4.3.2 Single Exploratory Shaft Alternative

It is physically possible to conduct the subsurface characterization activities from only one shaft. This alternative would, of course, eliminate the environmental impacts associated with constructing one of the two planned exploratory shafts. However, there are compelling reasons why this alternative is not the preferred approach. The first and foremost of these reasons is safety. A prime consideration for occupational safety is to provide at least two escapeways from any potentially hazardous work station. This principle is clearly stated in the regulations of the Mine, Safety and Health Administration (MSHA) 30 CFR Part 57. Although an exploratory shaft facility (ESF) is not a mine, since the purpose of a mine is to extract minerals for commercial use, an ESF does consist of shafts and underground openings constructed using mining techniques. Therefore, safety standards developed for mines are the most applicable safety standards for constructing and operating an ESF.

Section 57.11-50 of the MSHA regulations (30 CFR Part 57) states:

> Every mine shall have two or more separate, properly maintained escapeways to the surface from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed. A second escapeway is recommended, but not required, during the exploration or development of an ore body.

The DOE policy is that merely meeting minimum safety standards is not adquate. In DOE Orders 5480.1A and 5480.4, "Environmental Protection, Safety, and Health Protection Standards for DOE Operations," the DOE has adopted as a matter of policy the California Mine Safety Orders ("Escapeways and Refuge Stations," California Administrative Code, Title 8). Article 27, Section 7080 states:

> Every mine shall have two separate escapeways to the surface which are so positioned that damage to one shall not lessen the effectiveness of the other, or a method to refuge shall be provided when only one opening to the surface is possible.

Additionally, it is possible that personnel working in any underground opening in evaporites such as salt may encounter releases of flammable gases. MSHA regulations 30 CFR 57.21 detail the conditions that would cause a mine to be declared gassy. If a mine is declared gassy, 30 CFR 57.21-22 states:

> The main intake and return air currents in mines shall be in separate shafts, slopes, or drifts ....

Thus, conducting underground site characterization from two shafts would be in compliance with generally accepted safety practices, as described in the above-quoted MSHA and California standards.

Exploratory shaft sizes, discussed herein, were selected based on safety and the project needs. Each shaft must be large enough to contain utility lines, a conveyance for persons and material, and to provide necessary ventilation. Although shaft diameters might eventually be changed for the ESF, the selected sizes are representative diameters, and their impacts represent expected environmental consequences.

4.3.3 Alternative Water Supply

The exploratory shaft facility water requirements, peaking at 15 cubic meters per hour (65 gallons per minute), can be satisfied by trucking in water from municipal water sources. Preliminary hydrologic data indicate that insufficient ground water exists at the site to satisfy this demand. Should site-specific data show an adequate ground-water supply, the options will be re-evaluated. Because of the small extent of this water demand, it is believed that the impacts to any supply source are equivalent and minor.

4.3.4 Alternative Waste Disposal

It is believed that the procedures selected for control and disposal of liquid waste described in Section 4.1.2.6, represent the best available control technology, and that alternative control and disposal procedures, such as those described in the following sections, would have greater environmental impact.

Section 4.1.2.6 also describes selected disposal methods for solid refuse and excess salt; however, alternative procedures for disposal of these solid wastes have been identified and are discussed below.

4.3.4.1 Combustible Refuse

The selected disposal method for rubbish is to haul it to a permitted landfill near Grand Junction, Colorado, or Farmington, New Mexico (Sands, 1984; Smith, 1984). The impacts of this method are described in Sections 4.2.1.1, land use; 4.2.1.3, air quality; and 4.2.1.4, hydrological effects.

Alternatives to this disposal method include (1) onsite incineration with offsite disposal of ash residue at a licensed land fill, or (2) disposal in a landfill developed on site.

Existing landfills at Monticello and Moab are not permitted facilities; however, potential sanitary landfill sites are available in the region. For example, a permitted disposal site is located approximately 258 kilometers (160 miles) from the site, near either Grand Junction, Colorado, or Farmington, New Mexico (Sands, 1984; Smith, 1984).

Onsite landfill disposal requires acquisition of the required permit, dedication of a land area, assurance that no leachate contamination of ground water occurs, use of diesel-operated equipment for salt spreading and compaction, and control of gaseous (methane) emissions.

4.3.4.2 Disposal of Excess Salt

Approximately 65 percent of the salt excavated from the exploratory shafts and subsurface test areas will be required for backfilling the shafts and subsurface excavations, if the site is not selected for a repository. As discussed in Section 4.1.2.6, waste salt and residues from runoff detention ponds may be disposed of off site in a licensed landfill located near Salt Lake City (McCutchen, 1985). The effects of this method are discussed in Section 4.2.1.1, land use, and Section 4.2.1.4, hydrologic effects. The discussion indicates that there are one or more landfills that can accommodate the amount of waste expected and are licensed to do so. Present facilities are near either Grand Junction, Colorado or Farmington, New Mexico (Sands, 1984; Smith, 1984). Additional facilities may also be available if required. Thus, problems including preemption of land use, shortening the design life of an existing facility, and guaranteeing long-term integrity of the landfill with respect to erosion, leaching of salt, or contamination of ground water, are not expected to be significant.

The offsite disposal option for salt and salt-contaminated materials was chosen because of the need to return the site to its original condition if it is not selected for a repository. The facility identified for the disposal of these materials was selected, in part, to address the concerns about having the salt in a caretaker-type licensed facility. The offsite alternative and the facility identified represent the most conservative case for disposal of salt and salt-contaminated materials.

Impacts resulting from transportation of the salt and salt-contaminated wastes, including greater cost and the potential for contamination along the routes, have also been discussed previously.

In addition to the selected disposal method, there are five alternatives for the disposal of waste salt (BGI, 1983, ONWI-453; Parsons-Redpath, 1984):

- Disposal in an onsite landfill
- Disposal in existing, unused salt mines or salt flats
- Deep-well brine injection
- Offshore disposal
- Transfer, gift or sale of salt to Federal, State, or private parties.

All offsite alternatives require transport of excess salt. Most would also incur environmental impacts such as those associated with rail or truck transportation. A qualitative environmental analysis is presented below.

4.3.4.2.1 Onsite Landfill. Primary issues associated with this disposal option include land-use preemption and ground-water infiltration. If the salt is buried to sufficient depth, particularly if covered with a substantial soil, the land above the salt may be put to beneficial use, thus minimizing land-use impacts. The use of liners above and below the salt should minimize ground-water infiltration. Long-term integrity of the landfill would require detailed site information, particularly if sited in a flood plain area. The primary advantages of this option include the following:

- Relatively low cost (Parsons-Redpath, 1984)
- Absence of transportation impacts
- Limited environmental impacts (primarily on ground water and land use).

Disadvantages include the following:

- Potential long-term preemption of land use

- Problems in guaranteeing long-term integrity of the landfill with respect to erosion, subsequent leaching of salt, or subsequent water quality contamination.

4.3.4.2.2 Mine Disposal. Offsite disposal in existing or abandoned mines or salt flats has the primary disadvantages of increased cost and environmental impacts associated with rail or truck transports. The primary advantages include the following:

- Elimination of onsite impacts

- Minimal offsite environmental impacts, including those associated with rail or truck transport.

If existing or abandoned salt mines are used, there would be no alteration of the existing environment, hence no ground-water contamination. An additional benefit might be reduced subsidence as the mine is backfilled. If an existing or workable mine is used in this way, selection of this option might adversely impact resource exploitation for the mine that is used.

4.3.4.2.3 Deep-Well Injection. Deep-well injection would require offsite transport and the creation of an offsite brining facility, both of which would result in additional cost over onsite land disposal. The environmental impacts associated with brining and deep-well injection would be somewhat different from those associated with land disposal (NUS Corporation, 1985). Construction of the brining facility would produce the temporary impacts on land use, soils, resident biota, and air quality, which are typical of any construction project. Production of brine would require substantial amounts of water, and might affect the local water supply. Deep-well injection of brine might affect ground-water quality.

The major advantage of deep-well injection is that most environmental impacts (with the possible exception of the impact to ground-water quality) would be short-term and reversible. The major disadvantages compared to onsite land disposal include the following:

- Additional cost

- Additional impacts from rail or truck transport

- Water supply requirements (BGI, 1983, ONWI-453)
- Potential deterioration of ground-water quality
- Substantial, but temporary, environmental impacts associated with the construction and operation of a brining facility.

4.3.4.2.4 Offshore Disposal. Offshore disposal is likely to involve transport of the excess salt to the Great Salt Lake (BGI, 1983, ONWI-453). It is expected that salt would be loaded on barges and dispersed in the lake over a wide area. Costs (Parsons-Redpath, 1984) and environmental impacts, although higher than for the preferred option, are expected to be low. Some experience on this disposal technique has been acquired during performance of the DOE Strategic Petroleum Reserve Project (SPRP) (BPNL, 1979, DOE/ET-0029, 3 vols.). For the SPRP, very large amounts of saturated brine (approximately 32,000 cubic meters [200,000 barrels] per day) were discharged in the Gulf of Mexico. This project has shown that negligible impacts on offshore marine biota occur (DOE, 1983, p. 6). More detailed studies would be required, but the quantities of salt to be disposed of are not likely to result in any significant changes in the salinity of the Great Salt Lake.

The primary advantage of offshore disposal is that the impacts of disposal will be, for the most part, temporary. The primary disadvantages are the following:

- Increased cost, due primarily to transportation requirements
- Additional impacts from rail or truck transport
- Minor potentially adverse impacts to offshore aquatic biota.

4.3.4.2.5 Sale or Transfer of Salt. Mined salt could be offered first to Federal agencies through sales or transfers, for use in road salting or other applications. If the material is not needed by Federal agencies, it could be offered to interested State and local governments as a donation. If it is refused by these governments, it could then be offered for public sale. The feasibility of this disposal has not been verified. Primary disadvantages would be the cost and impacts from rail or truck transport of the salt.

4.3.5 Alternative Access Improvements

To mitigate some of the impacts described in Section 4.2.1.10, the DOE could make some permanent highway improvements for Utah State Highway 211 (Utah 211). These would be made for site characterization to reduce or mitigate impacts of the proposed activities described in Section 4.1.2. The improvements include a bypass around Newspaper Rock State Historical Monument, straightening a 0.32-kilometer (0.2-mile) section of Utah 211 above Newspaper Rock, and constructing a cloverleaf at the junction of Utah 211 and U.S. 191 (BNI, 1985d). The bypass will divert project traffic around Newspaper Rock while maintaining access for park visitors. Eliminating the sharp curves above Newspaper Rock will improve safety and increase the capacity of that section of highway. The cloverleaf at the junction of Utah 211 and U.S. 191 will provide easier, safer access to the Canyonlands National Park and the project site. The major features of these improvements are shown in Table 4-41.

During site characterization, project traffic will pass Newspaper Rock State Historical Monument located adjacent to the highway. Newspaper Rock is a large cliff mural of petroglyphs, some of which were carved by Anasazi Indians (BGI, 1982, ONWI-144). This archaeological site is listed in the National Register of Historic Places (BGI, 1982, ONWI-144). Visitors to Newspaper Rock are estimated at 61,000 per year.

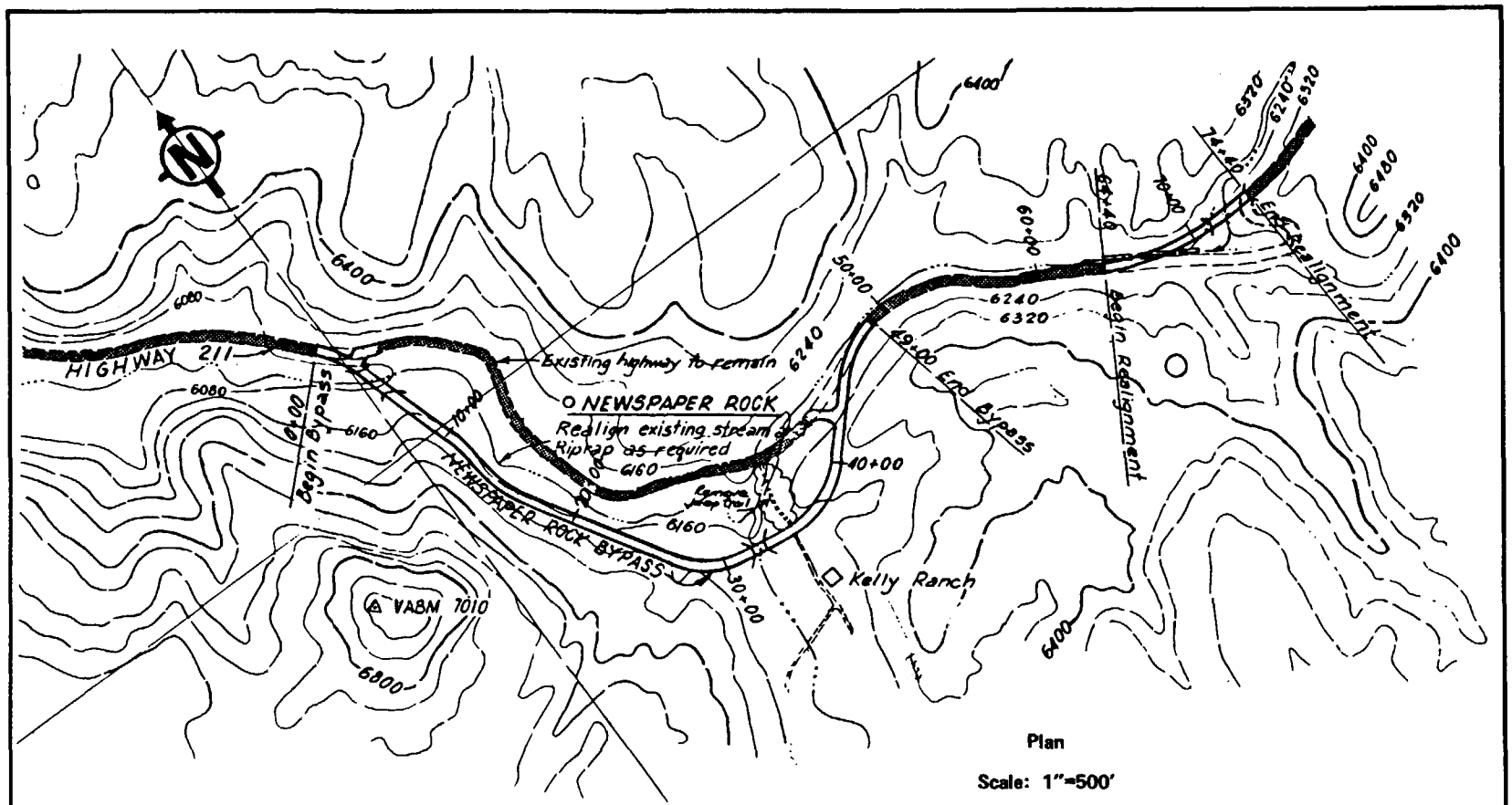
To minimize the impact of additional traffic from site characterization on visitors to Newspaper Rock and to reduce the possibility of an accident involving traffic on Utah 211, a permanent bypass of the monument (shown on Figure 4-38) has been proposed and evaluated. This evaluation has considered whether the bypass alternative would effectively reduce impacts.

Table 4-41. Characteristics of Improvements to Utah State Highway 211

Parameter	Newspaper Rock Bypass	Highway Utah 211 Realignment
Length of new construction (miles)	0.9	0.2
Bridges:		
Number	2	1
Cumulative length (feet)	300	300
Ruling grade	8	8
Total surface area disturbed (acres)	12	2
Total water usage (construction) (million gals)	1.5	0.7
Construction cost estimate ($ mils)	2	3[a]
Construction time estimate (months)	6	4

(a) Includes cost of separated T-interchange at junction of Utah 211 and U.S. 191.

Source: BNI, 1985d.



Plan

Scale: 1"=500'

Explanation

- Proposed bypass
- Existing highway to remain
- Existing highway to be removed

Scale

0 500 1000 Ft

0 100 200 300 M

Source: BNI, 1985d; USGS, 1954.

Proposed Utah State Highway 211
Newspaper Rock Bypass Plan
Davis Canyon Location

Figure 4-38

The Newspaper Rock bypass will begin approximately 250 meters (850 feet) northwest of the monument, and proceed southeast and cross Indian Creek via a 60-meter (200-foot) bridge and parallel a rockface west of the monument. An oxbow meander of Indian Creek will be straightened to make room for the bypass to the west. The bypass will join the present Utah 211, 300 meters (1,000 feet) to the east of Newspaper Rock. The current Utah 211 roadbed will be retained for use by visitors to Newspaper Rock.

The bypass will be 1.6 kilometer (1 mile) in length and involve realignment of the existing streambed and the placement of rip-rap to reduce erosion during periods of high water. Turnouts at each end of the bypass will create dedicated access to Newspaper Rock State Historical Monument. With this bypass, Utah 211 will be no closer than 91 meters (300 feet) from the monument. Utah 211 currently passes through the area, within 46 meters (150 feet) of the monument.

The primary advantage of the bypass will be the improvement of safety by providing a dedicated access to the monument, reducing the slowdown and parking along Utah 211, and reducing pedestrian crossings on the highway. By moving the highway and placing it on the other side of Indian Creek, there will be additional benefits to park visitors in the form of reduced visual, auditory, and air-quality impacts. The creek's riparian habitat will further enhance this sense of separation. Table 4-42 presents a comparison of impacts on visitors to the monument and camping area with and without the bypass.

Construction of the bypass will also result in a number of adverse effects. Short- and long-term effects include the following:

- Potential effects of blasting on visitors to the monument
- Loss of riparian habitat along Indian Creek
- Stream channelization
- Potential effects on archaeological resources in the vicinity.

The blasting associated with this construction could adversely affect the quality of visitor experience at the monument. To control these potentially adverse effects, the following procedures could be followed:

- Limit blasting to special times to minimize public exposure
- Require smaller explosive charges, where possible
- Time construction activities for periods of low visitor use.

Construction of the bypass will result in a loss of riparian habitat, mostly on the south side of Indian Creek where the road construction is taking place. Because access to the south side of the creek is limited due to the rock face, it is anticipated that some loss of riparian vegetation on the north side is also likely. The loss of vegetation on the north side of Indian Creek can be minimized by careful construction practices and reclamation practices acceptable to the Bureau of Land Management (BLM), including restabilizing the river bank and replanting naturally occurring species.

In addition, construction will cause increased stream siltation. Siltation will be limited by minimizing the use of equipment in the stream, and by drawing material toward the bank, rather than pushing material into the creek while shaping the stream banks. Construction will be timed to avoid the spawning season.

The construction of the cloverleaf at the junction of Utah 211 and U.S. 191 would cause loss of some habitat and require drainage modifications. The safety of the intersection would be improved, especially considering the increases in traffic turning onto and from Utah 211.

As shown in Figure 4-38, the new straightened section above Newspaper Rock State Historical Monument would be a 305-meter (1,000-foot) section of new road and a bridge to eliminate the steep switchback and improve safety. Some habitat would be destroyed and drainage patterns would be altered.

Table 4-42. Impacts to Newspaper Rock Visitors from Improvements to Utah 211

Users	Utah 211 Option Without Bypass	Utah 211 Option With Bypass
Campers	No blasting noise.	Blasting noise during initial construction.
	Traffic Noise during shift change may be disturbing.	Traffic noise during the shift change may be less disturbing with bypass.
	Lighting from passing vehicles at night may be disturbing.	Lighting from passing vehicles at night may be less disturbing.
Sightseers	Presence of flagmen[a] may reduce vandalism at the site.	Isolation of the site may increase its attractiveness as a target for vandals.
	Off road parking may be a problem.	Off-road parking would be less of a problem.
Interpretive Nature Trail Users	Less safe because they would have to cross the road.	More safe because the traffic volume would be less.
Persons Going to Canyonlands National Park	More traffic delays.	Less traffic delays after the bypass was built.

(a) See alternative mitigation measures below.

The access route improvements described in this section have been proposed primarily to reduce potential safety problems associated with Utah 211 in its present configuration. There is little doubt that projected increases in accident rates would be reduced through the use of measures. At this time, however, the DOE has determined that the unavoidable adverse impacts of the improvements on the environment (i.e., loss of habitat, impacts to the Indian Creek aquatic fauna, noise and other disturbances to visitors at Newspaper Rock) outweigh the projected benefits of the improvements.

Since the environmental impacts of the improvements to Utah 211 appear to be greater than justified by their benefits for site-characterization-related traffic, alternative mitigation measures are required to reduce the potential for traffic accidents during site characterization at the Utah 211/U.S. 191 intersection, at the steep "S" curves, and at Newspaper Rock. The proposed mitigation measures are as follows.

Bypass of Newspaper Rock and Camping Areas. The potential hazard at this point results from the blind entrances/exits from the camping area and monument parking lot, and the narrow, sharp curve and restricted clearance under the overhanging rock, near the monument. Warning lights and signs may be required to slow both eastbound and westbound traffic and flagmen may be required to signal people leaving the parking and camping area when it is safe to reenter Utah 211 going either direction. Flagmen could also be required to stop traffic from both directions when trucks large enough to encroach upon both lanes of the road are passing through this area. Such truck traffic may be restricted to off-peak, daylight, hours. In addition, a pedestrian overpass could be constructed over Utah 211 from the camping area to the monument.

Utah 211/U.S. 191 Intersection. The potential hazard at this point may result from northbound traffic slowing and turning left onto Utah 211, and eastbound traffic on Utah 211 turning both ways onto U.S. 191. Accident probabilities at this point can be reduced by widening both U.S. 191 and Utah 211 to allow for turning lanes and through-traffic passing lanes on U.S. 191. Traffic controls, either automatic signals and/or traffic officers controlling manual signals, could be used at peak traffic periods. In addition, warning lights and signs may be required several hundred yards north and south of this intersection to slow the approaching high-speed traffic on U.S. 191.

Straightening of Utah 211 "S" Curves. At this point, the potential hazard may result from failure of westbound autos and trucks to slow sufficiently to negotiate the curves and grade and insufficient clearance for autos to pass east or westbound slow-moving trucks in the sharp curves. Warning lights, signs, and speed restrictions could be used at the approach to this area from both directions. In addition, flagmen may be required to stop both eastbound and westbound auto traffic when trucks large enough to encroach upon both lanes of the road are passing through this area. Such truck traffic may be restricted to off-peak, daylight, hours only.

Studies described in Section 4.1.3.1.10 will monitor traffic along U.S. 191 and Utah 211 in order to confirm whether there are additional problems not addressed by the above measures. If it is determined in consultation with the state that improvements are necessary, the DOE will then initiate improvements as appropriate.

4.4 SUMMARY OF SITE CHARACTERIZATION IMPACTS AT DAVIS CANYON SITE

Site characterization activities including geologic field studies, exploratory shaft facility development, and environmental field studies have the potential to cause various levels of site characterization impacts.

4.4.1 Cumulative Site Characterization Impacts on Canyonlands National Park Including Tourism and Recreation

This section addresses those impacts caused during site characterization which may affect Canyonlands National Park. The section includes a review of relevant site characterization activities, and their impacts on the park's physical environment, and use, and the region's economy. The section concludes with a discussion of cumulative impacts to the park.

4.4.1.1 Approach

Site characterization activities are first reviewed, by phase, to highlight those which have greatest potential for having an impact on Canyonlands National Park. The physical environmental impacts, as detailed in Sections 4.2.1.1 through 4.2.1.10, are then summarized to identify the more significant and detectable impacts. The effect that these more significant and detectable impacts have on park use is then discussed, along with the resulting effect that changes in park use will have on the regional economy. To capture the complete effect that site characterization will have a Canyonlands National Park, the cumulative effects of all impacts are also examined.

4.4.1.2 Site Characterization Activities

There are four major activity phases during site characterization: (1) background and field investigations, (2) exploratory shaft facility (ESF) construction, (3) ESF testing, and (4) ESF site reclamation (see Sections 4.1.1, 4.1.2, and 4.1.3).

Background and field investigations include both geological and environmental activities. These investigations will begin with site access after Presidential approval of the sites to be characterized, and will continue on into ESF operation and site reclamation. Initial year investigations include environmental reconnaissance surveys, equipment setup, and baseline monitoring (Section 4.1.3), followed by drilling of the engineering design borehole and seismic reflection surveys (Section 4.1.1). The second year of activity includes drilling of the shallow and deep aquifer hydronests and the continuation of environmental monitoring. Third and fourth year activities include additional hydronest and deep well drilling, as well as continued environmental monitoring.

Approximately 13 months after initial site access, exploratory shaft sinking will begin. Two shafts with a finished diameter of 3.6 meters (12 feet) will be sunk using conventional drill and blast methods. Shaft sinking will last approximately 11 months, followed by 3 months of outfitting. The ESF site will occupy approximately 23.9 hectares (59 acres) in Davis Canyon, and will be accessible via an 8.2-kilometer (5.1-mile) access road leading north-westerly from Utah 211.

Once the shafts are sunk and the horizontal excavations (drifts) are completed, in situ testing will begin and last for 36 months. Predominant surface structures at the ESF include the 9.1-meter (30-foot)-high salt pile, the 60-meter (197-foot) meteorological tower, the 38-meter (125-foot) headframe, the 17,000-cubic-meter (4.5-million-gallon) evaporation and retention pond, and the 8,000-cubic-meter (2.1-million-gallon) sedimentation pond.

Reclamation of the ESF site will require 21 months of effort. Main reclamation activities include backfilling the drifts and shaft, installing the shaft plug, dismantling the headframe and hoist, and removing equipment and buildings. These activities are followed by site cleanup, grading, topsoil replacement, and revegetation. Environmental monitoring will continue for 12 months beyond revegetation to ensure satisfactory reclamation of the site.

4.4.1.3 Impacts Due to Site Characterization

Site characterization will have an impact on Canyonlands National Park in three areas: physical environment, park use, and regional economics. The following three subsections address these impact areas.

4.4.1.3.1 Physical Environmental Impacts. Sections 4.2.1.1 through 4.2.1.10 address 10 physical environmental impact areas. These sections contain discussions on site characterization impacts at the site, offsite, regionally, and within Canyonlands National Park. Table 4-43 lists these 10 sections, along with their respective impact areas. Alongside each impact area is a description of those impacts which affect Canyonlands National Park as detailed in the EA section. In the next column is the magnitude of these impacts, with the peak impact period noted in the third column. The table thus represents a summary of all physical environmental impacts expected to occur at Canyonlands National Park as a result of site characterization activities.

From the "Magnitude" column, it can be seen that impacts listed in the "Impact Description" column of Table 4-43 fall into three ranges:

- "No impact" to "insignificant"
- "Minimal," including "small" and "similar to existing"
- "Significant."

Those impacts judged as "none" or "insignificant" would be imperceptible or immeasurable, and would have no environmental consequence. The "minimal," "small," or "similar" impacts would be detectable, but would be at most only barely perceptible to the observer. For a given resource, these impacts would be of little environmental consequence. The "significant" impacts are detectable and may be of some environmental consequence, if great enough or of long enough duration. Using these guidelines, the three broad ranges written above have been recast by the DOE as the following:

- Insignificant (immeasurable, with no consequence)
- Detectable (measurable, with no/little consequence)
- Significant (measurable, with possible consequence).

Being of no environmental consequence, the "insignificant " impacts listed in Table 4-43 are not addressed further. From Table 4-43, there are four impact areas which can be categorized as "detectable", and three impact areas which are "significant." Tables 4-44 and 4-45 list these impact areas by magnitude category, and summarize the impacts.

Four impact areas will be detectably affected by site characterization activities (Table 4-44): land use; air quality; aesthetics; and archaeological, cultural, and historic resources.

A conflict in the use of park lands may occur from the illegal use of offroad vehicles. As noted in Section 4.2.1.1.3, the extent of this land use impact is expected to be small because project-related visitors will comprise a small percentage of total visitors to the area.

Potential air-quality impacts may occur in one of two ways: by intruding on the visitors' ability to view the night sky, and by increasing atmospheric contaminants, notably total suspended particulates (TSP) and nitrogen dioxide (NO_2). As summarized in Section 4.2.1.3.3, night sky glow from the ESF will be mitigated so as not to contribute more than existing sources of background light, such as that from the town of Moab. Consequently, night sky glow impacts are expected to be detectable, but of little environmental consequence.

Section 4.2.1.3.3 also discusses predicted maximum concentrations of TSP and NO_2 at the Canyonlands National Park boundary. These concentrations are between 18 (annual NO_x) and 31 (24-hour TSP maximum) percent of the National Ambient Air Quality Standards (NAAQS), which are established to help protect the public health and welfare from any known or expected adverse effects of air pollutants. The predicted maximum 24-hour TSP concentration is the result of modeling peak emission rates, which occur for only a relatively short time (a few months) during ESF construction. Thus, these impacts are not expected to be of any environmental consequence.

Table 4-43. Summary of Physical Environmental Impacts to Canyonlands National Park (CNP)

EA Section	Impact Area	Peak Impact Period	Impact Description	Magnitude	Impact Category(1)
4.2.1.1	Land use	Peak period corresponds with peak traffic volume: 3 months during ESF construction	a) Delays in gaining access to Needles District due to increse in traffic along Utah 211	a) Significant	S
			b) Increased use of CNP wilderness and recreational areas (principally within Needles District)	b) Insignificant	I
			c) Increased illegal use of off-road vehicles	c) Small	D
4.2.1.2	Terrestrial and Aquatic Ecosystems	Peak occurs during ESF construction	Terrestrial and aquatic ecosystem impacts	Insignificant	I
4.2.1.3	Air Quality	Peak occurs during ESF construction: for particulates, maximum annual period begins at the fourth month; for NO_x, maximum annual period begins at month 24	a) Visibility impairment	a) Imperceptible	I
			b) No odorous emissions except from diesel-engined equipment	b) Insignificant	I
			c) Night sky glow	c) Similar to existing sources, once mitigated	D
			d) Air Quality (TSP/NO_2)	d) Significant but temporary	D

Table 4-43. Summary of Physical Environmental Impacts to Canyonlands National Park (CNP)
(Page 2 of 3)

EA Section	Impact Area	Peak Impact Period	Impact Description	Magnitude	Impact Category(1)
4.2.1.4	Water Resources	Peak occurs during ESF testing period	a) Increased salinity of the Colorado River	a) Immeasurable	I
			b) Use of water	b) (From existing allotments)	I
4.2.1.5	Soils, Geology, Paleontology	Peak occurs during noise surveys and during ESF construction	a) Field personnel disturbing soils	a) Insignificant	I
			b) Impacts to geology	b) None	I
			c) Secondary impacts to paleontology from increased access and people	c) Insignificant	I
4.2.1.6	Noise	Peak occurs during ESF construction; peak period lasting 5 months, beginning at month 15. Blasting to occur no more than 3 times in 24 hours for a period of from 6 to 12 days	a) Equipment noise levels audible 2.4 kilometers into CNP	a) Significant	S
			b) 30 dB above audibility threshold at nearest park boundary	b) Significant	S
			c) Equipment noise levels below threshold of audibility at key points within CNP	c) None	I
			d) Blasting audible within CNP	d) Significant	S
			e) Blasting vibrations imperceptible to humans	e) None	I
			f) Impacts to delicate rock formations as a result of blasting	f) None	I

Table 4-43. Summary of Physical Environmental Impacts to Canyonlands National Park (CNP)
(Page 3 of 3)

EA Section	Impact Area	Peak Impact Period	Impact Description	Magnitude	Impact Category(1)
4.2.1.7	Aesthetics	Peak occurs as ESF surface facilities and meteorological tower are erected	a) Surface facilities visible from key observation points from within CNP	a) None	I
			b) ESF activities visible from jeep trails or other roads within CNP	b) None	I
			c) Individual ESF activities visible from limited areas within CNP	c) Minimal	D
			d) Met towers visible from isolated high ground within the Needles Distict	d) Minimal	D
			e) Visual contrast rating high at limited areas within CNP	e) Minimal	D
4.2.1.8	Archaeological, Cultural, Historic Resources	Peak occurs during ESF construction, corre-sponding to peak worker levels	Indirect impacts (e.g., illegal artifact collecting and vandalism, and off-road vehicle use) which may disturb or damage archaeological resources within the Salt Creek Archaeological District	Minimal	D
4.2.1.9	Radiologic	Peak occurs as ESF becomes fully developed	a) Radiological impacts expected due to site characterization activities	a) None	I
			b) Increases in radioactivity due to exploratory shaft development	b) Insignificant	I
4.2.1.10	Transportation and Utilities	Peak occurs at month 25 and lasts approximately 3 months	a) Increased vehicular traffic along Utah 211	a) Significant	S
			b) Utilities-related impacts	b) None	I

(a) Impact Categories: I = insignificant, D = detectable, S = significant.

Table 4-44. Detectable[a] Physical Environmental Impacts to Canyonlands National Park as a Result of Site Characterization Activities

Impact Area		Summary of Impact[b]
Land Use		Increased illegal use of off-road vehicles
Air Quality	a)	Night skyglow
	b)	Max 24-hour TSP concentration below NAAQS[c]
	c)	Max annual TSP concentration below NAAQS
	d)	Max annual NO_2 concentration below NAAQS
Aesthetics	a)	Individual ESF activities visible from limited areas within the park
	b)	Meteorological towers visible from isolated high ground within Needles District of the park
	c)	Visual contrast rating high at limited areas within CNP
Archaeological, Cultural, Historic Resources		Indirect impacts which may disturb or damage archaeological resources within the Salt Creek Archaeological District of the park

(a) Measurable, but not necessarily perceptible by humans, and of little or no environmental consequence.

(b) Details found in Table 4-42 and in Section 4.4.1.3.1.

(c) NAAQS = National Ambient Air Quality Standards.

Table 4-45. Significant[a] Physical Environmental Impacts to Canyonlands National Park as a Result of Site Characterization Activities

Impact Area	Summary of Impact[b]
Land Use	Park visitor delays in gaining access to the Needles District due to increased vehicular traffic along Utah 211
Transportation and Utilities[c]	Increased vehicular traffic along Utah 211
Noise	a) Equipment noise levels audible 2.4 km within the park
	b) Equipment noise 30 dB above audibility threshold at the nearest park boundary
	c) Blasting audible within park

(a) Measurable, with possible environmental consequences.

(b) Details found in Table 4-42 and in Section 4.4.1.3.1.

(c) Transportation and Utilities impacts taken out of order presented in EA Section 4.2 to illustrate the interconnection between the transportation impact and the land-use impact.

Regarding aesthetics, no key observation points (KOPs) will be affected, and in general those park areas which will be affected receive little visitor use due to their small, isolated, and inaccessible nature (see Section 4.2.1.7.2). Canyonlands National Park aesthetics will be minimally affected by ESF facilities, including meteorological towers, and by other characterization activities visible from certain locations within the park. Thus these impacts are of little to no environmental consequence.

Indirect activities (e.g., illegal artifact collecting and vandalism, and off-road vehicle use) could disturb or damage archaeological resources within the Salt Creek archaeological district of Canyonlands National Park. These indirect activities could arise from increased access and interest in the area as a result of site characterization. However, as noted in Section 4.2.1.8.2, the indirect activities and consequential impacts attributed to site characterization would be small.

Land use, noise, and transportation are impact areas which will be significantly affected by site characterization activities (Table 4-45). Land use within Canyonlands National Park will be affected in that park visitors using Utah 211 to enter the Needles district will experience delays. Site characterization workers will use Utah 211 to travel to the site's access road, thereby increasing the traffic load handled by the highway. As discussed in Section 4.2.1.1, worker traffic will temporarily increase the existing traffic flow of 45 vehicles per day, to peak of 1200 vehicles per day for 3 months. Average worker traffic will increase traffic volume on Utah 211 to 615 vehicles per day. Traffic impacts may be mitigated by improving Utah 211, and by bussing workers to the site.

Significant noise impacts are a result of equipment noise and shaft blasting. As discussed in Section 4.2.1.6, equipment used during site characterization may be audible up to 2.4 kilometers (1.5 miles) into Canyonlands National Park. Noise levels at the park boundary closest to the site will be 30 decibels above the threshold of audibility, which constitutes a major impact based on the criteria discussed in Section 4.2.1.6.

Under typical sound propagation conditions, exploratory shaft blasting may be audible up to 5.2 kilometers (3.2 miles) from the blast site under typical meteorological conditions. As the shafts are sunk, blasting will be increasingly muffled by the effects of shaft depth. After 6 to 12 days the shafts will be at a depth of approximately 27 meters (90 feet), a sinking stage will be installed which will further muffle the noise, and blasting will no longer be a significant noise source. Consequently, the park visitor who is exposed to blasting noise will not experience more than three blasts in any 24-hour period, and then only during one of the few days when blasting is occurring within 27 meters (90 feet) of the surface. The highest peak sound pressure level as a result of blasting is below the EPA's impulsive noise criteria (see Section 4.2.1.6.1), and thus no cumulative adverse health effects are anticipated.

4.4.1.3.2 Impacts On Users of Canyonlands National Park. The legislation which established Canyonlands National Park (Canyonlands National Park Act, 16 USC Section 271) stated that it was formed "to preserve an area in the state of Utah possessing superlative scenic, scientific and archeological features for the inspiration, benefit, and use of the public...." An area of particular interest to wilderness users is the Salt Creek Archeological District which is in the eastern half of the Needles district. Lavender, Davis, Horse, Salt, Squaw, Lost, Elephant, and Big Spring Canyons are included in the archeological district. Educational groups, researchers, and recreationists can access the area by hiking or driving off-road vehicles. Visitors there experience deep, winding canyons, where narrow corridors lead to outstanding erosional and archeological features such as ruins and rock art (NPS, 1978). Researchers have used these canyons to study various natural processes in an outdoor setting. Archeological researchers have identified numerous cultural resources, and have participated in the stabilization of ruins in the canyons. This area of the park is also occasionally used as an educational setting by wilderness experience groups which stress self awareness, environmental concern, interpretation of park resources, and discovery of heritage (NPS, 1984).

The following two sections address how site characterization investigation activities may affect recreational, scientific, and educational opportunities in the park.

Effects on Tourism and Recreation. Because physical environmental impacts will occur to the Needles District of Canyonlands National Park, the following analysis evaluates how tourists to the Needles district may be affected. To address how site characterization will affect the attractiveness of the Needles District to tourists, the magnitude of the physical environmental impacts must be distinguished from their importance to the recreationist. The magnitude of a physical environmental impact on tourists can be measured objectively in terms of frequency, extent, and other quantitative dimensions of the impact (the magnitudes of the physical environmental impacts associated with site characterization are presented in Section 4.4.1.3.1). Importance is measured subjectively. It reflects the value a person assigns to a phenomenon such as visual aesthetics. This value varies among individuals.

Figures 4-39 and 4-40 show the approximate locations where detectable and significant environmental impacts will occur. These figures graphically represent the information supplied in Table 4-46. An analysis of the magnitude of the cumulative physical environmental impacts on the park would suggest that the physical experience of wilderness would not be significantly affected in most areas of the park. However, visitors to Davis Canyon in the Needles district seeking a wilderness experience would find that occasional noise and other impacts resulting from site characterization activities might detract from their enjoyment. This canyon was formerly used as a missile test overflight area for the army (NPS, 1977) and has not been highly visited. Visitors to Davis Canyon account for about one percent of the annual visitation to Canyonlands National Park (see Section 3.6.2.4).

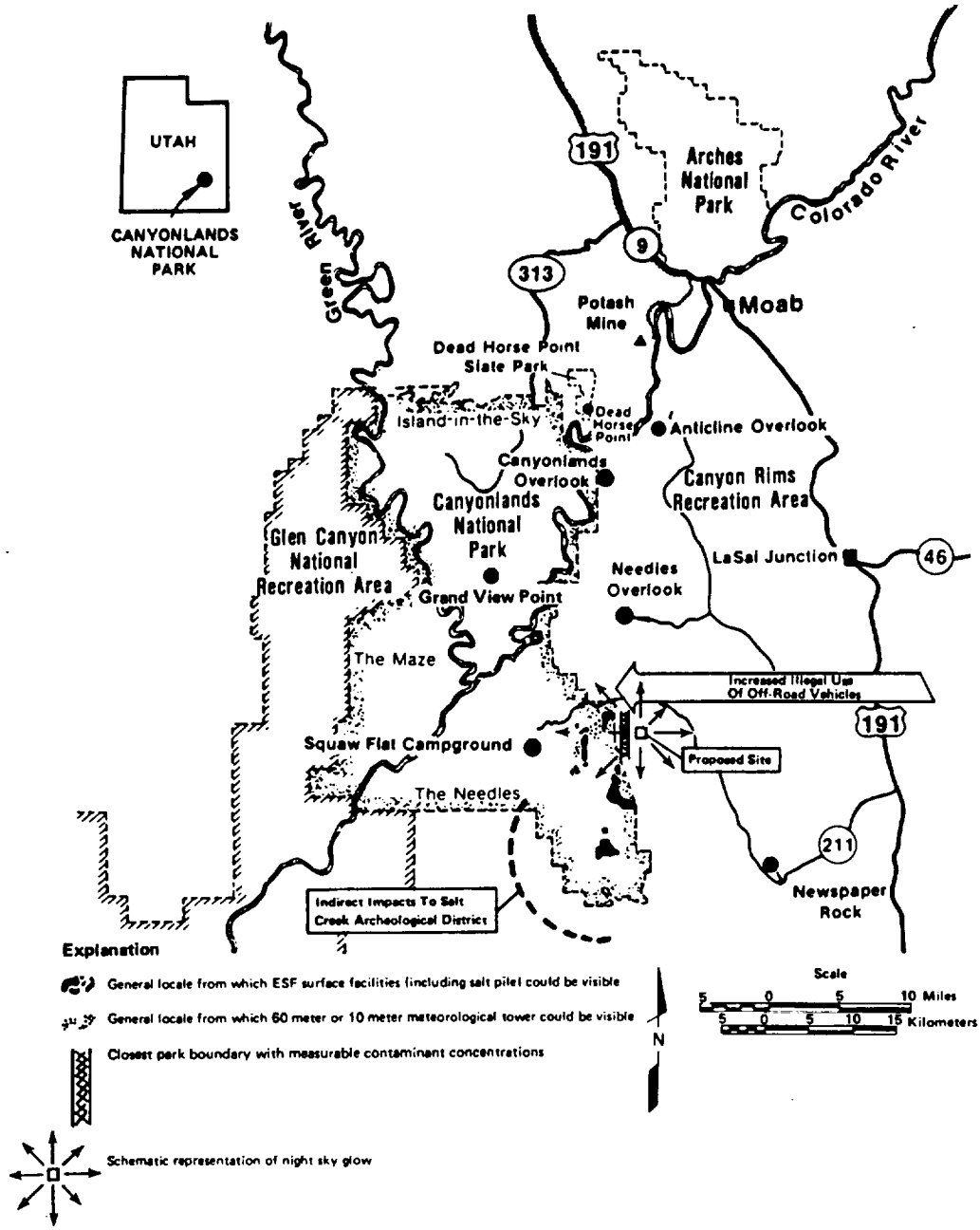
Visitors to the rest of the park may receive an impact on their physical in-park experience for a few weeks during initial shaft construction, when blasting might be audible throughout the park. However, this is the only time such impact might occur.

An analysis of the importance of the cumulative physical environmental impacts on the park suggests that the values and expectations of park users play a central role in describing their perceptions of their recreational experience (Harrison et al., 1980, p. 3).

A wide range of tastes and preferences for recreational opportunities exists among the public. Those who seek a chance to meet and visit with friends in convenient and comfortable surroundings prefer modern vehicle-oriented campgrounds. Those seeking solitude and minimal contact with others prefer more primitive environments. Machine sounds, visual instructions, and other impacts are less acceptable to visitors who prefer primitive or semi-primitive environments than to those who prefer vehicle-oriented campgrounds. Visitors to the Needles district of Canyonlands National Park can find vehicle-oriented camping at the Squaw Flat Campground, while primitive and semi-primitive camping can be found in the rest of the district.

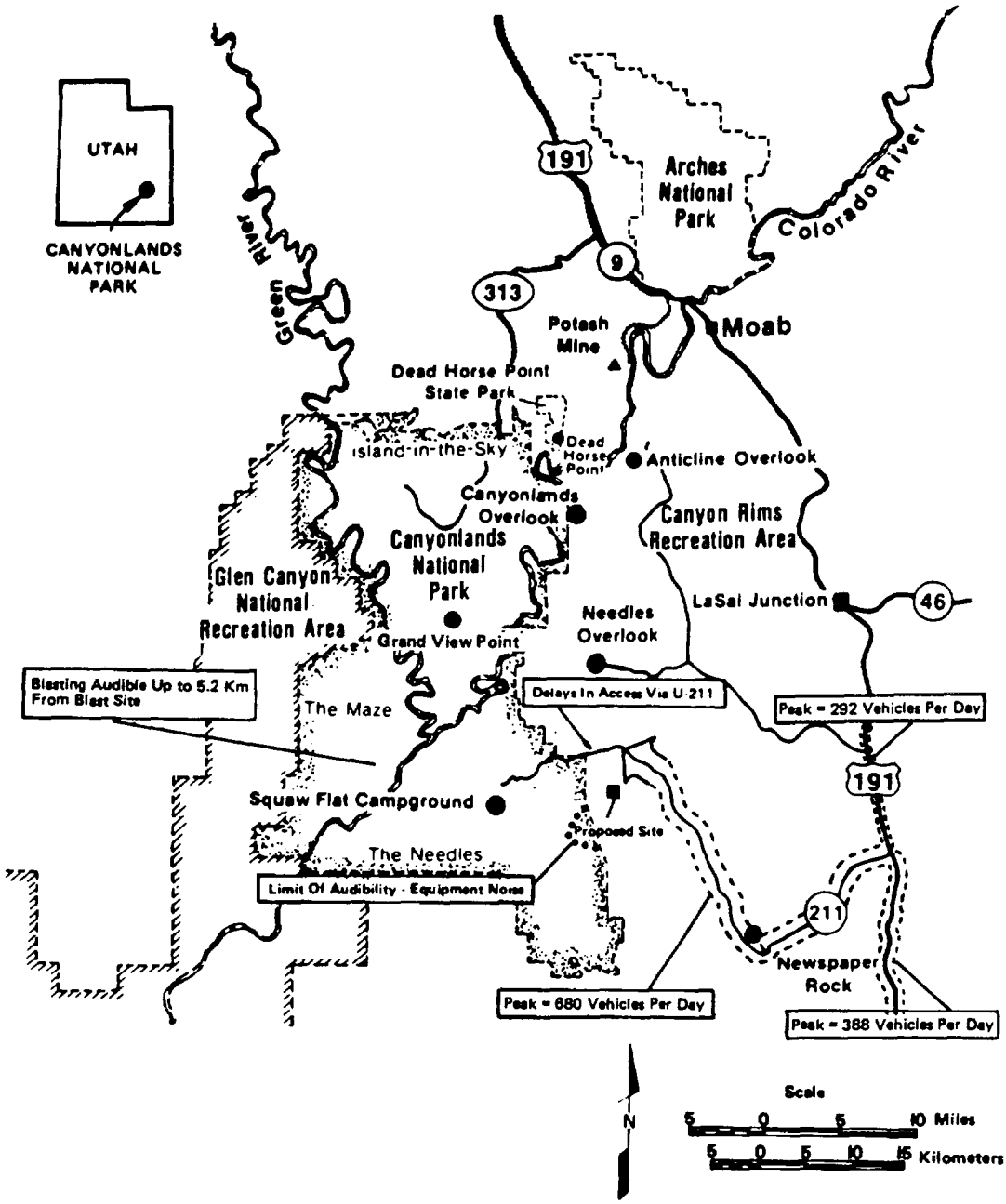
According to Davidson-Peterson and PBQ&D (1978), the ability to get away from people--to find solitude--is a highly-valued expectation of the visitors to the Needles District. This is assumed to be especially true for visitors who go to isolated areas in the Salt Creek archeological district to experience its primitive environment. Whether people perceive they can find places far removed from civilization in the Needles district is central to determining the importance of the impacts to the visitors.

The project and its associated activities would be most pronounced near the eastern boundary of the Needles District. Visitors to that area could be subject to traffic delays on Utah 211 (Figure 4-40). They will see the project activity as they approach the park. Visitors to Davis Canyon on the eastern edge of the district could also be affected by occasional noise and aesthetic impacts from the project (Figure 4-39). Hikers and campers in the most primitive sections of the Salt Creek Valley should experience no physical environmental impacts.



Detectable Physical Site Characterization Phase Environmental Impacts to Canyonlands National Park

Figure 4-39



Significant Physical Site Characterization Phase Environmental Impacts to Canyonlands National Park

Figure 4-40

Table 4-46. Significance of Physical Environmental Impacts on In-Park Activities

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]: Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River	Environmental Factors Associated with the Activity	Site Characterization Impacts: Audible Blasting Noise	Audible Mechanical Noise	Delay in Gaining Access	Characterization Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	Areas of the Park Where Activities may be Affected and the Significance of Those Effects to Park Users
Viewing Rock and Desert Formations[a]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[a], Visual Contrast				D			I	● Minimal impact from or perceptible visibility changes due to air pollutant levels in the park (Section 4.2.1.3). ● Visibility of ESF activities from limited areas near the eastern CNP boundary (Section 4.2.1.7).
Viewing Wild Animals[a]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[a], Low Noise Habitat, Human Presence	S	S					I	● No visibility changes due to project air pollutant emissions in the park (Section 4.2.1.3). ● Perceptible impacts result if impulsive noise causes animals and birds to alert and run in small portions of the park. The equipment noise audible within a limited area along the eastern park boundary (Section 4.2.1.6) is not expected to alter animal behavior. ● No impact on park habitat.
Viewing Indian Ruins[a]	●	●	●	●	●	●	●	●	●	●	●	●	Access, Quality of Ruin			S		D		I	● Access to ruins in Upper Davis Canyon will not be blocked but may be inconvenienced (Section 4.2.1.1). ● Increased visitation is expected to have minimal impacts on the resources within Salt Creek Archaeological District (Section 4.2.1.8). ● Indian ruins would not be affected because air pollutants are below NAAQS secondary standards designed to prevent material degradation.
Viewing from Scenic Overlooks[d]	●						●			●			High Visibility, Visual Contrast						D		● A person standing at Grand View Point would experience no more sky glow at the horizon than is currently visible from Moab (Section 4.2.1.3).
Viewing the Colorado River[a]	●									●	●	●	High Visibility[a], Low Noise	D							● Blasting noise heard at river overlooks in the Needles District will likely not be audible.
Getting Away from People[a]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise, Low Human Contact[a], Access, Solitude, Undeveloped	S	S	S	S				● Blasting noise heard in eastern portions of the Needles District might diminish the experience of solitude for visitors during the few days that blasting would be audible. ● Equipment noise and visible facilities may disturb Davis Canyon visitors who came to experience solitude. ● Delays in gaining access to the park may be disturbing to Needles District visitors.
Hiking Off the Trail[a]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise[a], Low Human Contact[a]	S	S		D				● Blasting noise heard in the Needles District might be momentarily disturbing to hikers. ● Equipment noise may disturb Davis Canyon visitors interested in solitude. ● The facility can be seen from Davis Canyon and may not be consistent with the visitors expectations of remoteness.
Hiking on Marked Trail[a]	●	●								●	●		Moderate Noise, Human Contact[a]	S							● Blasting noise heard in a limited portion of the park might be momentarily disturbing to hikers.

Table 4-46. Significance of Physical Environmental Impacts on In-Park Activities (Page 2 of 2)

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]												Environmental Factors Associated with the Activity	Site Characterization Impacts							Areas of the Park Where Activities may be Affected and the Significance of Those Effects to Park Users
	Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River		Audible Blasting Noise	Audible Mechanical Noise	Delay in Gaining Access	Characterization Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	
Rock Climbing[a]	●	●	●	●				●		●	●	●	Low Noise, Human Contact[e]	S	S		D				● Blasting noise may be audible in eastern portions of the Needles District and may be disturbing to rock climbers seeking solitude ● Equipment noise may disturb persons who climb to Mesa tops near Davis Canyon seeking solitude. ● Persons climbing to isolated Mesa tops within the Needles District could see ESF activities. This could disturb climbers seeking solitude.
Viewing the Stars[b]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Low Noise, Low Night Sky Glow		S				D	I	● Equipment noise may disturb persons viewing the night sky near Davis Canyon. ● Night sky glow at the horizon should not inhibit overhead viewing (Section 4.2.1.3). ● Visibility impairment would be imperceptible (Section 4.2.1.3).
Developed Camping Areas[b]	●												High Noise Level, Human Contact[b], Access			S					● Delays in gaining access to the park may be disturbing to campers going to Squaw Flat campground.
Semi-Developed Camping Areas[b]	●	●								●	●		Moderate Noise Level, Human Contact[b]								
Primitive Camping Areas[b]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise Level, Human Contact[b], Solitude		S		D		D		● Equipment and other man-made noise at night may disturb campers in Davis Canyon. ● Delays in gaining access to the park may be disturbing to campers going to the Needles District. ● The project can be seen from Davis Canyon, this may also disturb campers seeking solitude there.
River-Running[c]												●	High Noise Level, Low Human Contact[e]								
Four-Wheel Vehicle Driving on Designated Trails[b]	●	●	●	●	●	●	●			●	●		Moderate to High Noise Level, All Levels of Human Contact[b]	S	S	S	D				● Blasting noise heard in eastern portions of the Needles District could be disturbing to four-wheel vehicle drivers who stop for solitude. ● Delays in gaining access to Davis Canyon may disturb persons going there. ● Equipment noise from the project and its visibility may affect Davis Canyon drivers who stop their vehicles for solitude.
Scientific Study[b]	●	●	●	●	●	●	●	●	●	●	●	●	Ecosystems, Geologic Formations, Archaeological Resources					D			● Possible damage to archaeological resources in Salt Creek due to increased visitation.
Wilderness Experience[b]	●	●			●	●		●	●	●	●	●	Solitude, Low Noise, Low Human Contact, Undeveloped	S	S	S	S		D	I	● Blasting noise heard in limited areas of the Needles District might diminish the expectations of solitude for wilderness seekers present during the days when it occurs. ● Equipment noise and visible facilities may be disturbing to wilderness seekers in Davis Canyon interested in solitude. ● Delays in gaining access would be disturbing to Needles District visitors seeking to avoid civilization. ● Night sky glow at the horizon should not inhibit wilderness seekers from overhead viewing of the stars. ● No visibility impairment.

Sources:
(a) Davidson-Peterson Associates, Inc., and PBQD, 1978.
(b) NPS, 1984.
(c) Mintzmyer, 1981.
(d) NPS, 1978.
(e) Assumption.

Explanation
A blank in the Site Characterization Impacts column indicates factor is not important to the in-park activity.
● Indicates potential for a particular in-park activity being performed within selected areas of the park based on references a, b, c, and d.

I - Insignificant (immeasurable, with no consequence).
D - Detectable (measurable, with little or no consequence).
S - Significant (measurable, with possible consequence).

Even though mitigation measures may eliminate physical environmental impacts on areas of the district where people seek wilderness experiences, it is possible that some of the potential visitors would view the project's activities as being in conflict with their expectations of a primitive experience. For them, intensive mining activities near the park may symbolize those aspects of civilization which they are seeking to avoid.

Many of the visitors to Canyonlands National Park have other national parks and monuments in the travel region as their primary destination. However, 17 percent of the Canyonlands National Park visitors have the Needles District as their primary destination. Some of those visitors who are drawn to the travel region specifically to experience the Needles District go there to get away from people. Although projected environmental impacts of site characterization should not affect the visitors physical experience of the wilderness and solitude, some may perceive characterization activities as interfering with their anticipated wilderness experience. Those who believe it will disturb their hoped-for experience may avoid the areas of the park near the facility. Some may decide to avoid the park altogether.

Effects on Scientific and Educational Users. Scientific resources contained in the Salt Creek archeological district could be slightly disturbed by the increased access to and interest in the area (Figure 4-39). This should not inhibit scientific inquiry and discovery in the area. However, Davis Canyon would be of questionable value to wilderness experience groups. Because wilderness groups are seeking to promote the tangible and intangible aspects of the wilderness experience, some of the groups may believe that the characterization activities would be an intrusion on the wilderness experience - even if the physical experience remains unaffected. These groups may seek out other areas of the park further away from the site; other groups may avoid Canyonlands altogether.

4.4.1.3.3 Economic Impacts. The analysis of potential economic impacts resulting from site characterization activities compares losses to the retail and service sectors from tourists who might not stay in the area, to gains in these sectors from site characterization worker expenditures. It assumes several conservative-case scenarios concerning park avoidance, tourist displacement, economic displacement, project purchases outside the region, and project worker wages spent outside the two-county study area. These assumptions were used whenever empirical data were not available concerning probable human behavior. For example, Baker et al. (1980) have presented empirical evidence that the construction of nuclear power plants adjacent to state beaches did not contribute to a significant reduction in beach use. This does not mean that there was no drop in visitation from the types of users who formerly were attracted to these parks; it is possible that park visits by project-related users counterbalanced this loss.

It can be expected that some project visitors will also visit Canyonlands. Whether they will counterbalance any losses in park visitation by the types of visitors currently drawn to the park cannot be reliably predicted at present. Such insights will not be available until monitored data from site characterization activities are evaluated. This means that when projecting the impacts of Canyonlands National Park visitors on the local economy, the conservative approach would consider the potential losses attributed to current visitors without any added expenditures by project visitors.

Consideration focuses on visitors to the Needles District because the other districts of the park are not near any project activity. Any loss in visitation to Canyonlands National Park during site characterization by people who would have been drawn to the travel region primarily to experience the Needles District would have a small effect on the local economy. Visitors who currently come to the region with the Needles district as their major destination account for about 1 percent of the retail and service sector sales in the two-county area (see Section 3.6.2.4). If some of these people are no longer attracted to the region, a portion of this amount could be lost.

Another area of potential economic loss concerns the displacement of tourists from hotel and motel accommodations. These individuals would not be able to spend additional money in the local retail and service sectors. If project workers are renting motel rooms that would normally be used by tourists, then these tourists might also avoid the region. This would

affect the level of tourist expenditures for food, lodging, entertainment, other retail services, and transportation that are provided locally. Using the Intermountain Power Plant (IPP) experience as a guide, 8 percent of the total in-migrating workforce might stay in motel rooms. IPP, which is in Millard County, Utah, had a peak workforce of 434 individuals in 1982. At that time 8 percent of its in-migrating workforce stayed in motel rooms (Paul Nelson Associates, Inc., 1982). If 8 percent of the peak site characterization work force (488) is used, and it is assumed that workers are not sharing rooms, then 44 rooms would not be available for tourists during the tourist season. A loss of 44 rooms for tourists would result in a loss of 1 percent of the two-county retail and service sector sales to tourists (see Section 3.6.2.4). This assumes that there are 2.6 persons per tourist party, 2 nights accommodation per party, a tourist season of 275 days, and expenditures of $33.95 per tourist (Hunt and Cadez, 1981).

The time when these negative impacts could be the greatest coincides with increased expenditures made in the local economy by site characterization project workers. This means that there would be worker purchases at the local restaurants, motels, hotels, food stores, gas stations, and other retail and service establishments considered to be part of the tourist economy. The tourist-oriented businesses that would benefit least from project worker purchases would be those which deal in specialty items and services for sale or rent to tourists.

The following limiting assumptions were made to calculate worker expenditures in the local retail and service sector: (1) the average wage would be $28,000 (1981 dollars), (2) no local purchases for durable goods such as furniture, automobiles, etc. would be made in Grand or San Juan Counties, (3) the rate of local expenditures for non-durable goods and services would equal the U.S. average of 36 percent of wages (Bureau of the Census, 1983), (4) the expenditures by single workers would not be included because a substantial portion of wages earned by weekly commuters would be sent to the region of their permanent residence, (5) 55 percent of the site characterization phase workers would be single workers, and (6) the average workforce size would be 315 workers. With these conservative assumptions, workers would account for about 2.4 percent of the retail and service sector sales. When this 2.4 percent is added to the two potential losses presented in the above analysis there would be a net gain for these sectors. Section 4.2.2 provides a further analysis of economic impacts to the local economies.

Therefore, even if no assumptions are made about the amount spent in the local economy by weekly commuters and singles or curosity seekers drawn to the area to see the project, and no assumptions are made about the purchases by the project for oil, gas, and other nondurable goods and services, the local economy should still experience a net gain in the retail and service sectors. However, losses to specialized tourist businesses could occur if tourists avoid the Needles district of Canyonlands National Park or if tourists cannot find hotel and motel accommodations in the area.

4.4.1.4 Discussion of Cumulative Impacts Resulting from Site Characterization

Visitors coming to the Needles district might experience increased traffic and delays in getting to the park. Those who formerly sought out Davis Canyon, adjacent to the park boundary, would experience changes to the area's aesthetics and noise conditions. Visitors to the Needles district of the park would be subject to blasting noise only during a period of a few days when the exploratory shafts are constructed.

The environmental impacts to the park should not interfere with physical aspects of a primitive experience. Activities in Davis Canyon which may be affected by site characterization can be found in many other areas of the park (see Table 4-45). Researchers should also not be significantly hampered in completing in-park studies. However, some educational groups and wilderness seekers may think the park, or that area of the park nearest the facility, can no longer provide the perceived intangible aspects of a primitive experience. How many will continue to come to this area of the park for a wilderness experience, how many will seek out the other numerous isolated areas in the park where a wilderness experience would be possible, or how many will avoid Canyonlands National Park altogether cannot be predicted.

Nevertheless, Section 4.4.1.3.3 demonstrated that total expenditures in the retail and service sectors by visitors who had the Needles district as their primary destination and those who might be displaced from hotel and motel accommodations are less than the projected expenditures in those sectors by site characterization workers and their families. Although retail and service sectors of the local economy should experience a net gain, those businesses which specialized in tourist-oriented items and services for sale or rent could suffer losses.

4.4.2 Summary of Site Characterization Impacts

Site characterization activities including geologic field studies, exploratory shaft facility development, and environmental field studies have the potential to cause various levels of site characterization impacts. The following information (Table 4-47) is a summary of such impacts drawn from the text of Chapter 4.

The summary table identifies impacts that are projected or expected to occur and those not expected to occur. Impacts are discussed in terms of their duration, intensity, or significance. The use of mitigation measures is noted in determining intensity of the impact. As applicable, location of the impact is also identified.

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site

I. Geologic Field Studies

1. Land Use (Section 4.2.1.1)

   - No significant impacts to grazing districts in the area
   - Minor and temporary disturbance of land uses on 243 hectares (600 acres) during geologic characterization activities
   - No significant conflict with mineral resource development by geological field studies
   - No salt-related impacts
   - Access to Newspaper Rock State Historical Monument and Canyonlands National Park will be temporarily inconvenienced; no activities in Canyonlands National Park.

2. Terrestrial and Aquatic Ecosystems (Section 4.2.1.2)

   - Minimal and temporary loss of vegetation, wildlife habitat, and sedentary terrestrial biota due to land disturbance; temporary increase in competition for food and cover and subsequent mortality as bird and mammal species move to adjoining habitats; amount of loss not significant relative to existing resources
   - Minimal impacts to biota in proximity to study areas from vehicle movements, increased noise, and human presence
   - No impacts to threatened and endangered species or critical habitat expected
   - No significant impacts to aquatic ecosystems because aquatic communities are absent from the site area and site runoff and discharge will be controlled.

3. Air Quality (Section 4.2.1.3)

   - Significant but temporary impacts to air quality in the park from geologic characterization activities.

4. Surface-Water Quality (Section 4.2.1.4)

   - No significant impact to surface water quality; impact limited to local and temporary increases in sediment loads prior to completion of temporary sedimentation basins.

5. Ground-Water Quality (Section 4.2.1.4)

   - No significant impact on ground-water quality because drilling procedures include measures to prevent potential aquifer contamination

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 2 of 7)

I. Geologic Field Studies

- There is no impact on ground-water flow regime because pumping tests are not expected to affect any local wells
- Possible localized impacts to ground-water quality if salt-pile liners, runoff retention pond liners, or fiberglass fuel tanks leak.

6. Soils (Section 4.2.1.5)

- Mitigation measures will minimize soil impacts such as increased erosion, mixing of soil horizons, and disturbance of drainage patterns.

7. Noise (Section 4.2.1.6)

- Minor and temporary increase in sound levels from drilling activities which last from 1 to 6 months at each drill site
- Minor increases in sound levels due to vehicular traffic
- Equipment noises will be audible 2.4 kilometers (1.5 miles) into Canyonlands National Park for 3 years.

8. Aesthetic Resources (Section 4.2.1.7)

- Temporary impact to visual resources from the presence of drilling rigs at specific locations for 6 months or less
- Long-term impact within Davis Canyon and along a stretch of Utah 211 near Davis Canyon
- Seismic reflection line and 3-D seismic survey will result in significant long term impacts on the Davis Canyon jeep trail.

9. Cultural Resources (Section 4.2.1.8)

- No direct impacts to National Register-eligible sites expected; however, some indirect impacts to cultural resources are expected.
- Development of a Programmatic Memorandum of Agreement resulting in the avoidance or mitigation of potentially adverse effects.

10. Radiation Levels

- No radiological impacts from site characterization expected.

11. Transportation and Utilities (Section 4.2.1.10)

- Geologic field studies resulting in a minor increase in traffic and traffic delays.

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 3 of 7)

I. Geologic Field Studies

- No impact to utilities.

12. Socioeconomics (Section 4.2.2)

The socioeconomic impacts are based on the cumulative effects of geologic, environmental, and exploratory shaft activities during site characterization. Summary impacts for all these activities are listed under Environmental Field Studies (Section III of this table).

II. Exploratory Shafts

1. Land Use (Section 4.2.1.1)

- No significant impacts to grazing in the area; project-related disturbances could temporarily remove an insignificant amount of land (24 hectares [59 acres]) from the range inventory
- No significant conflicts with mineral resource development in the area
- Project activities will temporarily impact recreational character of the area and create a temporary inconvenience along access routes, but no current access routes will be eliminated by project activities
- Insigificant salt-related impacts because the salt pile will be managed on site and the majority of wind-blown salt particulate will be retained on site.

2. Terrestrial and Aquatic Ecosystems (Section 4.2.1.2)

- Minor and temporary loss of vegetation, wildlife habitat, and sedentary terrestrial biota due to land disturbance; temporary increase in competition for food and cover and subsequent mortality as bird and mammal species move into adjoining habitats; amount of loss not significant relative to existing resources
- No impacts to threatened and endangered species or critical habitat expected
- No significant impacts to aquatic ecosystems because aquatic communities are absent from the site area and site runoff and discharge will be controlled.

3. Air Quality (Section 4.2.1.3)

- Significant but temporary impacts to air quality in the park

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 4 of 7)

II. Exploratory Shafts

- Concentration of pollutants projected to be below the National Ambient Air Quality Standards (NAAQS)
- Small projected impacts on air quality related values (AQRVs)
- Negligible wind erosion of salt pile due to natural crusting or covering of pile
- Imperceptible impact on visibility in Canyonlands National Park, because visual range and visual contrast changes due to facility emissions are not projected to be perceptible.

4. Surface-Water Quality (Section 4.2.1.4)

- No significant impacts to surface water; impacts are limited to local and temporary increases in sediment loads prior to completion of sediment ponds on site
- Project water requirements are likely to be met by current allotments to the San Juan County Water Commission would be purchased from existing municipal allotments
- Flooding effects include reduction in runoff due to retention ponds and potential increases in flood heights and extent due to floodplain encoachment resulting in minor impact of flood levels and floods
- No significant degradation of water quality from wind blown salt is expected because salt deposition increases of less than 2 tons per year are not measurable relative to the large salt load of the Colorado River.

5. Ground-Water Quality (Section 4.2.1.4)

- There is no significant impact to ground-water quality because the control measures, detection systems, and any remedial action will limit contamination to an insignificant portion of total aquifer volume.

6. Soils (Section 4.2.1.5)

- Minor soil impacts as a result of increased erosion, mixing of soil horizons, and disturbance of local topography and drainage patterns
- Use of engineered control measures, leak detection systems, and any necessary remedial action preventing any significant soil impacts.

7. Noise (Section 4.2.1.6)

- Sensitive receptors at which noise impacts will be significant or major are: Dugout Ranch, Newspaper Rock State Historical Monument, Bridger Jack Mesa, and the nearest Canyonlands Park boundary

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 5 of 7)

II. Exploratory Shafts

- Sound level increases from equipment nearest the Canyonlands Park boundary will extend 2.4 kilometers (1.5 miles) into the park and will have an audibility level 20dB above acceptance levels

- Blasting during the first several weeks of shaft construction perceptible at distances up to 5.2 kilometers (3.2 miles), under typical meteorological conditions.

8. Aesthetic Resources (Section 4.2.1.7)

- Significant long-term visual impacts from the ESF from the Davis Canyon jeep trail and Bridger Jack Mesa and short-term impacts from a section of Utah 211 in the immediate vicinity of the site

- The ESF shaft headframe will be potentially visible from a total of 22.7 square kilometers (8.8 square miles); potential visibility of facilities from limited and isolated high ground on mesa tops and some high ground along the eastern boundary of Canyonlands National Park; this area is not often visited because of poor accessibility.

9. Cultural Resources (Section 4.2.1.8)

- No direct impacts of National Register-eligible sites expected

- Development of a Programmatic Memorandum of Agreement resulting in the avoidance or mitigation of potentially adverse effects

- Indirect impacts for the increased activities in the area will not result in the loss of artifacts before their significance is recorded

- Indirect impacts to be minimized by training of project personnel regarding the sensitivity of cultural resource sites.

10. Radiation Levels

- No radiological impacts from site characterization are expected.

11. Transportation and Utilities (Section 4.2.1.10)

- Transportation impacts consisting of increased traffic on roadways from the movement of workers, supplies, and equipment: the greatest impact to Utah 211 where the current average annual daily traffic of 45 will be increased by 506 averaged over the entire site characterization period.

- Additional traffic leading to an increase in road wear, traffic accidents, and traffic fatalities

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 6 of 7)

II. Exploratory Shafts

- Electricity to be generated on site and other project needs to be met by existing facilities.

12. Socioeconomics (Section 4.2.2)

- The socioeconomic impacts are based on the cumulative effects of geologic, environmental, and exploratory shaft activities during site characterization. Summary impacts for all activities are listed under Environmental Field Studies (see Section III of this table).

III. Environmental Field Studies

1. Land Use (Section 4.2.1.1)

- Little land disturbance required by activities beyond installation of meteorological monitoring stations.

2. Terrestrial and Aquatic Ecosystems (Section 4.2.1.2)

- Little land disturbance required by environmental studies, collection of samples will have an insignificant impact.

3. Air Quality (Section 4.2.1.3)

- No significant air-quality impacts expected as a result of environmental studies.

4. Surface-Water Quality (Section 4.2.1.4)

- Minimal disturbance to drainages due to tasks related to the surface-water monitoring program
- No deterioration of surface water quality expected because studies require little land disturbance.

5. Ground-Water Quality (Section 4.2.1.4)

- No impacts expected on ground water.

6. Soils (Section 4.2.1.5)

- No impacts to soils expected because of limited surface-disturbing activities.

Table 4-47. Summary of Site Characterization Impacts at the Davis Canyon Site (Page 7 of 7)

III. Environmental Field Studies

7. Noise (Section 4.2.1.6)

- No significant impact on sound levels from environmental studies.

8. Aesthetic Resources (Section 4.2.1.7)

- Significant impact to visual resources along Davis Canyons' jeep trails due to presence of meteorological towers
- No significant impacts from meteorological towers from other key observation points.

9. Archaeological, Cultural, and Historical Resources (Section 4.2.1.8)

- No impact on resources expected, study area relocated as necessary to avoid impacts.

10. Radiation Levels

- No radiological impacts expected.

11. Transportation and Utilities (Section 4.2.1.10)

- Activities generating an insignificant amount of additional traffic and demand for utilities.

12. Socioeconomics (Section 4.2.2)

The socioeconomic impacts are based on the cumulative effects of geologic, environmental, and exploratory shaft activities during site characterization.

- About 965 in-migrants are expected during the peak of site characterization activities
- There will be a shortage of housing in Monticello and Blanding during the peak of activity
- No major disturbance or relocation of residents is expected
- A total of 12 additional teachers would be needed for the children of in-migrants
- San Juan County would receive grants-equal-to-taxes through the NWPA, but Grand County, Monticello, Moab and Blanding may not
- Impacts on most services would be limited to the need to purchase additional equipment and hiring additional part-time staff.

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Chapter 5

REGIONAL AND LOCAL EFFECTS OF LOCATING A REPOSITORY AT THE SITE

This chapter is intended to meet the requirements of Section 112(b)(1)(E)(vi) of the NWPA (42 USC Sections 10101-10226) that mandates the environmental assessment (EA) include "an assessment of the regional and local impacts of locating the proposed repository at such site." This chapter meets these requirements by describing the environmental, transportation, and socioeconomic effects of locating a representative repository at the Davis Canyon site.

This chapter is organized into four sections:

1. Section 5.1 describes a representative repository and those activities that occur during repository construction, operation, and decommissioning, and presents the impacts of some recent design variations.

2. Section 5.2 describes effects of representative repository activities on the physical environment.

3. Section 5.3 describes the effects of transportation and utilities access to the repository site.

4. Section 5.4 describes the socioeconomic impacts of a repository.

5.1 THE REPOSITORY

The representative repository concept described in this chapter is based on site-specific engineering feasibility studies for constructing and operating a repository at candidate salt sites (SCC, 1984a). The impact analyses presented in this chapter are based on engineering parameters developed using this feasibility study, which will hereafter be referred to as the reference repository design. This concept had the most complete design information available during the time that the EA impact analyses were prepared. However, this reference design must not be construed to represent a final site-specific conceptual design. Rather, the design feasibility data generated should be treated as the first step of a design process that progresses from feasibility studies to the conceptual design phase (Site Characterization Plan Conceptual Design and Advanced Conceptual Design), and to the Title I and II design phase (License Application Design and Final Procurement and Construction Design). The site-specific conceptual design and license application design will resolve remaining uncertainties and serve as the basis for the environmental impact statement (EIS) that will be prepared prior to submittal of a license application. The Salt Repository Project Office (SRPO) is currently developing the site characterization plan (SCP) Conceptual Design for the SCP. Development of the Advanced Conceptual Design will follow completion of SCP conceptual design.

To illustrate differences which could occur in the future as the design process matures, two alternative repository design concepts are presented in Table 5-1 for comparison of design characteristics and impacts (environmental, socioeconomic, and transportation). The "reference design" in the table is the design concept upon which, as mentioned previously, regional and local impacts are assessed in this EA. The reference design is a single-phase concept; that is, all surface and initial underground construction activities are completed prior to acceptance of nuclear wastes. The reference design was based on receipt of both spent fuel (SF) (36,000 metric tons of heavy metal [MTHM] [39,690 tons]) and commercial high-level waste (CHLW) (36,000 MTHM [39,690 tons]) plus approximately 3,510 MTHM (3,879 tons) of defense high-level waste (DHLW). Gassy mine conditions were not assumed in the reference design.

The second concept presented in Table 5-1 is the "Current Two-Phase Concept." This modification of the reference design meets the requirements presented in the DOE final Mission Plan (DOE, 1985, DOE/RW-0005). This concept differs basically from the reference design in three areas:

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
1. Incorporation of exploratory shaft into repository[b]	Not included	Being evaluated	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a slight reduction in work force and supplies required during repository construction and, in turn, worker and truck traffic in the locality would be less.	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a minimal reduction in environmental impacts. Impact reductions would be attributable to less emissions and less resource consumption.	If one or more exploratory shafts are not incorporated into the repository, repository-related impacts are expected to be identical because the number and size of repository shafts are the same. However, if one or more exploratory shafts are incorporated into the repository and the number of shafts to be constructed during the repository phase is reduced, there would be a minimal reduction in socioeconomic impacts. Impact reduction would be attributable to reductions in the required work force.
2. Number and sizes of exploratory shafts[b] (feet, inside diameter)	Not included	Two: 12, 12	See response to Characteristic 1.	See response to Characteristic 1.	See response to Characteristic 1.
3. Number and sizes of repository shafts (feet, inside diameter)	Five - 21, 22, 23, 25, 31	Five: 21, 22, 23, 25, 31	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
4. Gassy conditions assumed	No	Yes	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. The transportation consequences of gassy mine conditions result from the possible increased amount of salt to be disposed of and increased work force. These potential impacts are addressed in Characteristics 7 and 18.	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. More or larger equipment to power ventilation fans will be required. Because the fans are electrically driven, no additional impact on air quality is expected. Additional or larger equipment to handle increased ventilation air flow would not increase noise levels because noise mitigation equipment is assumed to be used. For the reference case, mitigation was	Gassy mine conditions require increased ventilation. This may require additional passageways and consequent increases in the amount of excavated salt. The socioeconomic consequences of gassy mine conditions result from the increased work force requirements associated with additional underground excavation. These impacts are addressed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 2 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Gassy conditions assumed (Continued)				applied to the ventilation exhaust system to reduce noise levels attributable to ventilation fans to 0 dB above acceptable audibility threshold levels (defined in Section 4.2.1.3). A 50 percent increase in air flow will produce no more than a 1.8 dB increase in emission sound levels for the same level of mitigation. Thus, additional baffling and muffling will be required to reduce noise attributable to larger ventilation air flows. This additional reduction of 1.8 dB of the source of noise is achievable within the current state of the art. Thus, no change in reference case noise impacts at the park boundary is expected. Estimated normal use of the steam plant is 18 percent of capacity to heat buildings and supply miscellaneous needs for both the reference case and current concepts. Because the reference case modeled emissions assuming 100 percent capacity usage, the impacts modeled are conservative. Steam plant capacity is established to meet the emergency backup air conditioning requirement. Impacts from additional excavated salt are addressed under Characteristics 6, 7, and 18.	
5. Approximate repository depth (feet)	3,015	3,015	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 3 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
6. Salt Total quantity excavated (tons) Quantity stored on site (tons)	 23,083,000 3,254,000	 31,800,000 4,270,000	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. The increase in salt excavation and onsite storage is expected to result in a larger work force. The transportation impact is addressed in Characteristic 18.	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. Airborne emissions of salt from salt handling operations are expected to increase over the life of the facility. Fugitive salt is conservatively estimated to increase up to 30 percent more than the 15 tons per year estimated for the reference case even though the salt pile will have formed a hard crust and the working face will be kept about the same size. Salt particulates from the mine exhaust will increase due to, roughly, a 50 to 60 percent increase in air flow. Repository salt deposition rates (used also for the site characterization deposition estimates) between 1 and 2 kilometers (0.6 and 1.2 miles) from the salt storage pile and exhaust ventilation shaft are projected to be 0.1 kilogram per hectare (0.09 pound per acre) per year for the reference case. This deposition rate is expected to net: • A 0.2 part per million increase in the upper 0.3 meter (1 foot) of soil of assumed 100 pound per cubic foot density (Section 4.2.1.11.2)	The alternative to the reference case will increase by about one-third the amount of salt to be excavated and stored on site. The increase in salt excavation is expected to result in a significant proportion of the total work force increases associated with the two-phase repository and higher project expenditures. The impacts of these changes are addressed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 4 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Salt (Continued)				• Less than 5 one-hundred-thousandths of a percent (2 tons) of the total salt burden of the Colorado River (3.8 million tons per year) (Section 4.2.1.11.2) • Insignificant impacts on the native terrestrial ecosystems (Section 4.2.1.11.2). If, through the life of the facility, the rate of deposition or the total accumulated salt increased by 50 percent due to increased salt handling and increased exhaust ventilation shaft air flow, the values reported above for soil and the Colorado River would increase to no more than 0.3 part per million and 8 one-hundred-thousandths of a percent, respectively. These levels for the current concepts case are considered insignificant and would lead to insignificant impacts on native terrestrial ecosystems which are known to be tolerant to elevated salt concentrations. Salt storage pile and retention pond areal dimensions do not change in the two-phase concept; the salt pile is extended higher by roughly 3 meters (10 feet) and the salt-runoff retention pond is deepened. Hence. no additional surface area is disturbed (Characteristic 8). The salt pile will be visible from the Davis Canyon jeep trail and from Utah 211 for both reference and current concepts. The salt pile is not expected to be visible	

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 5 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Salt (Continued)				from any other key observation points, because the shaft headframes, much taller structures, are not visible. The salt pile for the reference case is visible from less than 3 square kilometers (1.2 square miles) of park area near the eastern edge of the Needles District (Figure 5-9). The shaft headframes are visible from less than 9 square kilometers (3.5 square miles) of park area near the eastern edge of the Needles District. Because the headframes are 81 meters (265 feet) tall and the salt pile for the current concepts is estimated at 14 meters (45 feet) tall, it is reasonable to project that the salt pile would be visible from no more than about 9 kilometers (5.6 miles) of park area (Figure 5-17). None of these areas are key observation points, nor are they accessible areas. Indirect impacts of additional workers are addressed under Characteristic 18. Indirect impacts from increased traffic-induced air and noise emissions are minor and are not considered to provide significant differences in impacts.	
7. Nonradioactive offsite disposal requirements					
Salt (tons)	9,665,000	14,200,000	The two-phase concept will result in an increase of 47 percent in offsite salt disposal. This can be accommodated within current plans (Section 5.3.3) by increasing the number of covered hopper cars in the daily and weekly trains estimated to accommodate the	The two-phase concept will result in an increase of 47 percent in the offsite disposal requirement. Salt disposal options, especially ocean, surface (salt flat) and mine disposal, have large capacities to accept the reference or two-phase concept volumes of waste salt. For	The two-phase concept will result in an increase of 47 percent in offsite salt disposal. Because this can be accommodated within current plans, no significant differences in socioeconomic impacts are expected.
Repository-generated wastes (truck loads/year)	135	170			The increase in other

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 6 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Nonradioactive offsite disposal requirements (Continued)			reference case. The increase in other repository-generated waste of 35 truck loads per year is about 1/10 truck load per day and will cause no significant transportation impacts.	example, a Stearns Catalytic Corporation study (SCC, 1984b) cites that numerous evaporite mines were available with the capacity to accept the anticipated waste salt volumes. These options can typically accommodate more salt than is to be disposed under the two-phase concept. Transporting salt in closed hopper cars would minimize the potential for salt to be released to the environment during shipment. For the reference case about 4,000 rail carloads of waste salt will be removed from the site. This estimate is based on one train per day carrying 16 carloads over 250 days per year for 27 years. The additional 4.2 million tons of salt to be removed from the site will require that a second train (to carry 16 carloads of salt) be added about two days per week, or that 7 carloads and 1 engine be added to a typical train. Air quality impacts from NO_x, the primary emissions from diesel locomotives, are not expected to be significant because the emissions will be small. The third locomotive does not alter this conclusion. Noise will be audible approximately 8 kilometers (5 miles) from the rail line twice per day for the reference case (Section 5.3.2.2.7) and for the current concept for the extra train scenario. If a second train is	repository-generated waste of 35 truck loads per year (1/10 truck load per day) is not large enough to create a significant difference in the work force requirements for the repository.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 7 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Nonradioactive offsite disposal requirements (Continued)				added on two days the area impacted would experience the same noise levels twice more per week. For the extra locomotive, extra carload, scenario the third engine would add 1.8 dB which would be audible about 6 miles from the rail line. A 26 percent increase in truck loads of repository-generated wastes exists between concepts. The estimated increase of 35 truck loads per year (1/10 truckload per day) will cause negligible changes in impacts to the noise and air quality environments and negligible increased utilization of a disposal facility.	
8. Total area required					
Surface facilities (acres)	467[d]	467[d]	Impacts of increases in underground development acreage of 34 percent affect transportation only in terms of increased salt disposal and work force. These impacts associated with these increases are addressed in Characteristic 7 and 18.	No significant difference in impacts is expected because surface land areas are the same for the two concepts and the impacts attributable to the increased underground area relate to gassy mine conditions and increased salt considerations discussed in Characteristics 4 and 6.	The increase of 34 percent in the underground development acreage will require a larger work force. The effects of additional two-phase repository work force requirements are addressed in Characteristic 18.
Underground development (acres)	1,930	2,590			
Access and utility corridors (acres)	1,578	1,578			
Land control rights (acres)	5,760	5,760			
9. Repository duration - years					
(1) Construction period (years)	8.0	4.5[e,f]	The more concentrated construction period will favorably reduce the time period over which worker-, equipment-, and supplies-traffic have to be accommodated in the local transportation infrastructure. However	As indicated in footnote "f," the construction period for the two-phase concept overlaps with operations and thus extends 7.5 years. The schedule influences air and noise emission rates. Major schedule differences include:	The two-phase concept will require a more concentrated construction effort in the early years and therefore contributes to a higher peak work force. The estimated differences in peak work force require-
(2) Operational period (years)	50 (26 emplacement, 24 caretaker)	50 (25 emplacement, 25 caretaker)			
(3) Decommissioning period[g]	5	5			

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 8 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Repository duration - years (Continued)			this is somewhat offset by the increased worker traffic volume during the shorter period. The same applies to equipment and supplies. On balance, the impacts of increased traffic volume resulting from the more concentrated construction period can be accommodated even though additional improvements and traffic controls may be required on local roads as discussed in Section 5.3.3.	overlapping batch plant operations with site preparation. Schedule adjustments, such as the slowing of site preparation to extend over a 2-year period and staggering the start of waste, exhaust, and service shafts may also be implemented to mitigate impacts. Taken together, these schedule changes have the effect of achieving a more uniform distribution of emissions over the construction period for the two-phase case. With application of the above mitigation measures, differences in impacts are expected to be minor. Emissions from increased traffic are discussed under Characteristic 6. The above factors form the basis on which the impact differences are judged not to be significant.	ments between the reference and two-phase concepts are presented and the incremental impacts discussed in Characteristic 18.
10. Total repository capacity (MTHM)	36,000 SF (47.7%) 36,000 CHLW (47.7%) 3,510 DHLW (4.6%)	62,000 SF (88.6%) 8,000 HLW[h] (11.4%)	The change in waste mix and loading will result in a slight decrease in waste shipments to the repository but an increase in worker traffic and salt disposal transportation. The impacts of these increases are addressed in Characteristics 7 and 18.	Differences between concepts in impacts attributable to repository waste loading and waste mix are reflected in differing salt volumes and shipment amounts discussed in Characteristics 6, 7, and 18.	The change in waste mix and loading will contribute to increased work force requirements based on the need to expand the size of the underground area. The effects of the additional work force associated with the two-phase repository are addressed in Charscteristic 18.
11. Approximate waste receipt rate planned (MTHM/year)	2,050 (initial) 3,250 (max)	400 (initial) 3,400 (max)	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. The maximum receipt rate variation between the two concepts (approxi-	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. Therefore, no significant differences in environmental impacts between	Although initial waste receipt rates are much lower for the two-phase concept, over the long term waste receipt rates are similar. The differences between the concepts have little effect on the total

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 9 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Approximate waste receipt rate planned (MTHM/year) (Continued)			mately 5%) is less than variations already anticipated in fleet operations due to other causes. No significant impact differences are expected.	the concepts are expected.	number of repository workers required. Therefore, no significant differences in impacts are projected.
12. Emplacement configuration	Vertical	Vertical[i]	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
13. Number of waste handling buildings on site	One	Two	Two waste handling buildings will require more workers, equipment, and supplies, resulting in a slight increase in auto and truck traffic. However, based on current estimates (see Section 5.3.3) the additional traffic can be accommodated by the existing network with no further improvements.	The requirement for an additional waste handling building is not expected to create any significant differences in impacts to the aesthetic values of the area due to its relatively low profile. The waste handling building will be visible from the Davis Canyon jeep trail and from Utah 211 for both reference and current concepts. The waste handling building is not expected to be visible from any other key observation points, because the shaft headframes, much taller structures, are not visible. The waste handling building for the raference case is visible from less than 6 square kilometers (2.3 square miles) of park area near the eastern edge of the Needles District (Figure 5-18). The shaft headframes are visible from less than 9 square kilometers (3.5 square miles) of park area near the eastern edge of the Needles District. Because the headframes are 81 meters (265 feet) tall and the waste handling	The requirement for two waste handling buildings in the two-phase concept results in increasing the size of the work force. The effects of the additional work force associated with the two-phase concept are addressed in Characteristic 18.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 10 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Number of waste handling buildings on site (Continued)				building for the current concepts is estimated at about 21 meters (70 feet) tall, it is reasonable to project that the waste handling building would be visible from no more than about 9 square kilometers (3.5 square miles) of park area (Figure 5-17). None of these areas are key observation points, nor are they accessible areas. Construction and operational impacts of the second waste handling building are part of of the overall construction and operations schedules. The impact discussion of schedule differences is presented in Characteristic 9.	
14. Highest structure on site (by name)-feet (height)	Service shaft headframe - 265	Service shaft headframe - 265	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
15. Utilities, consumption			Offsite transportation is not impacted by utility requirements.	No difference in electrical utility access is expected because the larger electrical load can be handled within the utility corridor plans of the reference case. Noise impact differences from additional or slightly larger ventilation equipment (which use more electricity) are expected to be negligible as discussed in Characteristic 4.	The design changes are not large enough to create a significant difference in socioeconomic impacts.
Electricity, diversified load - kVA	29,800	33,400			
Natural gas - cubic feet per day	2,400,000	2,400,000			
Water, construction, gallons[j]	416,000,000	416,000,000			
operation, gallons[k]	2,450,000,000	2,430,000,000			

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 11 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
16. Repository wastes generated on site Radioactive - canisters drums Non-radioactive - cubic yards per year	 2,706 18,392 4,000	 4,660 31,250 5,000	An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. This will contribute slightly to the larger work force and greater offsite salt disposal addressed in Characteristics 7 and 18. The increase in non-radioactive waste disposal is addressed in Characteristic 7.	An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. These impacts are discussed in Characteristics 6, 7, and 8. No significant differences in impacts from the 25 percent increase in non-radioactive waste volume are expected because the increase can be accommodated by additional space in a licensed facility or in additional facilities.	An increase in the amount of underground storage needed for more onsite-generated radioactive waste containers for the two-phase concept will account for approximately 2 percent of the total increase in the amount of excavated salt estimated to be required for the two-phase concept. This will contribute slightly to the larger work force which is addressed in Characteristic 18. The increase in non-radioactive waste is not large enough to create a significant difference in the work force requirements for the repository.
17. Retention ponds, total area-acres	34.2	34.2	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
18. Repository personnel requirements, number of people - construction (peak) operation (average) decommissioning (average)	1,591 1,000 1,040	2,259[1] 1,260 1,360	The increase in workers of 42 percent during construction and 26 percent during operations will result in proportional increases in worker auto traffic on local roads. This may require additional road improvements and traffic controls. However, based on current estimates (see Section 5.3.3) the additional traffic can be accommodated by the existing network with improvements discussed in Section 5.3.3.	Because total water use is assumed to be roughly the same, and because additional commuter vehicles will contribute only slightly to increased noise levels and air pollution along roads to the site, no significant differences in impacts are projected.	Higher work force requirements for peak construction will increase by 42 percent and will occur in a shorter time frame. This will result in an increased amount of in-migration to the region, although measures such as increased local hiring for project jobs and job training will reduce the increase in the number of in-migrating workers expected. Demands for housing and community services will increase in communities receiving new residents. Smaller

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 12 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts
Repository personnel requirements, (Continued)					communities may experience a slight increase in social problems. Consequently, government expenditures for services and planning will increase. Increases in tax revenues from property taxes, sales taxes, and user fees should help meet local government's revenue needs. In addition, project expenditures by workers and their families will increase in the region. Additional local employment opportunities will be created through the additional project jobs and indirect jobs. The Nuclear Waste Policy Act of 1982 provides for mitigation funds to the states affected by a repository development.
19. Access options, length					
Railroad[m] - miles	54	54	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.	No differences in impacts are expected because design parameters are the same.
Highway - miles	25	25			

(a) The repository design concept in this column assumes a requirement to meet MSHA proposed rule for gassy mines (30 CFR 57.31). The major result of this assumption is an increased underground ventilation requirement with a corresponding increase in total excavated salt, power consumption, and personnel. The Mission Plan does not specifically require that gassy mine regulations be included. Elimination of the gassy mine requirement would therefore reduce a number of parameters listed in this column (e.g., salt quantities, power consumption, and personnel).

(b) Incorporation of exploratory shafts in the repository was not included by the design contractor during the development of the reference design concept. However, the salt project has considered exploratory shaft facility (ESF) incorporation in the past and is continuing to evaluate various ESF incorporation scenarios. No decision has been reached whether the ESF will be included or integrated into the repository.

(c) Relative impacts noted consider offsite transportation logistics and economic considerations. Transportation-related environmental and socioeconomic impact considerations are included under those respective columns.

(d) Includes Visitor Center and parking.

(e) This schedule assumes both ESF shafts, one of which is usable by the repository, are available at construction authorization.

Table 5-1. Comparison of Alternative Repository Design Concepts - Davis Canyon Site
(Page 13 of 13)

Repository Characteristics	Reference Design	Mission Plan[a] (Current Two-Phase Concept)	Transportation Impacts[c]	Environmental Impacts	Socioeconomic Impacts

(f) The total construction period for the phased repository is estimated to be 7½ years. Repository construction will be in two phases, which will start simultaneously. The Phase 1 construction period lasts approximately 4½ years and consists of construction, acceptance, and start-up testing of the Stage I surface facility, shafts, and underground facilities needed to accept 400 MTU per year by 1998. The Phase 2 construction continues for an additional 3 years (ending in the year 2001) and consists of the completion of all the facilities, including the Stage II waste building, needed to consolidate and accept 3,000 MTU per year. The Phase 2 construction period overlaps with the beginning of the Operations Period, which starts in 1998. The underground excavation will continue well into the Operations Period as required to accommodate waste emplacement schedules.

(g) Approximate value.

(h) Includes DHLW and West Valley CHLW.

(i) Horizontal emplacement is now being considered.

(j) Construction water requirements for both repository concepts are assumed to be the same because total construction person-hour and earthmoving requirements are assumed to be similar. Actual water consumption numbers would differ slightly because of differing schedule and personnel loadings between the two concepts.

(k) Operations water requirements are slightly less because the operating period is shortened by one year.

(l) Includes 180 personnel for Phase I operations concurrent with 2,079 personnel for Phase II construction.

(m) The number listed is for the longest among four alternative railroad routes listed in Table 5-4.

the repository is developed in two phases, the repository subsurface is designed on a "gassy mine" basis, and the waste received is 62,000 MTHM (68,355 tons) spent fuel and 8,000 MTHM (8,820 tons) DHLW and West Valley CHLW.

The current two-phase concept is designed to receive waste in two phases because the phased approach provides a mechanism for waste acceptance according to the Mission Plan schedule. The first phase is to be operational by January 1998 with an initial waste receipt rate of 400 MTU (441 tons) per year of spent fuel. Construction of the second phase will start concurrently with the first phase and will begin accepting spent fuel in 2001. The repository will begin to receive DHLW at a rate equivalent to 400 MTU (441 tons) per year beginning in the year 2003. (DHLW shipments may be by either truck, or rail, but if by truck would result in approximately three shipments per day for defense waste.)

The current two-phase concept assumes that the subsurface area of the repository be designed to the Mine Safety and Health Administration's (MSHA) proposed rule for gassy metal and nonmetal mine requirements (30 CFR 57.31). The major impacts of this requirement are the need for enhanced ventilation capability with a corresponding increase in subsurface excavation to handle the increased ventilation air when compared with the reference design. It should also be noted that MSHA's current "gassy mine" regulations (30 CFR 57.21) require crosscuts every 30.5 meters (100 feet), whereas the proposed rule is based on maintaining minimum air-flow standards which correspond to the amount of gas actually present in the mine.

Several factors are now being considered by the DOE in conducting repository engineering design activities. These factors may change the characteristics of the repository and will have the potential to increase or decrease the environmental impacts of repository construction and operation. These factors include: (1) the density of the salt used as a backfill material, (2) the rate of closure of repository emplacement rooms due to lithostatic pressure, (3) the horizontal emplacement of waste packages, (4) the presence of gassy mine conditions, and (5) the age of the waste to be emplaced. A discussion follows that illustrates potential impacts of varying characteristics of each of these factors (when considered independently) on volumes of salt excavated, stored on site, and shipped off site for disposal. Impacts associated with the repository relate closely to these salt volumes. While other impacts would occur, e.g., those relating to changes in personnel and utilities requirements, they would be minor compared to impacts associated with the management of salt.

Backfill Density. The reference repository design assumes that backfill is emplaced at a density of 95 pounds per cubic foot, occupying 97 percent of the available volume. This assumed density was based on the "natural density" of crushed salt, i.e., the weight of crushed salt occupying one cubic foot of volume. The density of undisturbed salt (prior to mining) was assumed to be 135 pounds per cubic foot. Because of the gradual creep closure of the repository openings, not all of the excavated salt can be replaced in the repository. Increases in the backfill densities that can be achieved would reduce the salt quantities to be shipped off site.

Assuming that a conventional technology is used and that moderate compaction of backfill material is achieved, an estimate of the backfill density to be achieved is 115 pounds per cubic foot. This would result in 6.9 million tons of salt being disposed off site (a 2.8-million-ton or approximately 30 percent reduction), compared to 9.7 million tons in the reference case. In addition, the onsite salt storage pile would increase by approximately 700,000 tons (a 21 percent increase) to permit backfilling (repository closure) to take place with this increased density of backfill material.

Room Closure. In the reference design, it was assumed that the anticipated closure of the underground openings (other than the waste emplacement rooms) was 10 percent of the cross-sectional area in 3 years. This value was based on structural stability limitations but would still allow the access of mining equipment. Waste emplacement rooms were assigned design dimensions that would accommodate 3 years of closure before instability and equipment access problems started to occur. In the reference design, 2 years are required to open a room, emplace waste in it, and close it; thus there is a 1 year conservative margin contained in the design.

Calculations that were utilized in the design based on commercial high-level waste (CHLW) with areal thermal loading of 25 watts per square meter indicate a range from 5 percent to 16 percent volumetric closure in 3 years. These calculations, however, were performed for CHLW alone and not for a 50/50 mix of spent fuel (SF) and CHLW which would cause lower temperatures in the 3-year period because of the lower areal thermal loading used for SF. The reduced temperatures would cause lower room closure rates than those indicated. It is anticipated, therefore, that the 10 percent closure value in 3 years is realistic. It should be noted, however, that the repository depths used in these calculations are only approximate.

Uncertainties in the predictive capability of the exponential-time law (salt constitutive model) exist and at present the state of the art in such model development does not allow a quantitative evaluation of the reliability of the model. Qualitatively, such reliability can only be estimated based on limited laboratory and in situ testing. Qualitatively, results to date indicate that calculations for preemplacement room closure would underpredict closure, whereas postemplacement closure calculations for a 3-year period after emplacement would either be approximately correct or overpredicted. The degree of which overprediction or underprediction occur cannot be evaluated effectively at this time.

Results obtained from modeling of room closure at ambient preemplacement temperatures at the Waste Isolation Pilot Plant (WIPP) site indicate that the best calculations underestimate room closure by about a factor of three. If it is accepted that the predictive capability of the salt constitutive model seems to improve as the 70 to 100 C (167 to 212 F) range (approximate emplacement room maximum temperatures in the first 3 years) is approached, it may be assumed that predictions of closure would be a factor of three, or less, too low (since the maximum room temperature in the first 3 years lies in this approximate range). This, therefore, gives rise to a qualitative uncertainty of about 30 percent in 3 years. This discussion assumes that the WIPP constitutive model and the exponential-time law are not vastly different, which is the case.

A very approximate estimate of the amount of extra salt that will need to be excavated to accommodate this uncertainty is therefore about 20 percent (The salt which is allowed for in the initial 10 percent closure has already been included in the initial excavation quantities estimate.). The additional amount of salt that may need to be excavated is therefore about 4.6 million tons.

Overall, it is difficult to make any firm statements about the amount of salt that may need to be excavated to maintain stability and access to the emplacement rooms and passageways. The numbers presented are estimates based on limited data. It should further be recognized that a significant amount of judgement has been used to interpret these data.

Horizontal Emplacement. In the reference design the vertical mode of waste package emplacement is the assumed method of storing high-level waste in the subsurface facilities of the repository. The horizontal mode of waste package emplacement is also being considered as a method for storing the high-level waste in the subsurface facilities. The waste package instead of being emplaced in the floor of the storage rooms would be placed in the pillars of the storage rooms.

This emplacement configuration changes the storage room size and provides a reduction in the cross-sectional area of the storage room by about 20 percent. The reduction in the size of the storage room results in an overall excavated tonnage reduction of 2.1 million tons, a reduction of the surface salt stock pile of 0.3 million tons, and a reduction of salt shipped off site by 0.9 million tons, compared to the reference design.

The selection of the mode of waste package emplacement will be established in subsequent design activities to manage environmental impacts. The studies will consist of cost tradeoff analysis and repository long-term stability analysis.

Gassy Mines. Gassy conditions were not assumed in the reference design, and, based on the borehole data available, the presence of gas is not expected in any significant quantities. Recently, the DOE has directed that gassy mines be considered in future repository

design efforts. Assuming that the repository subsurface is designed to gassy mine criteria (Mine Safety and Health Administration's [MSHA] proposed rule for gassy mines, 30 CFR 57.31), there are substantial changes to the number of underground openings due primarily to increased ventilation requirements. Based on the reasonable assumption that the proposed rule (30 CFR 57.31) will become effective, incorporation of gassy mine regulations in the reference case would increase the total salt quantities excavated by about 27 percent (6.3 million tons). Offsite disposal would increase by 4.7 million tons.

Waste Age/Waste Loading. Waste age for the reference repository design has been assumed to be 10 years. This is a conservatively low estimate of the expected average age of the waste, and future design activity will refine this estimate. The range of the age of spent fuel that will arrive at the repository will vary, depending on the growth of nuclear power demand, and is from 5 to about 40 years. The average age of the waste received over the life of the repository is likely to be no less than 15 years, with older waste emplaced initially, which is the current emplacement plan. Thus, 15 years average waste age is reasonable and still conservatively low. If the overall average age of the waste at emplacement is 15 years, the mass areal density at emplacement can be increased approximately 10 percent above the reference case (based on preliminary sensitivity studies). A 10 percent increase in emplacement density would lead to a total quantity of excavated salt of about 21.1 million tons, which is 2.0 million tons or about 10 percent less than that of the reference design of 23.1 million tons. Offsite disposal would be reduced by about 0.75 million tons. Specific emplacement strategies could affect this conclusion, e.g., a strategy of emplacing oldest waste first would lead to older average ages of emplaced waste. Conversely, a strategy of minimizing handling of waste would lead to younger average ages at emplacement.

Summary. Each of the factors considered above would have impacts on the volumes of salt excavated, stored onsite, disposed off site, or backfilled into the repository, compared to the reference design of Table 5-1. The presence of gassy mine conditions and accelerated room closure could cause an additional 11 million tons of salt to be excavated, whereas the use of a horizontal emplacement mode and receipt of older aged waste could cause 4 million tons less to be excavated. Changes in procedures for operation, not discussed above, would also decrease the amount of excavated salt.

The presence of gassy mine conditions and accelerated room closure could also be associated with an additional 7 million tons of salt being shipped off site for disposal, whereas the use of horizontal emplacement, receipt of older aged waste, and increased density of backfilled salt could be associated with 4.5 million tons less being shipped off site. The maximum size of the onsite salt storage pile would be affected by these considerations, with some factors causing the pile to increase by 1.5 million tons and other factors causing the pile to decrease by 0.5 million tons.

The principal environmental impact is associated with offsite disposal of salt. Taking the possible increases and decreases in offsite salt disposal together, it is possible that the offsite disposal estimates could increase from 9.7 million tons in the reference design to 12.2 million tons, approximately a 26 percent increase over the reference design discussed in this chapter.

Of the factors considered, only the physical forces associated with room closure are beyond the capacity of the DOE to manage. Consequently, it can be concluded that with proper management, and using realistic and conservative assumptions, the impacts of future repository design concepts are approximately the same as those for the reference repository design and are contained within the impacts of the Mission Plan case discussed in Table 5-1.

Recent work by Fluor Technology, Inc. (1985), which was used as a basis for the "Two-Phase Concept" presented in Table 5-48 of the draft EA, was reviewed to qualitatively reassess the impacts which may result from a repository conservatively designed in accordance with the 30.5-meter (100-foot) crosscut regulation. Because the impacts resulting from such a large repository may be significantly greater than those shown for the reference design (as discussed in the draft EA Section 5.5) and the 30.5-meter (100-foot) crosscut interval regulation is not in accord with the desire to minimize underground disturbance, such large repository

designs are no longer being pursued by the DOE. Further, if the 30.5-meter (100-foot) crosscut regulation remains as an MSHA requirement in the future, the DOE will apply for a variance on this issue. Increasing the crosscut intervals minimizes the environmental impacts and increases the underground safety.

A consideration from the 1985 Mission Plan (DOE, 1985, DOE/RW-0005) not reflected in Table 5-1 is the impact of incorporating a monitored retrievable storage (MRS) facility. The possibility of including an MRS facility is being evaluated by the DOE as part of the overall waste-management strategy. Specifically, Section 141 of the NWPA directs the DOE to study the need for and the feasibility of an MRS facility for spent fuel and high-level waste. The DOE analyzed the provisions of the NWPA and programmatic options in the 1985 Mission Plan and is evaluating an integrated waste-management system that consists of both storage and disposal components. The primary function of the MRS is waste preparation for emplacement in a geologic repository; its role in providing temporary backup storage is secondary. Performing the waste-preparation functions (i.e., spent-fuel consolidation and packaging) in an integral MRS facility may simplify the design, construction, and operation of the repository facilities. By providing a processing and storage capacity between waste acceptance from the utilities and emplacement in a repository, the MRS would help maintain better and more consistent control over the transfer of waste from reactor to repository.

An integral MRS facility, still awaiting Congressional authorization, would also provide a central location for the management of spent-fuel transportation, cask-fleet operations, and cast-fleet servicing. Because consolidating waste at the MRS site would result in decreased repository facilities and activities in an integrated MRS/Repository System, the nonradiological and socioeconomic impacts discussed in this EA should encompass those of a repository design coupled with the MRS.

The Mission Plan directs the DOE to submit to Congress a proposal that establishes a program for the siting, construction, and operation of MRS facilities. The DOE plans to submit this proposal to Congress in January 1986. To provide a technical basis for the Congressional decision, the following documents would be included in, or would accompany, the proposal to Congress: site-specific facility designs, need and feasibility report, program plan (funding, integration, deployment), and environmental assessment. Studies conducted during the summer of 1985 to support the January 1986 proposal will define more precisely the waste-preparation functions which would be performed by an MRS in an integrated waste-management system.

The DOE has not yet conducted studies to assess the impact of accommodating the potential amount of 5-year-old waste which might be received by a repository; therefore, Table 5-1 does not fully reflect this consideration. The "Standard Contract for Disposal of Spent Nuclear Fuel and/or High Level Radioactive Waste" (10 CFR Part 961) establishes the contractual terms and conditions under which the DOE will make available nuclear waste disposal service to the owners and generators of spent nuclear fuel and high-level radioactive waste as provided in Section 302 of the NWPA. The contract designates spent fuel aged as little as 5 years out of the reactor as "standard spent fuel." Both the Standard Contract (10 CFR Part 961) and the Mission Plan (DOE, 1985, DOE/RW-0005) specify that the DOE will accept fuel for disposal on an "oldest first" basis. Therefore, for most of the first repository receiving and emplacement period, the average age will be greater than 10 years with an estimated 5 to 10 percent aged as little as 5 years. The EA reference design (SCC, 1984a) is based on receipt of 10-year-old fuel. At this point, the DOE believes that the incremental impacts of a repository designed to accommodate the requirement to accept 5-year-old fuel should be minor.

Appendix A of this EA presents general background information on transportation topics and issues. Qualitatively, the nonradiological environmental impacts discussed in the EA will encompass those involving transportation coupled with the MRS, if Congress authorizes an MRS facility. The MRS transportation analysis is found in Appendix A.

Table 5-1, comparing the current two-phase concept with the Chapter 5 reference repository, and with the limitations noted above provides a reasonable representaton of the range of impacts expected from repository designs in salt. It is, however, not the intention of Table 5-1 to provide a limiting analysis for design and impacts.

In summary, the DOE believes that the environmental, socioeconomics, and transportation impacts for the reference design concept are within reasonable limits or are mitigable. Similarly, the current two-phase concept also has impacts comparable to the reference case and are mitigable. The DOE believes, therefore, that the conclusion reached on the guideline findings in EA Chapter 6 would not change due to variations in the repository design concepts analyzed.

5.1.1 General Description

An operating nuclear waste repository consists of surface and subsurface facilities licensed by the U.S. Nuclear Regulatory Commission (NRC) for the permanent, deep geologic disposal of nuclear waste. The repository design is a fully integrated facility for the receipt and long-term geologic disposal of nuclear waste and can handle, package, and dispose of spent fuel, commercial high-level waste (CHLW) from reprocessing of spent fuel, transuranic (TRU) waste, defense high-level waste (DHLW), and low-level wastes generated on the repository site. The reference repository facility concept is depicted in Figure 5-1; major project characteristics are listed in Table 5-1. The current estimate of repository personnel requirements per year is listed in Table 5-2.

5.1.1.1 Repository Site Layout

Repository surface facilities would comprise four major components as follows:

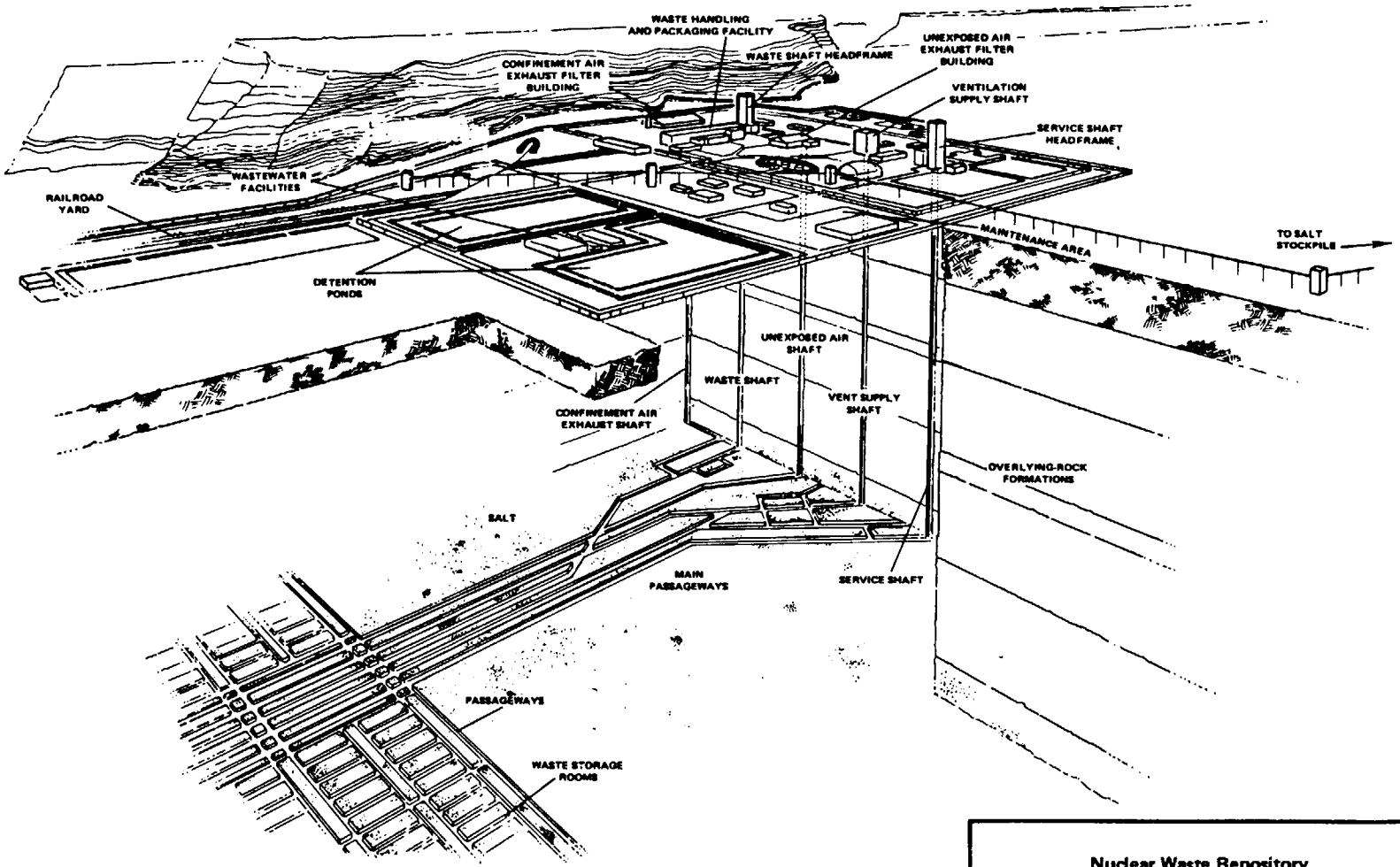
- Waste handling building
- Mine support facilities (head frames, salt storage pile, ventilation exhaust, and supply buildings)
- Administration and support buildings
- Utilities and utility support facilities (steam plant and tank farms).

These surface components will be located on approximately 189 hectares (467 acres) of land, exclusive of the access corridors (i.e., road, rail, and utilities) discussed in Sections 5.1.2.2 and 5.3.2. The underground facilities will extend beyond the surface facility; therefore, a controlled area will be established. Future subsurface activities such as drilling or mining will be prohibited within this area, but various controlled surface uses may be permitted. The site, including surface facilities, underground facilities, and controlled area, is estimated to be 2,330 hectares (9 square miles) but will be determined explicitly during site characterization. Definition of its extent will be based on ability to comply with 10 CFR Part 60, 40 CFR Part 191, and 10 CFR Part 960. The controlled area for Davis Canyon site was determined by adding a buffer zone around the area required for the underground repository. The buffer zone extends out to the controlled area perimeter and allows for protection from radionuclide release. Figure 5-2 presents the controlled area for the Davis Canyon site.

Road and rail access to the site will be designed and constructed to support the expected shipments of personnel, material, and waste. Offsite acquired utilities, such as electrical power and natural gas, will run to tie-in points to service the repository.

During surface construction, topsoil will be removed, used for onsite landscaping, or stockpiled for future restoration. During subsurface construction and operation, excavated salt will be stockpiled in a storage area designed to minimize runoff.

Estimated surface drainage and wind conditions were considered in the layout of the surface facilities, including the waste-water ponds. Nonradioactive liquid wastes will be shunted to a treated waste-water storage pond. A salt runoff pond sized for a greater than 100-year, 24-hour precipitation event will collect runoff from the salt pile. Storm water retention ponds will have sufficient capacity to hold rainfall runoff. All these ponds will be designed to minimize water seepage into the ground. All waste water will be recycled to the maximum extent possible.



Source: Adapted from SCC, 1984a.

Nuclear Waste Repository Facility Concept

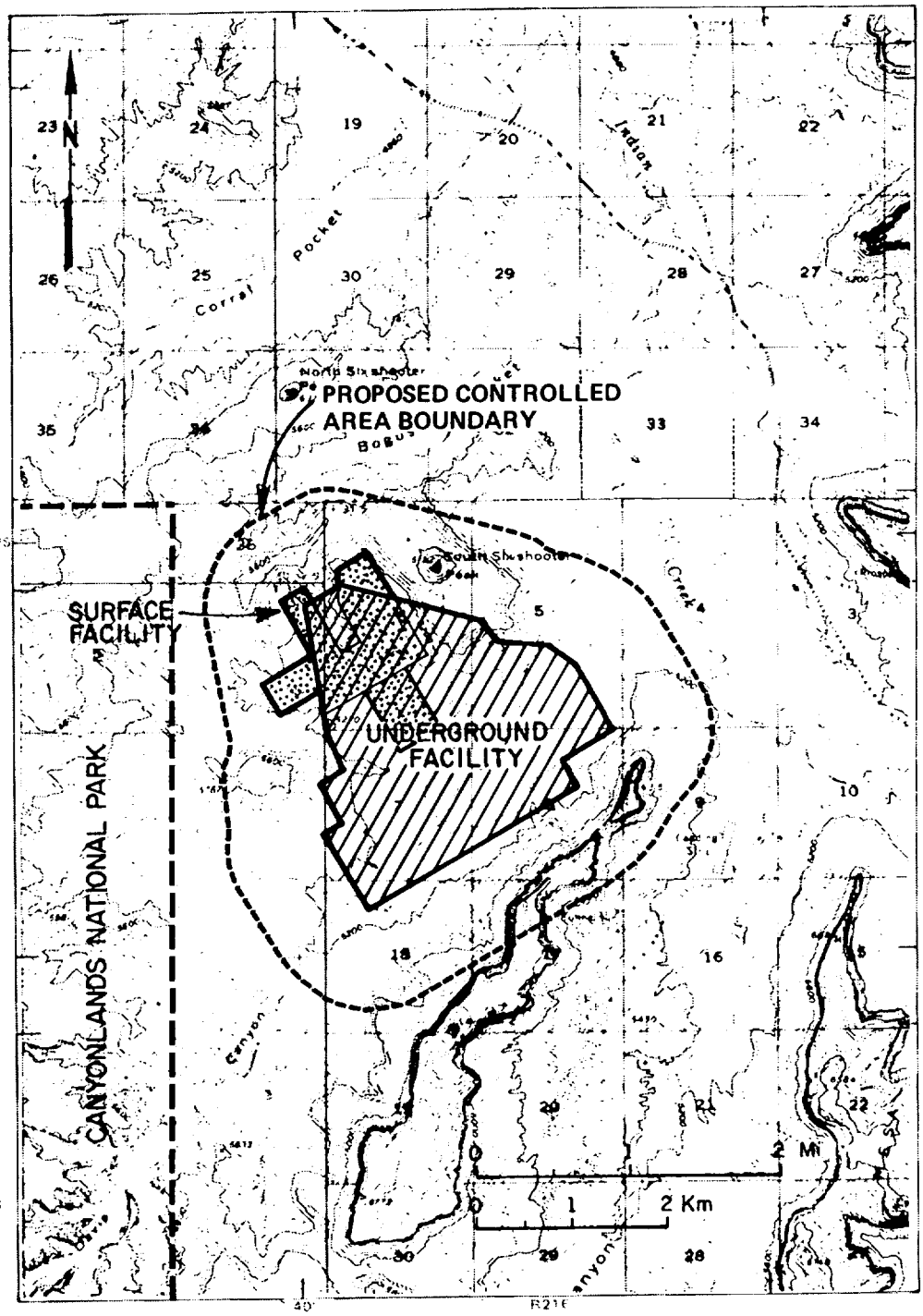
Figure 5-1

Table 5-2. Average Annual Repository Personnel Requirements, Davis Canyon

Years Into Project	Construction	Operation	Caretaker	Decommissioning
1	688			
2	1,112			
3	1,032			
4	1,112			
5	1,220			
6	1,538[a]			
7	1,380			
8	918			
8-32		1,000		
32-56			230	
56-61				1,040

(a) Peak repository construction personnel requirement is 1,591 and occurs in the third quarter of sixth year.

Sources: SCC, 1984a; Eschen, 1985.



Source: Adapted from SCC, 1984a.

Preliminary Facility Location Within the Site

Figure 5-2

All disturbed areas not paved, gravelled, or otherwise covered will be landscaped. Buildings and other structures will be painted to minimize their contrast with the surrounding site environment.

A perimeter fence will enclose the entire surface facility with the exception of the visitor center parking lot. An inner security fence will surround the radiological operations area, including the shafts, receiving and packaging facility, and other waste-related support facilities.

5.1.1.2 Waste Receiving, Handling, and Packaging Facilities

The primary functions of the repository surface-waste receiving, handling, and packaging facilities are to receive, handle, and package nuclear waste arriving at the repository and to transfer the packaged waste to the repository subsurface.

The waste handling and packaging facility (WHPF) (Figure 5-3, Item 29; Figure 5-4), the largest building on the repository site, provides for washing down contaminated shipping casks, unloading the cask from the transport vehicle, removing the waste from the shipping casks (if required), inspecting and recording identification of waste forms, temporarily storing waste forms and waste packages, packaging of the waste forms, closure welding of the waste packages, inspecting the completed waste packages, and transferring the waste packages in a transfer cask to the waste shaft.

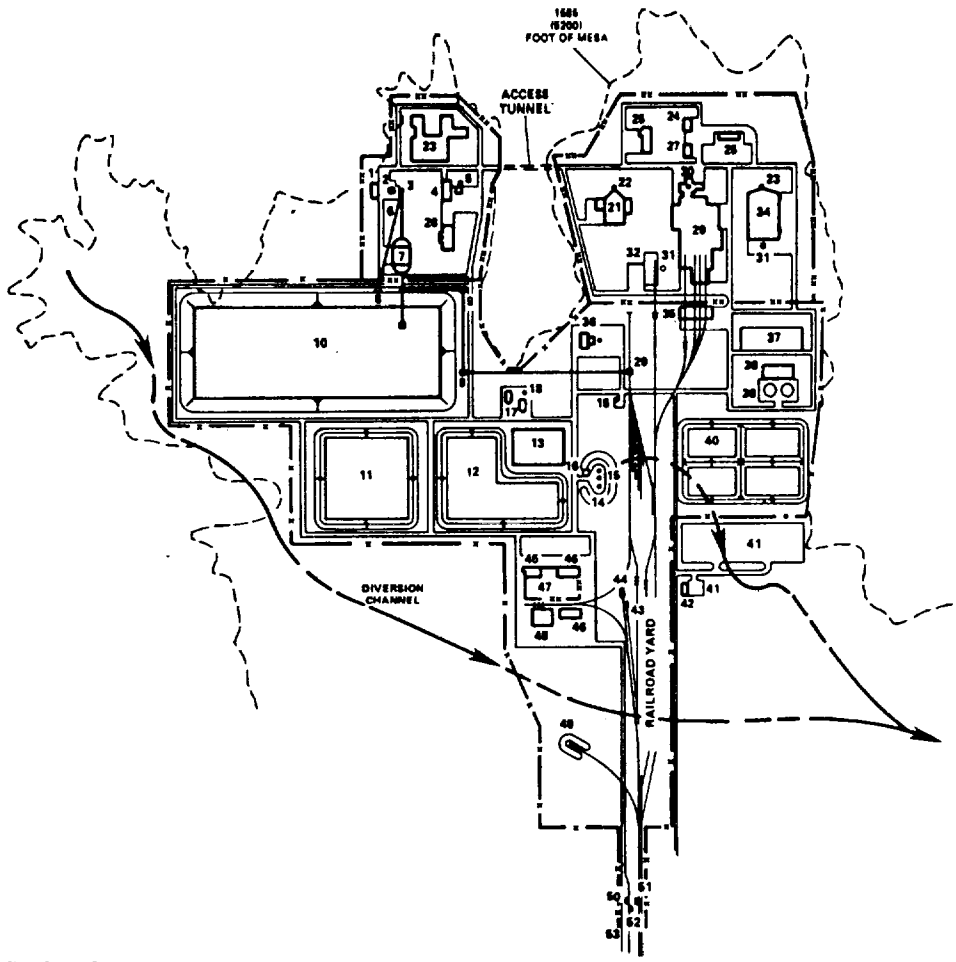
The functions required to receive the shipping casks from the transport vehicles (i.e., rail and truck), and to prepare the waste form for subsurface emplacement, up to and including the transfer to the waste shaft hoist, will be performed within the confines of the WHPF. The overall functional-flow schematic diagram for the WHPF is shown in Figure 5-5.

Waste handling activities would begin with the receipt of the transport vehicle from the cask contamination survey station. As necessary, the casks will be reinspected and contaminated casks will be washed down in a separate decontamination wash bay. Casks would then be unloaded from the transport vehicle and positioned for removing their radioactive waste forms.

With the exception of contact-handled TRU, all the waste forms would be removed from the shipping casks into the hot cell portion of the facility where the waste forms would be inspected, sorted, and temporarily stored. Contact-handled TRU is not highly radioactive and would be handled outside the hot cells. It would be unloaded, inspected, and placed on pallets before being transferred to the waste hoist.

The functions performed within the hot cell depend on the waste type. Spent-fuel assemblies would be disassembled and spent-fuel pins repackaged. The packages and canisters of CHLW and DHLW would be placed in containers. Typically, remote-handled TRU would be inspected and passed through the hot cell without repackaging. However, if it is externally contaminated, they will be cleaned or enclosed in containers to provide a contamination-free exterior. These waste packages would be passed out of the hot cell area via transfer casks, which would be used to move the waste packages to the waste hoist, and subsequently down through the underground workings to the emplacement area.

The WHPF would have several support areas not directly involved in the handling of radioactive waste. Most significant of these in size and importance would be the heating, ventilating, and air conditioning (HVAC) systems constituting the major engineered-safety feature system for the containment of the radioactive materials. The largest system is the hot cell HVAC "once-through" system, which would move air through the hot cells and then through 60-percent, 90-percent prefilters and double high efficiency particulate air (HEPA) filters in series, and charcoal adsorbers. The system would have 100 percent flow and filtering redundancy. Separate ventilation systems similar to the hot cell HVAC system would be provided for other major functional areas such as the shipping cask handling area, the personnel area, and the contact TRU handling area.



Explanation

1 Service shaft filter building
2 Service shaft
3 Transfer tower
4 Ventilation supply filter building
5 Ventilation supply shaft
6 Reclaim tunnel
7 Live storage & surge building
8 Reclaim hopper
9 Salt transfer tower
10 Salt stockpile
11 Salt runoff pond
12 Treated wastewater holding pond
13 Wastewater treatment facilities
14 Potable water tank
15 Fire water storage tanks
16 Fire/potable water pumphouse
17 Cooling towers
18 Chemical feed building
19 Railroad control tower
20 Salt loadout structure
21 Unexposed air exhaust filter building
22 Unexposed air exhaust shaft
23 Underground operations building
24 Firehouse, security & medical treatment center
25 Administration & operation control center
26 Electric power building
27 Environmental & instrument laboratory
28 Compressor chiller building
29 Waste handling & packaging facility
30 Waste shaft
31 Confinement exhaust stack
32 Storage yard
33 Confinement air exhaust shaft
34 Confinement air exhaust filter building
35 Noncontaminated railcar/truck washdown area
36 Steam plant
37 Abandoned material & equipment storage yard
38 Raw water treatment
39 Raw water storage tanks
40 Storm water detention ponds
41 Parking lot
42 Visitors center
43 Railroad inspection pit
44 Railroad maintenance building
45 Maintenance building
46 Storage shed
47 Storage yard
48 Warehouse
49 Suspect Railcar/truck storage area
50 Truck inspection pit
51 Railcar inspection pit
52 Monitoring station
53 Guardhouse

Scale

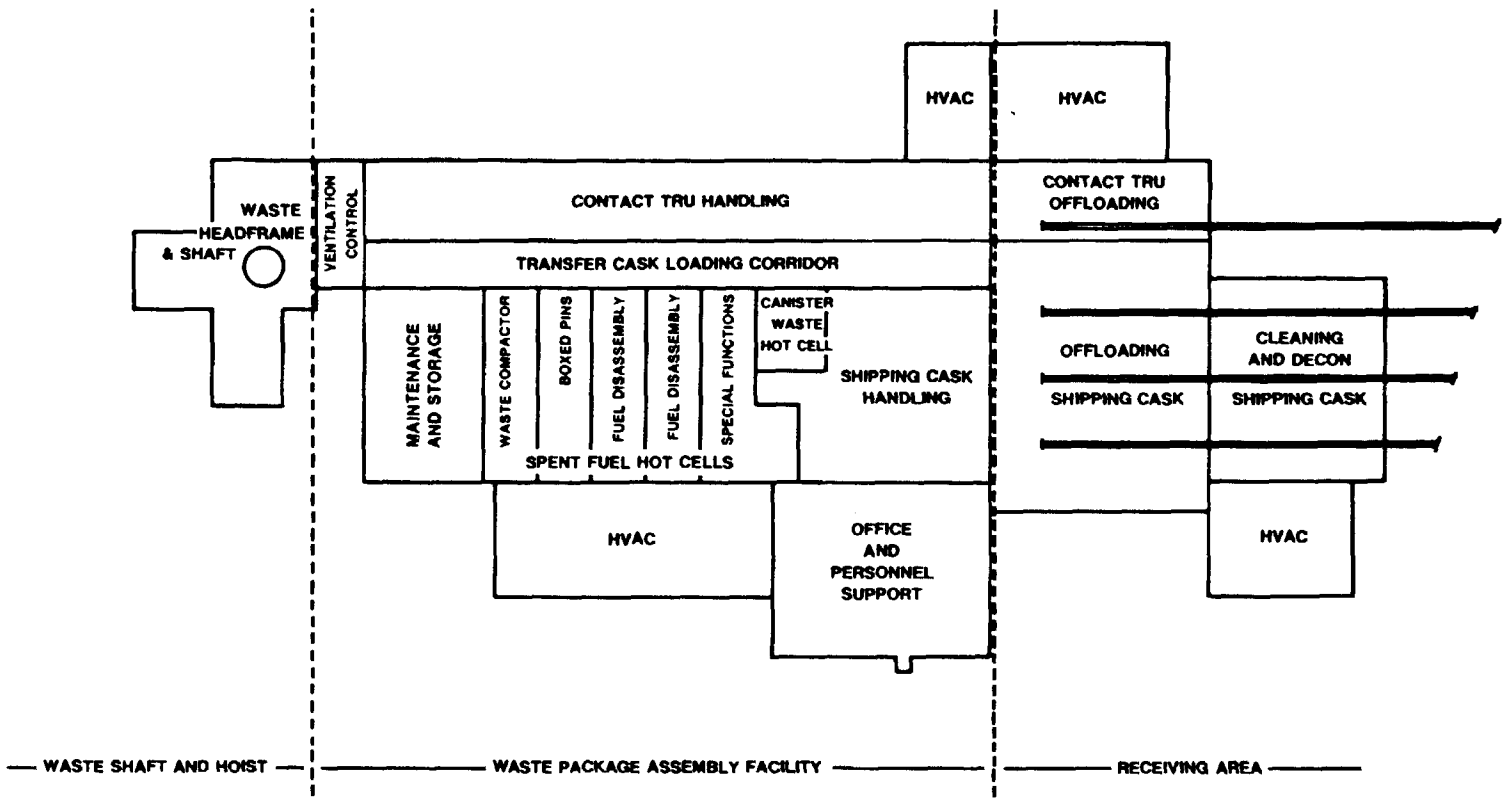
0 500 1000 Feet

0 150 300 Meters

Source: Adapted from SCC, 1984a.

Repository Site Layout Plan
Davis Canyon

Figure 5-3



Scale

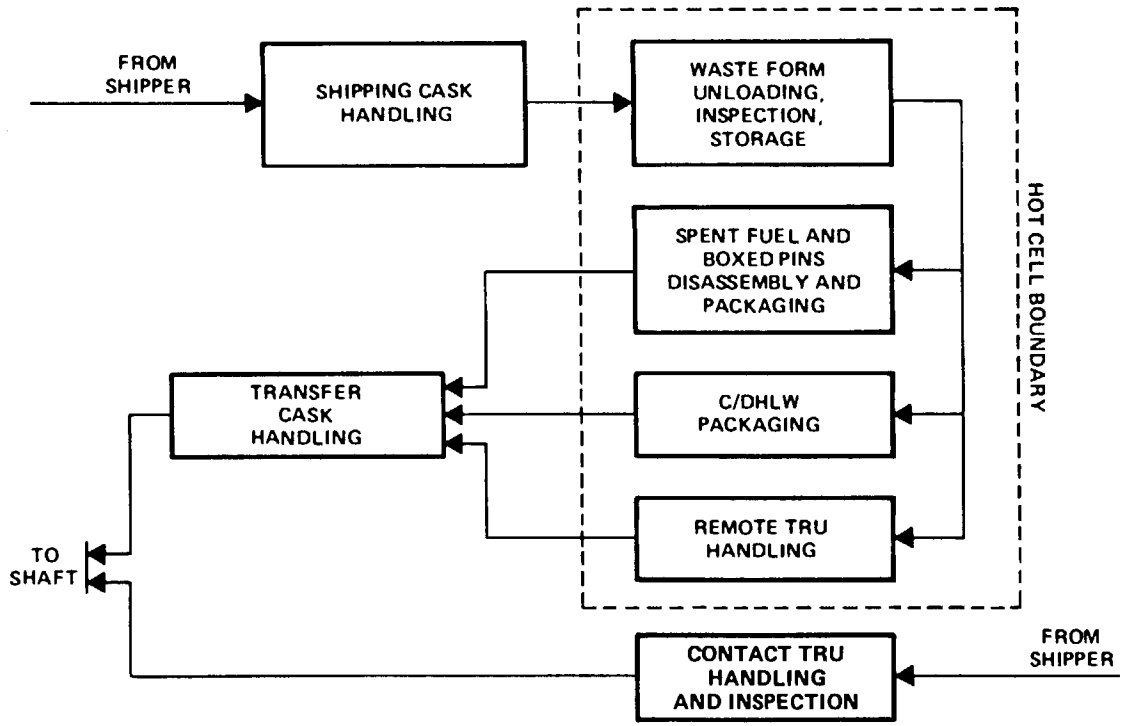
0 40 80 120 Feet

0 10 20 30 Meters

Waste Handling and Packaging Facility Layout Davis Canyon

Figure 5-4

Source: Adapted from SCC, 1984a.



Source: Adapted from SCC, 1984a.

Waste Handling and Packaging Facility
Overall Functional Schematic
Davis Canyon

Figure 5-5

5.1.1.3 Repository Shafts

Repository shafts would provide the means of ingress and egress of personnel, transport of materials and nuclear waste packages, and ventilation of the subsurface workings of the repository. The reference design in Table 5-1 (SCC, 1984a) proposes five shafts which would serve the requirements of the repository:

- Waste shaft - transport of waste canisters from surface to subsurface
- Service shaft - transport of personnel, equipment, material, salt, air supply, and utility lines
- Ventilation supply shaft - supply air, utility lines, and emergency egress
- Unexposed air exhaust shaft - exhaust air from the subsurface development area, utility access
- Confinement air exhaust shaft - exhaust air from the waste emplacement area.

All shafts would be circular in cross section and range in size from 6.4 to 9.4 meters (21 feet to 31 feet) finished inside diameter. The depths of the shafts into the repository horizon would vary from the repository level to some distance below the repository depth to accommodate the excavated salt hoist skips in a loading position, salt spillage storage area, and hoist equipment. The service shaft headframe will be 81 meters (265 feet) in height. The DOE will comply with "Objects Affecting Navigable Airspace" (14 CFR Part 77) which requires notifying the Federal Aviation Administration of plans to construct structures 61 meters (200 feet) or greater in height.

The shaft pillar, which encompasses all five shafts, is an area containing little excavation and no emplaced nuclear waste. It would be offset or placed to one side of the underground facilities. This shaft pillar offset will isolate the shafts and main surface facilities from any potential effects of subsidence or uplift over the storage room panels.

The shaft liner designs and installation will take into account the site-specific stratigraphy and major aquifers, with seals installed to isolate the aquifers from the waste storage level and from each other. The design and construction of the shafts and liners will take into account the eventual decommissioning of the repository.

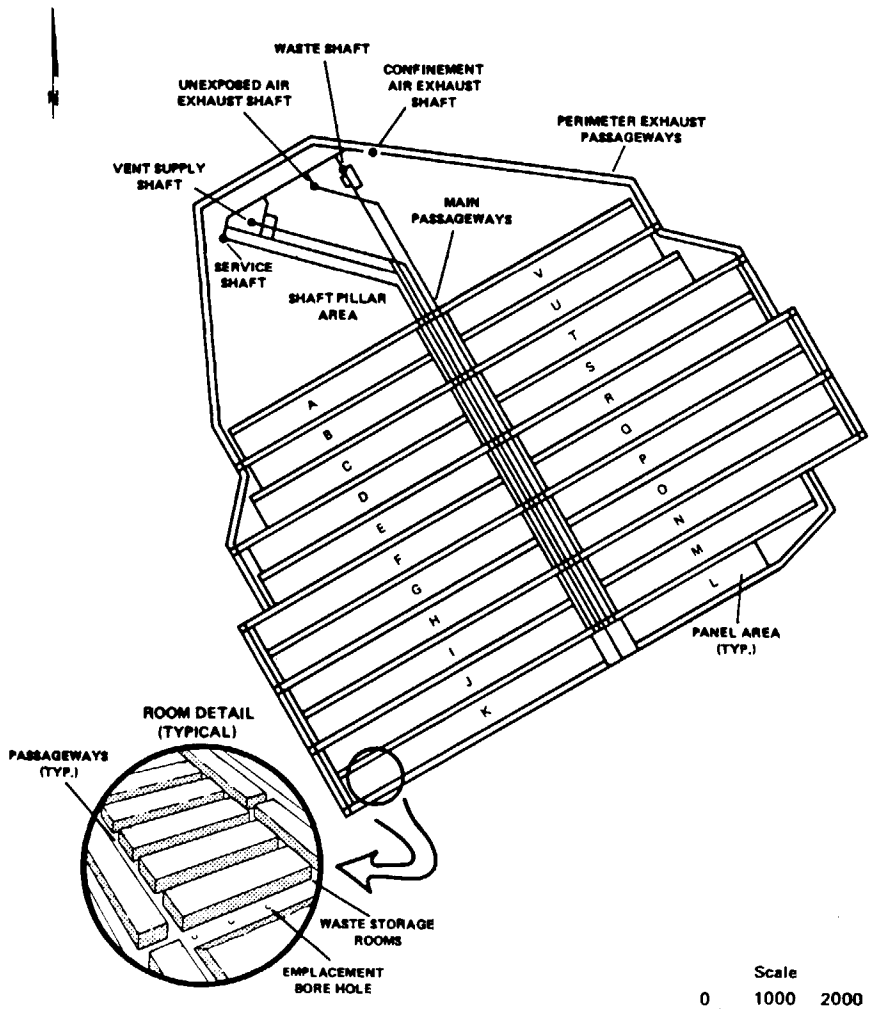
The waste shaft, service shaft, and ventilation supply shaft would be equipped with hoisting systems. The ventilation exhaust shafts will not have hoisting facilities.

The repository ventilation system will utilize the shafts to provide ventilation air to the underground facility. The exhaust shafts would be used solely for ventilation and would not contain hoists. The ventilation system would provide air flow throughout the repository to service the two underground functions of mine development and waste-emplacement operations. Exhaust ventilation air from the mine development operations would be kept separate from air exhausting from waste-emplacement activities.

5.1.1.4 Repository Subsurface Facilities

The repository subsurface would consist of the excavated rooms for waste emplacement, branch and main passageways for transporting the mined salt and waste packages, and corridors for ventilation. Additional areas would be excavated for equipment maintenance, parts and materials storage, operations control and monitoring, first aid and emergency systems, and other miscellaneous facilities normally associated with underground mining operations.

Figure 5-6 is a simplified layout of the repository subsurface area showing a completed repository development at the end of operations. The following five horizontal main passageways would be driven down the approximate centerline of the repository storage room area:



Note:
All rooms are not shown, see room detail.

Source: SCC, 1984a.

Scale
0 1000 2000 Feet
0 300 600 Meters

PANEL TABLE		
PANEL	WASTE	NO. ROOMS
A	TRU	46
B	TRU	46
C	DHLW/CHLW	25/29
D	CHLW	54
E	CHLW	55
F	SF	78
G	SF	78
H	SF	78
I	SF	78
J	SF	78
K	SF	78
L	SF	39
M	SF	59
N	SF	78
O	SF	78
P	SF	78
Q	SF	78
R	CHLW	58
S	CHLW	58
T	DHLW/CHLW	26/29
U	TRU	47
V	TRU	47

Repository Underground Layout
Davis Canyon

Figure 5-6

- A path for fresh air to both the development areas and emplacement areas
- An exhaust-air path from the development areas
- A corridor for waste transport
- Access to both the development areas and emplacement areas for personnel and equipment
- A corridor for mined salt transport.

The cross section of the passageways would be rectangular with major dimensions of approximately 9 meters wide by 5 meters high (30 feet wide by 15 feet high). There would be a total of 9,900 meters (32,600 feet) of drifts in the main passageways and 7,300 meters (24,000 feet) of drifts in the shaft pillar zone.

The waste storage areas of the repository would consist of branch passageways, exhaust branch passageways, and 22 panels of storage rooms. The branch passageways would provide access to the individual storage rooms and would be interconnected by cross cuts. During the excavation of storage rooms, the passageways would provide a path for intake and exhaust air. During emplacement operations, the branch passageways would be used to transport waste to the individual rooms and provide fresh air. The exhaust passageways would be connected to the exhaust end of the storage rooms and to the perimeter exhaust passageways. These passageways, in conjunction with the perimeter exhaust passageways, would provide a completely isolated path for confining exhaust air.

Each waste type would be located in separate panels of the repository, according to the reference repository feasibility study (SCC, 1984a). The storage room quantities and related parameters are shown in Table 5-3.

The waste package concepts for defense and commercial high-level waste and spent fuel consist of the canisterized waste form, surrounded by a steel waste package container, and, after emplacement, a packing and cover of crushed salt. This concept is described in Section 6.4.2.2.1 and as the Alternate II concept in Westinghouse (1983, ONWI-438).

The defense and commercial high-level waste forms consist of high-level waste melted into borosilicate glass that is poured into thin-walled stainless steel canisters by the waste form producer. They are then shipped to the repository for assembly into the waste package container.

The spent fuel waste form consists of spent fuel rods which have been removed from several fuel assemblies and consolidated into a close-packed bundle. The bundle of spent fuel rods is surrounded by a thin-walled canister of low carbon steel.

The waste package container is a thick-walled low carbon steel vessel surrounding the waste form. It is designed to provide containment for the desired period when exposed to the external geologic pressure and corrosive environment.

Waste package concepts for TRU wastes are in the very early stages of development. At this time, it is anticipated that the disposal containers for both contact and remote handled TRU wastes will be either standard 0.24-cubic meter (55-gallon) drums or other mild steel containers.

Table 5-3. Approximate Waste Storage Room Quantities

Waste Type	Waste Package Characteristics			
	Rows Per Room	Pitch (feet)[a]	Number Per Room	Total Number
Spent Fuel	1	60	9	7,899
CHLW	1	40	13	3,673
DHLW	2	7 square	138	7,020
Remote TRU	3	7 triangular	200	37,050
Contact TRU	3	N/A	480	18,406 (pallets)

(a) "Pitch" is spacing between adjacent waste packages.

5.1.1.5 Repository Land Acquisition

The requirements for ownership and control of interests in and for a repository are established in 10 CFR 60.121 which states:

> (a) Ownership of land. (1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under the jurisdiction and control of the DOE, or lands permanently withdrawn and reserved for its use. (2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) Rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

The DOE is also required to exercise any jurisdiction and control over surface and subsurface estates outside of the controlled area, to prevent adverse human actions that could significantly reduce the geologic repository's capability to achieve isolation, 10 CFR 60.121(b).

The DOE currently estimates that a repository site in Davis Canyon will consist of (1) a fenced central area of about 189 hectares (467 acres) for support buildings and repository surface facilities, (2) the geologic repository underground operations area of about 781 hectares (1,930 acres), and (3) a controlled area extending outward from the edge of the underground facility. The total site could be a maximum of approximately 2,330 hectares (5,760 acres). On a technically conservative basis, a minimal 4,060-acre site was recommended (Chen and Raines, 1985), and because of the uncertainties involved in developing this recommended size for the controlled area, the DOE has added an additional margin around this area to bring the site area up to the 5,760-acre size. Preliminary analyses indicate that a site area of 5,760 acres would allow all EPA and NRC repository performance requirements to be met (see Sections 6.3 and 6.4). See Figure 5-2 for a schematic drawing of the controlled area. The exact size of the controlled area will depend on the rate of ground-water flow and other site characteristics and will be established after completion of site characterization in accordance with EPA standards and NRC regulations.

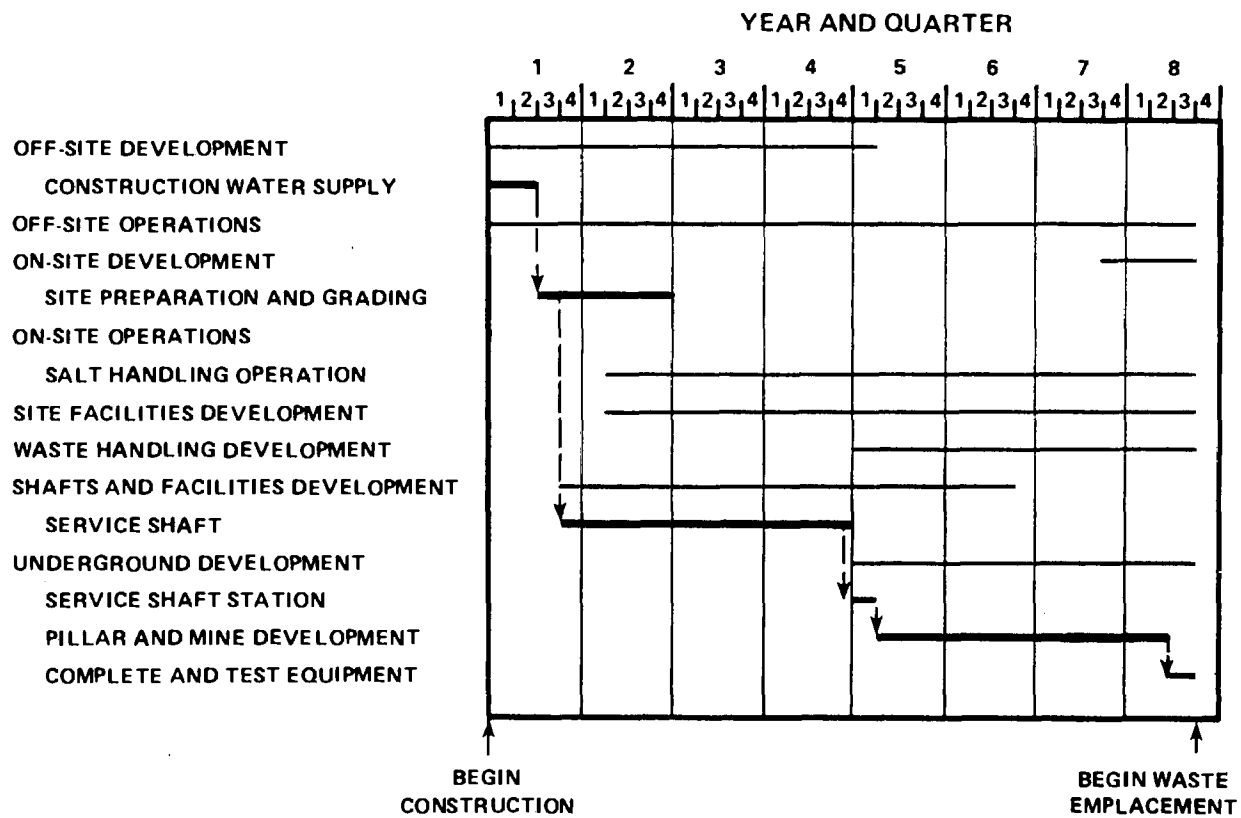
For the Davis Canyon site, the DOE will purchase surface and subsurface rights to required State and private lands. Federal land managed by the BLM will be obtained by way of a permanent withdrawal through an act of Congress. This withdrawal will transfer jurisdiction of the land to the DOE.

5.1.2 Repository Construction Activities

The sequence and duration of repository construction activities are depicted in Figure 5-7. The total time estimated for construction is approximately 8 years, including 3 months for equipment tests.

5.1.2.1 Construction Schedule and Personnel

The critical path for the construction of the repository would begin with the development of offsite utility and transportation access corridors and the establishment of a water supply. A temporary water-supply line will be constructed during approximately the first 6 months of construction activity. This temporary supply line will be routed to the repository site along the route of the transportation access corridor. After the construction water supply has been established, site preparation and grading would begin. Site preparation and grading must be completed in the service shaft vicinity before shaft sinking activities can start. The development of the construction water supply, site preparation, and grading activities are estimated to take approximately 24 months, of which 9 months are on the critical path.



Explanation

Summary level critical activity

Logic

Activity duration

Critical activity duration

Source: SCC, 1984a.

Schedule Summary Bar Chart
Davis Canyon

Figure 5-7

The next critical phase will involve sinking, lining, and equipping the service shaft and stations, which will be completed before at-depth excavation begins. The shaft and shaft-station construction activities are estimated to take approximately 42 months, and are on the critical path.

Before waste emplacement operations begins, the shaft-pillar and mine development will be completed to a point where 1 year's waste receipt could be emplaced. This activity is estimated to require approximately 42 months, and is on the critical path.

Preoperations-testing of emplacement equipment and ventilation systems will be completed before actual waste emplacement activities begin. This testing is estimated to require approximately 3 months, and is on the critical path.

The estimated personnel requirements for underground work and the total project are shown in Figure 5-8. Corresponding estimated construction personnel requirements per year are listed in Table 5-2. The construction estimate includes personnel for the DOE, NRC, architect-engineers, construction manager, and other personnel.

Over 50 percent of the water projected to be required for construction at the repository site is associated with earthwork. For the purpose of estimating this water requirement, it has been assumed that all of the voids in the soil must be filled with water in order to achieve proper compaction. This provides a rather conservative (i.e., high) estimate of water required and does not attempt to take credit for probable water conservation practices employed. Water required for dust suppression is considered to be covered by this estimate. The remaining portion of water use will be associated with concrete production, consumption by personnel, and minor miscellaneous uses. The scheduling of these water demands is linked to the schedule for concrete production and the approximate distribution of personnel at the site over time.

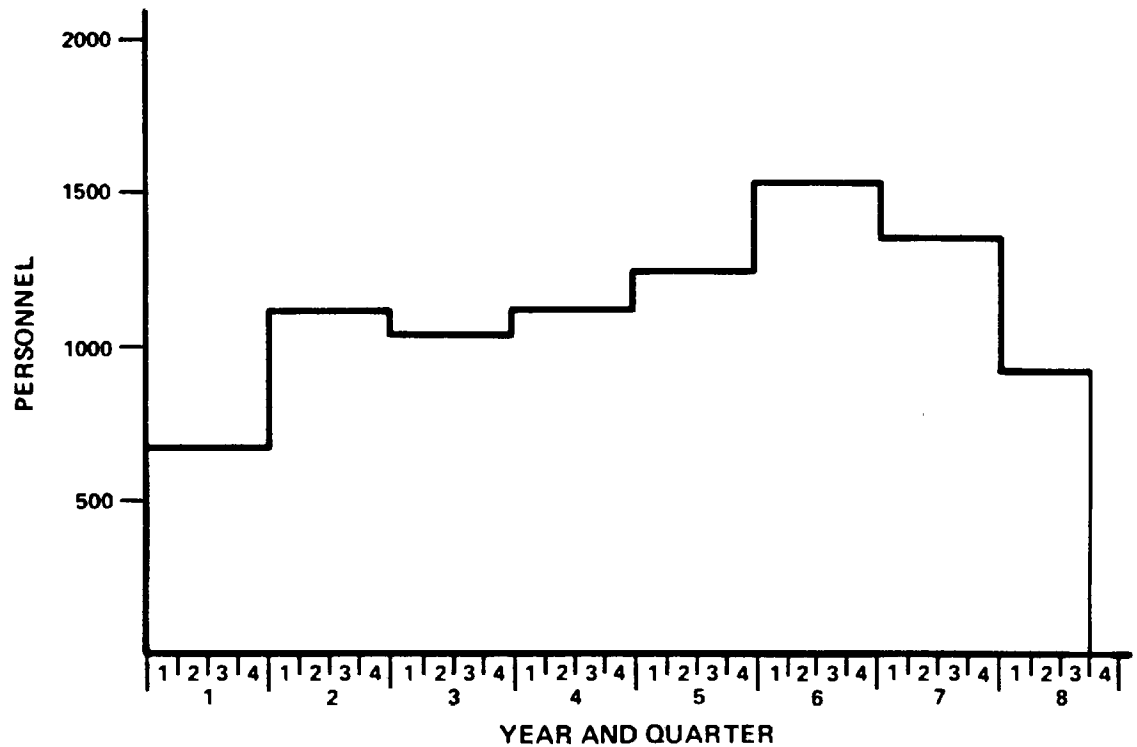
5.1.2.2 Offsite Development

Offsite development activities consist of constructing the transportation access corridors and utility supply lines from the public and commercial domain (Section 3.5) to the repository site. The selection of preferred transportation routes to the site will occur later in the siting process and will use the results of detailed investigations during site characterization (Section 4.1.3.1.10). For the purposes of this environmental assessment and in order to fulfill the requirements of the siting guidelines, the approach taken has been to select alternative routes as described below and shown in Figure 5-9. The final selection process will include further economic and environmental impact analyses as well as participation of State and local officials and the public.

Railroad and highway access routes to Davis Canyon have been extensively studied since 1980. Bechtel Group, Inc. (BGI, 1982, ONWI-404; BGI, 1984, ONWI-454) and SCC (SCC, 1984b) have evaluated various corridors in terms of costs and environmental impacts. In 1985, Bechtel National, Inc. carried out further engineering work sufficient to establish constructibility, and provide a more detailed basis for an environmental assessment of alternatives. This study (BNI, 1985e) identified several feasible railway and highway access routes which are shown in Figure 5-9.

Highway access to Davis Canyon could be provided by Utah State Highway 211 (Utah 211), its National Park Service (NPS) extension, and a new 8-kilometer (5-mile) access road. Use of this route for access to the repository would require major upgrading of the existing roadway, including an interchange at the intersection of U.S. Highway 191 (U.S. 191) and Utah 211, realignment of Utah 211, and the Newspaper Rock bypass as discussed in Section 4.3.5. Upgrading would also include widening lanes, widening and paving shoulders, three-lane design on grades, and several turnouts along the route from U.S. 191 to the repository access road.

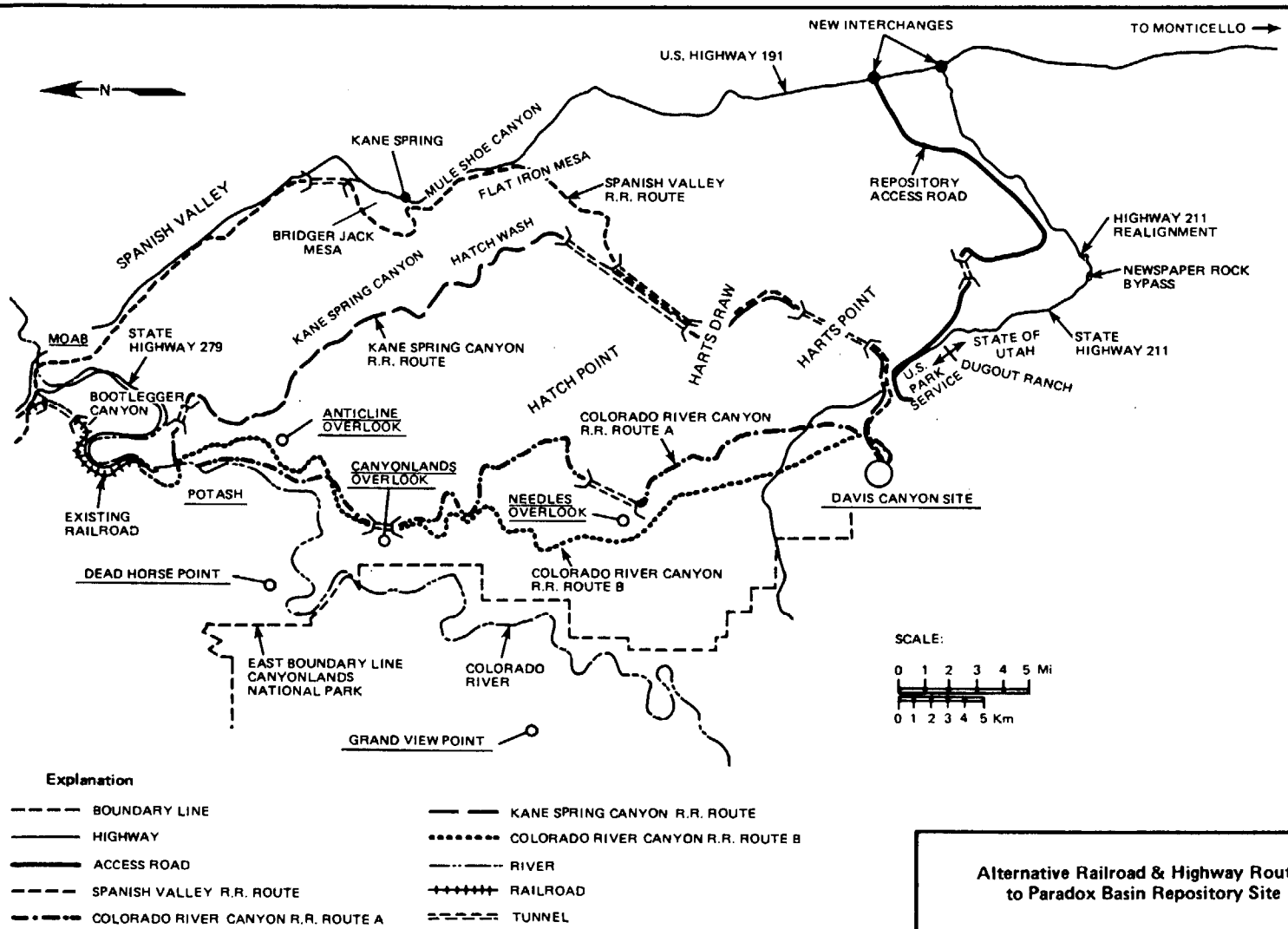
An alternative would be an exclusive-use access highway following an alignment such as illustrated in Figure 5-9. This 40-kilometer (25-mile) route leaves U.S. 191 5 kilometers (3 miles) north of the U.S. 191/Utah 211 junction, and continues in a "U"-shape, paralleling



Construction Personnel Requirements
Davis Canyon

Figure 5-8

Note: Values were taken from Table 5-2.



Source: BNI, 1985e.

Alternative Railroad & Highway Routes to Paradox Basin Repository Site

Figure 5-9

Utah 211 for a few kilometers. It then turns north, enters a descending 2 kilometer (1.2-mile) tunnel into a canyon near Dugout Ranch, and again parallels Utah 211 before crossing the NPS extension of Utah 211 and terminating in Davis Canyon at the repository site.

The alignments of four feasible railroad access route alternatives which were investigated are also illustrated in Figure 5-9. All of the routes extend south from the Denver & Rio Grande Western (D&RGW) Cane Creek branch line. All require a bridge over the Colorado River. The grades on all railroad routes are limited to less than 3 percent and minimum curve radius is 10 degrees (572 feet). A comparison of key physical characteristics of the alternative access routes is given in Table 5-4.

Colorado River Canyon Route A stays in the canyon near the base of cliffs except when tunnelling beneath Canyonlands and Needles overlooks. Colorado River Canyon Route B diverges from Route A after the Canyonlands Overlook tunnel, following a more westerly route around Needles Overlook. The Kane Spring route diverges from the two Colorado River Canyon routes after crossing the river, heading southeast through Kane Spring Canyon and Hatch Wash to a major tunnel under Harts Point. A second tunnel under Harts Point opens into the canyon near Dugout Ranch and then the route crosses Utah 211 NPS extension. The Spanish Valley route leaves the Cane Creek branch near Arches National Park, and parallels U.S. 191 on its west side beyond Kane Spring. It then turns southwest to join the Kane Spring route for the remaining distance to the site. Environmental assessment of these alternatives is discussed in Sections 5.3.2 (Construction) and 5.3.3 (Operation).

Utility supply lines, existing and planned, are shown in Figure 5-10. The assumed suppliers of electricity and natural gas are Utah Power and Light Company (UP&L) and Northwest Pipeline Company, respectively. The normal operating electrical power for the Davis Canyon repository may be supplied from a new substation located about 35 kilometers (22 miles) east of the repository site. The substation would be tied into the existing 138-kV transmission line of the UP&L. A new 43-kilometer (27-mile) long power line would be constructed from the substation to the repository. Natural gas for the repository may be obtained by tapping a Northwest Pipeline Company 66-centimeter (26-inch) gas line running northwest about 32.2 kilometers (20 miles) east of the site. A new 20.3-centimeter (8-inch) branch line 40.0 kilometers (25 miles) long, would be constructed to the repository site.

The water supply for the Davis Canyon repository would be taken from the Colorado River about 9.6 kilometers (6 miles) south of Potash, Utah. There would be a pump station at the intake and two booster stations along the pipeline. A 20-centimeter (8-inch) water pipeline 35 kilometers (22 miles) long would be constructed from the river and along the railroad access route to the repository site if the Colorado River rail access route is selected.

5.1.2.3 Onsite Development

Onsite development would consist of site preparation and grading, completion of the onsite sections of the rail lines and site roadways, and construction and erection of the repository surface facilities.

Site preparation would encompass approximately 189 hectares (467 acres). An estimated 3,606,000 cubic meters (4,717,000 cubic yards) of fill and 3,602,000 cubic meters (4,712,000 cubic yards) of excavation would be required to level the site and develop the desired drainage patterns. Most of the fill would be produced by excavation at the site, and approximately 4,000 cubic meters (5,000 cubic yards) would be collected off site.

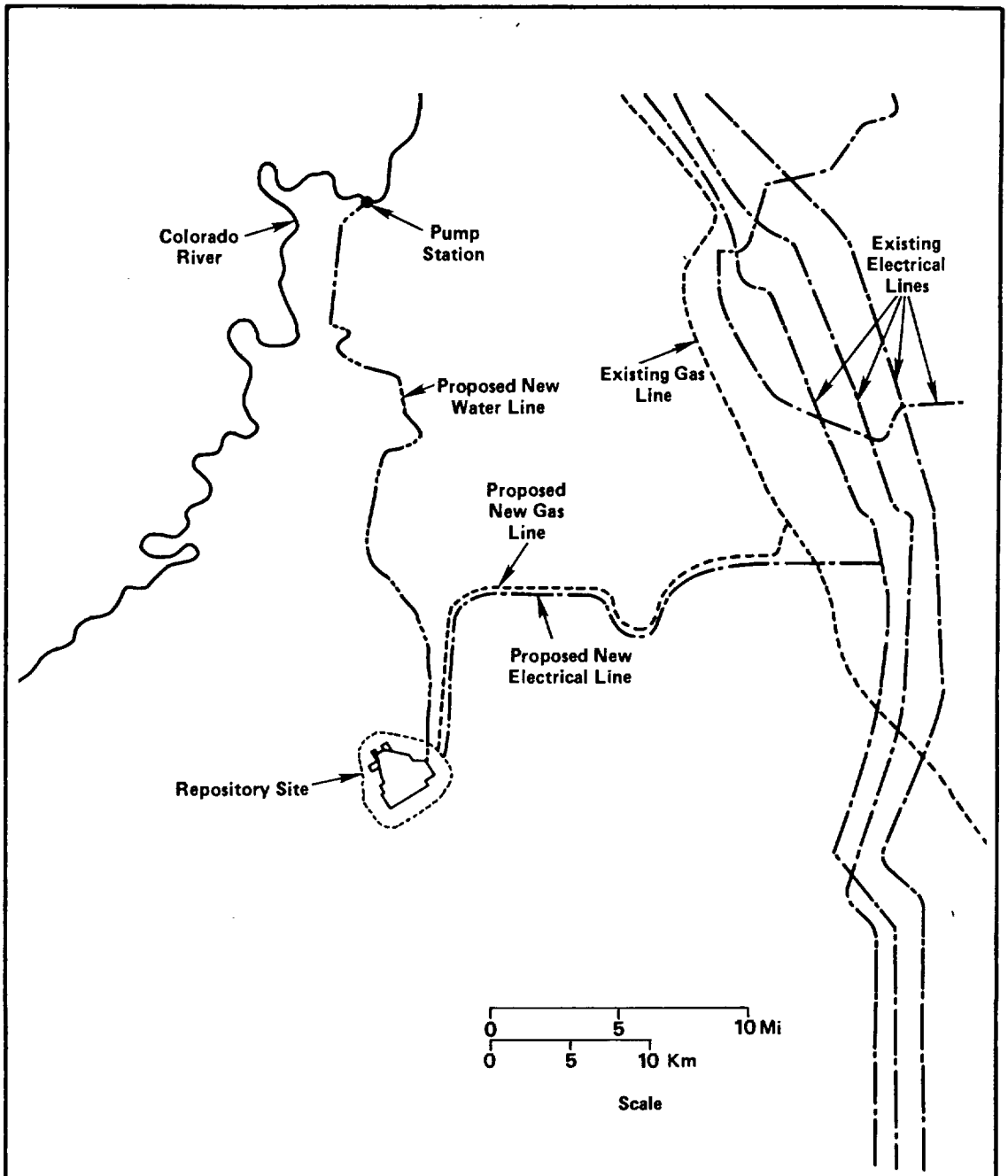
The primary excavated material storage area would be the salt stockpile containing approximately 2.95 million metric tons (3.254 million tons) of mined salt, which is the estimated maximum needed to backfill all open underground excavations at any time during the life of repository operations. The excavated salt would be mechanically conveyed to this 20.3-hectare (50.2-acre) area and stockpiled to an approximate height of 10.6 meters (34.7 feet).

Table 5-4. Paradox Basin Access Route Comparative Table, Davis Canyon Site

Parameter	Spanish Valley Route	Kane Spring Canyon Route	Colorado River Canyon Routes		Exclusive-Use Repository Access Road	Utah 211 Upgrade	
			Colorado River Canyon Route A	Colorado River Canyon Route B		Newspaper Rock Bypass	Utah 211 Realignment[a]
Length of new construction (miles)	54	47	38	39	25.2	0.9	0.2
Bridges:							
Number	13	18	13	18	8	2	1
Cumulative length (feet)	5,830	3350	8940	6690	2800	300	300
Height of highest (feet)	300+	100	100	180	100	25	60
Tunnels:							
Number	3	3	3	1	4	0	
Cumulative length (miles)	9.0	10.4	4.2	1.4	2.4[b]	0	0
Excavation volume (blasting surrogate) (thousand cubic yards)	903	1043	421	140	211	0	0
Ruling grade/required power (%/hp)	3/7200	3/7200	3/7200	3/7200	8/NA	8/NA	8/NA
Sharpest curve (radius/feet)	572	572	572	572	300	500	1300
Cut volume:							
Blasting surrogate (million cubic yards)	2.88	0.76	1.79	6.41	0.22	0.12	0+
Other (million cubic yards)	6.49	3.97	5.25	4.62	1.28	0.03	0+
Fill volume (million cubic yards)	9.40	5.66	6.48	12.92	3.30	0.11	0.06
Total surface area disturbed (acres)	764	589	609	680	366	12	2
Total water usage (construction) (million gallons)	114	69	79	157	40	1.5	0.7
Construction cost estimate ($mil)[c]	269[d]	233	157	142	79	2	3
Construction time estimate (months)	36	36	24	24	12	6	4

(a) Includes cost of Utah 211/U.S. 191 interchange; does not include Utah 211 widening and 3 lanes on grades and turnouts.
(b) Two highway tunnels with two parallel barrels each. Total barrel length = 2.4 miles.
(c) 1985 dollars: Land acquisition not included.
(d) Includes an allowance for relocating utilities and residences.

Source: BNI, 1985e.



Offsite Development – Davis Canyon Proposed Utility Connections to Repository Site

Source: BGI, 1982, ONWI-144.

Figure 5-10

Although it is not a standard practice in the salt industry to line salt storage areas, possible leaching of brine into the ground will be prevented through use of liners. These can be natural (clays) or synthetic materials (polyvinyl chloride, polyethylene, or polypropylene). Before emplacement of a liner, the existing topsoil would be stripped, the subsoil material would be excavated to a certain depth, and selected backfill materials would be placed and compacted to form a sound foundation subbase for the liner, and for the retention ponds and storage areas as a whole. Once the liner has been placed in the salt pile area, an additional layer of compacted backfill material would be placed on top of the liner. This added backfill would allow use of heavy construction equipment on the salt pile without fear of tearing or puncturing the liner.

When salt is exposed to the weather, a hard surface crust forms in a few days which tends to shed rainwater (Ver Planck, 1958; DOE, 1984a). According to the experience of the salt industry, stockpiled salt is not a source of windblown particles and crusting can be accelerated by wetting the pile. It is possible, however, that during salt handling, namely, transfer of the salt from hoist to rail cars or other conveyances, and salt pile buildup (pile working surface), salt particles may become windblown.

Three major retention ponds would be constructed. The first pond would serve as the salt pile runoff detention pond, which would be sized to hold a 100-year, 24-hour storm with an area of 4.2 hectares (10.3 acres). Because of the positive net evaporation rate in this region (evaporation exceeds precipitation), use of this pond and the other ponds for evaporation disposal of the storm water or wastewater is feasible.

The second major retention system will serve as the treated wastewater holding pond. This pond would be the collection point for all nonradioactive liquid wastes (e.g., cooling tower blowdown, sewage plant effluent, etc.) and would cover approximately 4.5 hectares (11.2 acres) of the repository site.

The third major pond would be the receiving point for other storm water runoff excluding the previously mentioned salt pile storage area. This storm water detention pond would cover approximately 5.1 hectares (12.7 acres) of the repository site and be sized to handle a 100-year, 24-hour storm event.

All three retention pond systems would be lined with a suitable material to prevent seepage of contaminated water into the ground. The lining of brine ponds is a common practice and has proven effective and reliable. Ponds as large as 50 acres are in use which are lined with, for example, 20-mil polyvinyl chloride on the bottom, where the plastic sheet is not reached by sunlight, and 30-mil hypalon (chlorosulfonated polyethylene) reinforced with nylon webbing on the sides, where the sheet is exposed to sunlight. It is a common practice to remove the existing topsoil before emplacement of the membrane and set in place a network of plastic pipes, perforated at the top, to be covered by compacted backfill material. These pipes perform a dual function: (1) they permit the escape through vertical side vents of gases which may collect under the lining, and (2) provide access to leachate samples for monitoring the effectiveness of the liner. Natural materials, such as brine-resistant clays, can also be used in place of the synthetic liners. Monitoring is performed as above. It is presently planned to provide a monitoring system for the retention ponds and storage area which would characterize atmospheric emissions, surface runoff, subsurface seepage, and soil disturbance interactions.

Onsite roadways, along with the onsite rail yards, will be constructed during this phase. Interior site roads will be crowned while the perimeter site roads would be sloped inward to contain all surface runoff.

Major buildings will be constructed of concrete and steel. Building areas which will confine radioactive materials will be designed to withstand a design basis earthquake, a design basis tornado, and other credible natural and human-induced events.

The waste handling and packaging facility is the largest building on the repository site and will encompass approximately 18,580 square meters (200,000 square feet) of ground floor

area. The tornado- and earthquake-resistant sections of the building will have walls and roofs constructed of thick reinforced concrete. All other areas of the building will be constructed of either steel or concrete.

It is estimated that 15,000 truck visits will be required to deliver concrete and steel, and approximately 9,000 truck visits will be needed to deliver other materials. The estimated total number of truck deliveries will be 24,000 at a rate of approximately 12 per day over the construction period. The number of passenger vehicles transporting personnel to the site during the peak construction year is estimated to be 769 per day.

5.1.2.4 Shafts and Facilities Development

All of the repository shafts will be excavated using conventional drill-and-blast methods. High ground-water flows and unstable-ground conditions above the salt are not expected.

Shaft linings will consist of concrete in the nonsalt rocks from the ground surface to a depth below the repository horizon. The linings will be cast in place behind the excavation as sinking progresses. Water seals will be placed where necessary to forestall interconnection between aquifers and to prevent ground water from passing downward along the shaft lining. For more detail of the shaft sinking process, see Section 4.1.2.

The scheduled sequence of shaft development will begin with the service shaft and ventilation supply shaft, allowing initial subsurface development to begin. The remaining three shafts will be completed concurrently with the initial subsurface development.

Individual shaft outfitting will immediately follow the shaft excavation and lining activities. Shaft outfitting would encompass the installation of the hoisting systems, utility conduit runs (such as electrical, communication, and others), instrumentation, and all other equipment necessary for the shaft systems to operate properly. The parallel effort on the surface would be the construction of the surface support facilities such as the shaft headframes, intake air filter buildings, exhaust air filter buildings, and related surface construction.

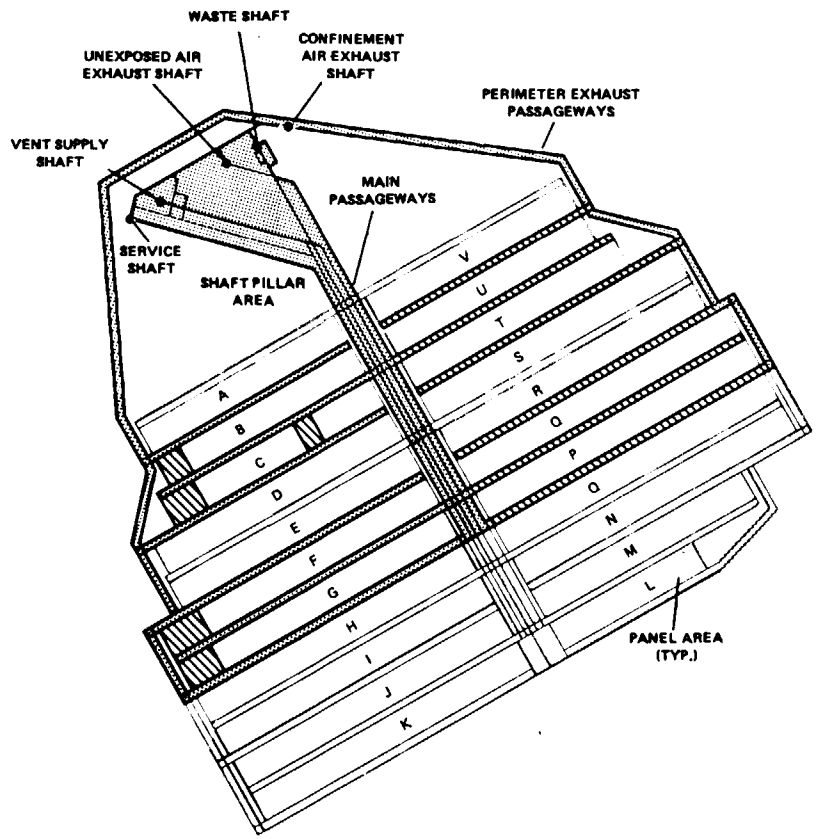
5.1.2.5 Subsurface Development

The repository reference design (SCC, 1984a) proposes that most subsurface excavation will be performed mechanically. The excavated salt will be transported by a haulage vehicle from the excavation face to a conveyor belt that will transport the salt to surge bins located near the service shaft. Conventional drill and blast excavation will be needed for the initial development of the shaft station areas. A feeder/breaker will be necessary to crush oversized rock prior to its placement on a conveyor system. Excavated salt in the surge bin would be loaded into the skips which would then hoist the material to the surface. From the service shaft headframe, the excavated salt would be mechanically conveyed to either the salt stockpile area for long-term storage, or to the railcar area for transport and eventual disposal off site as described in Section 5.1.3.

After an appropriate monitoring period storage rooms will be backfilled when waste has been emplaced. Backfilling will be accomplished by mechanically compacting and pneumatically stowing salt as backfill material. Branch and main passageways will also be backfilled soon after the associated waste emplacement rooms are backfilled.

The initial development phase of the repository subsurface will begin when the service shaft and ventilation supply shaft are completed. The subsurface excavation to be performed in this initial development phase is shown in Figure 5-11 and would include the following:

- Excavation of passageways in the shaft pillar area
- Excavation of the five main passageways to access all panels necessary for the various waste types in the first year of emplacement



UNDERGROUND STORAGE ROOM DEVELOPMENT INITIAL DEVELOPMENT PHASE		
PANEL	WASTE	NO. ROOMS
G	SF	10
F	SF	11
C	CHLW	7
C	DHLW	5
B	TRU	6

Explanation

- Previously developed
- Initial Development Phase

Scale

0 1000 2000 Feet

0 300 600 Meters

Source: Adapted from SCC, 1984a.

Underground Activities
Initial Development Phase
Davis Canyon

Figure 5-11

- Excavation of branch passageways, exhaust branch passageways and perimeter exhaust passageways, necessary for the first two years of emplacement

- Excavation of storage rooms required for the first year of waste emplacement

- Completion of the remaining three shafts.

Table 5-5 lists a summary of estimated excavation, reexcavation (scaling), and backfill quantities for the repository subsurface. Reexcavation of passageways is necessary due to the slow closure that occurs because of the plastic flow of the salt.

5.1.3 Repository Operation Activities

The start of repository operations will be marked by the granting of an operating license by the Nuclear Regulatory Commission (NRC) and waste emplacement period initiating nuclear waste receipt, packaging, and emplacement activities. The estimated operating life of the repository will be approximately 26 years, during which the waste emplacement activities will be completed. The number of employees required to operate the repository is shown in Table 5-2. Of this staff, approximately 20 percent will be directly involved in waste receiving, packaging, and emplacement operations; approximately 15 percent will be involved in underground mining operations; and the remaining 65 percent will be involved in administration, engineering, maintenance, security, and other support categories.

Estimated vehicular traffic during repository operation is given in Table 5-6. Upper limit shipping volumes for nuclear waste are based on the assumption that all shipments would be made by truck or rail in existing cask designs. However, it is expected that a large portion of the nuclear waste will come via rail and that future cask designs, both truck and rail, will have greater capacity. It is expected that both of these factors will markedly reduce nuclear waste shipment traffic.

In addition to the incoming nuclear waste, the repository facility would also receive waste packaging material and additional equipment and materials to service the facility.

The estimated quantity of excess salt to be disposed of over the operating period of the repository is given in Table 5-5. A specific method for permanent disposal of excess salt has not been selected. This will be accomplished as part of the site-specific, conceptual design for a repository in salt, which cannot be initiated until the President approves a salt site for site characterization. Several feasible candidate methods for salt disposal do exist and will be evaluated during conceptual design. These methods are discussed in Section 5.1.3.4, Salt Disposal, and a representative disposal method is selected, and its impacts evaluated, in Section 5.3.5.

The Mine Safety and Health Administration (MSHA) is authorized to administer and enforce certain kinds of safety and health standards for protecting employees in the mining industry, pursuant to the "Mine Safety and Health Act of 1977" (30 USC Secs. 801 et seq.). The role of MSHA in the repository program has not been fully determined. However, principal design, construction, and operating features include provision for worker protection by following the relevant requirements of "Safety and Health Standards - Metal and Non-Metal Underground Mines" 30 CFR Part 57.

Moreover, 10 CFR 60.131(b)(9) states that the design of the geologic repository operations area shall include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions.

The repository design will therefore consider the following relevant design requirements stated in three subchapters of 30 CFR Part 57, Chapter I:

- Subchapter D - Electrical Equipment, Lamps, Methane Detectors; Tests for Permissibility Fees

Table 5-5. Summary of Excavation Quantities (all values in tons)

	Construction	Operation/Decommissioning	Total
Passageways	5,533,000	4,391,000	9,924,000
Storage Rooms	362,000	12,033,000	12,395,000
Shafts	626,000	0	626,000
Miscellaneous	69,000	0	69,000
Subtotal Initial Excavation	6,590,000	16,424,000	23,014,000
Scaling	0	69,000	69,000
Total Excavation	6,590,000	16,493,000	23,083,000
Tons Required for Backfill	-0	-13,418,000	-13,418,000
Excess Mined Rock	6,590,000	3,075,000	9,665,000

Source: SCC, 1984a.

Table 5-6. Typical Vehicular Traffic Volume During Repository Operations[a]

Vehicles	Frequency
Rail Cars	
Nuclear[b]	15/week
Salt	52/week
Supplies	4/week
Truck	
Nuclear[b]	19/week
Salt	None
Supplies	270/week
Passenger Vehicles	500/day

(a) Assumed for design purposes; see Section 5.3 for analyses of transportation scenarios.

(b) The majority of the nuclear waste material would be transported to the site by rail car. A total of approximately 15 rail cars per week make the trip using various rail routes to the site. The repository could also accommodate the processing of 19 truck loads of nuclear waste per week.

Source: SCC, 1984b.

- Subchapter E - Mechanical Equipment for Mines; Tests for Permissibility and Suitability; Fees

- Subchapter N - Metal and Non-Metallic Mine Safety and Health.

Specific areas of interest in maintaining occupational safety during mining include the following:

- Mining methods
- Fire prevention and control
- Working environment
- Ventilation systems
- Materials handling and storage
- Underground utility systems
- Occupational safety programs and personnel protection
- Emergency plans
- Inspection, testing, and maintenance.

The Occupational Safety and Health Administration (OSHA) administers the "Occupational Safety and Health Act of 1970" (29 CFR Part 1910). The purpose of OSHA is to establish standards with which industries are generally familiar, and on whose adoption interested and affected persons have already had an opportunity to express their views. Such standards are either (1) National consensus standards whose adoption by affected persons have reached substantial agreement, or (2) Federal standards already established by Federal statutes or regulations. The DOE will utilize, as applicable, the OSHA regulations, in particular, "Occupational Safety and Health Standards" (29 CFR Part 1910), and "Safety and Health Regulations for Construction" (29 CFR Part 1926).

Predictions of worker injury and fatality rates during salt mining operations at a repository are given in Section 4.1.2.2. Table 5-7 indicates possible injury and fatality rates to be expected during waste handling operations. Actual expected injuries cannot be predicted until repository designs are final.

5.1.3.1 Surface Waste-Handling and Packaging Operations

The estimated nominal design capacity of the reference repository design would be 72,000 metric tons of heavy metal (MTHM) (79,200 tons) in the form of spent fuel and commercial high-level waste (CHLW). Additionally, the repository has been designed to accommodate 3,510 MTHM (3,869 tons) of defense high-level waste (DHLW). The waste receiving rates for each waste form comprising this nominal capacity are plotted in Figure 5-12.

The anticipated sequence of repository operations would begin when the waste form has arrived at the repository by rail or truck in an approved, licensed shipping container. Notification of shipment would have been received and approved earlier so that receipt, handling, and emplacement operations for this waste shipment would be integrated into the overall repository operations schedule.

At the repository security entrance, the shipping documents would be verified. Preliminary inspection of the shipping cask and carrier vehicle would then be performed. The shipping cask and carrier vehicle would then be moved into the repository facility area to the inspection station where they would be thoroughly checked for condition, including checking for sabotage, the structural condition, and the surface contamination level. Based on the results of these inspections, the cask and vehicle would then be moved to either the isolation bunker or the WHPF.

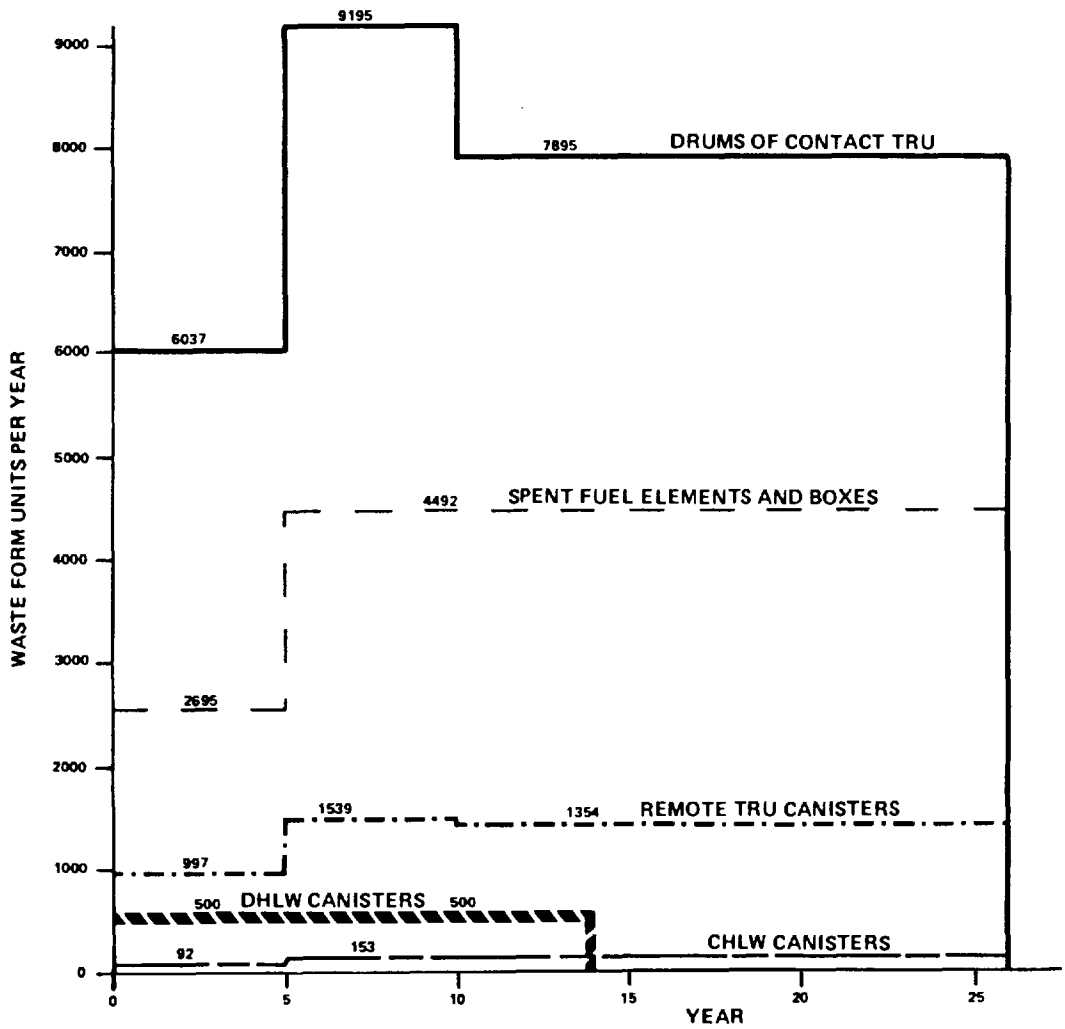
At the WHPF, the cask and vehicle would be moved to the cask cleaning and decontamination area where the exterior of the cask and vehicle would be cleaned to remove road dirt and any contamination. The cask and vehicle would then be moved into the receiving and packaging facility where the cask would be unloaded from the vehicle.

Table 5-7. Atomic Energy Commission Injury and Fatality Incidence Rates, 1943 to 1975[a]

	Lost-time Injuries per Million Work-Hours[c]	Fatalities per Million Work-Hours[c]
Construction	5.24	0.117
Operations	2.01	0.024
Overall[b]	2.75	0.046
Since 1958	2.2	

(a) Total work-hours for repository construction, 17,500,000. Total work-hours for repository operation, 52,000,000.
(b) Overall = weighted average based on total number of work-hours for each category.
(c) Derived from injury incidence rates by multiplying injury incidence rates by ratios of fatalities to injuries.

Source: AEC, 1975.



Input to Packaging Facility
Davis Canyon

Source: Adapted from SCC, 1984a.

Figure 5-12

The shipping cask would then be moved to the cask preparation station to be prepared for the removal of the waste. The shipping cask would be positioned under the waste transfer port and the cask lid would be removed. The waste would then be removed from the cask, inspected, and transferred either to temporary storage or directly into the packaging hot cells. The cask lid would then be replaced and the shipping cask prepared for loading back onto the carrier vehicle. After loading, the cask and vehicle would be dispatched from the WHPF area to await movement off site.

The waste form would enter the hot cells either directly from the shipping cask or from the temporary storage area. Depending on the form of the waste, additional operations may be performed in the hot cells. For spent fuel, the waste form would move into the disassembly station where the fuel pins would be removed from the fuel assembly or box, consolidated, and placed into a waste package canister. This spent fuel waste package canister or the CHLW and DHLW canisters would then be moved to the packaging station where they would be placed inside of the thick-walled container and the container lid would be installed. The waste package would then move to the inspection station where the lid closure weld would be nondestructively examined, the surface contamination level checked, and appropriate identification numbers verified and recorded.

Remote TRU would be inspected without repackaging and passed through the hot cell to the transfer cask station. Contact TRU would be assembled onto 12-drum pallets which would then be loaded directly by forklift into the waste shaft hoist cage. At this point, it would be lowered to the repository subsurface level.

At the transfer cask station, the waste package would be loaded into the transfer cask (a heavy, shielded container similar to a shipping cask) through a transfer port with the transfer cask located outside of the hot cell. The transfer cask containing the waste package would then be moved to the waste shaft hoist. The transfer cask would then be loaded onto the hoist cage, lowered to the repository subsurface level, and unloaded onto an underground transporter. At this point, subsurface operations would begin.

Requirements for waste storage on the surface are established in "Generic Requirements for a Mined Geologic Disposal System" (DOE, 1984, DOE/NE/44301-1). A temporary storage capacity equivalent of 3 months waste receipts will be provided in order to minimize the effects of scheduled or unscheduled interruptions in repository operations. This requirement is subject to change if the MRS is developed and will depend upon the established role of the MRS facility in the disposal scheme.

5.1.3.2 Subsurface Waste-Handling Operations

Subsurface waste emplacement operations would begin upon completion of the initial development phase. During this first year of operation, the room excavation operations would be moved to the side of the main passageways opposite the emplacement operations.

Once the waste package transfer cask is unloaded from the hoist onto a subsurface transporter, the transporter would move the waste in the transfer cask to the designated storage room and position the cask over the vertical borehole in the storage room floor. This vertical borehole and other waste storage room emplacement preparations would have been performed prior to starting emplacement operations in that storage room. Once over the borehole, the bottom of the transfer cask would be opened and the waste package lowered into the borehole. The borehole would then be backfilled with crushed salt to storage room floor level. The transporter would then carry the empty transfer cask back to the hoist where the transfer cask would be loaded onto the empty hoist cage for transfer to the surface and reuse. The underground transporter then would be available to transport the next loaded transfer cask.

5.1.3.3 Retrievability

Section 122 of the Nuclear Waste Policy Act of 1982 (NWPA) mandates that the repository shall be designed and constructed to permit retrieval of any spent fuel emplaced in the repository during an appropriate period of operation of the facility. The reasons for such

retrieval, as per the NWPA, may pertain to public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel.

The Civilian Radioactive Waste management (CRWM) program's position on the issue of retrievability is that the repository be designed, constructed, and operated so that the capability to retrieve the previously emplaced waste package is retained. This condition will be maintained until the satisfactory completion of a performance confirmation program as stipulated by the NRC's 10 CFR 60.111 and decommissioning activities are authorized by the NRC.

In accordance with the NWPA and 10 CFR Part 60, the geologic repository operations area will be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a longer or shorter time period is specified by the Secretary (DOE) and approved by the NRC. For design purposes, it is assumed that the actual retrieval, if retrieval proves to be necessary, would take as long as approximately the period used for waste emplacement and repository construction. This length of time is consistent with the NRC's provision in 10 CFR 60.111, in which public health and safety considerations are of primary importance in any waste retrieval operation.

The capability to retrieve the waste packages would be demonstrated prior to a decision to backfill the waste package storage rooms and would be maintained regardless of whether the storage rooms have been backfilled. Therefore, the decision to backfill would be based on an evaluation of the advantages of early backfilling versus the disadvantages of increased difficulty of retrieval.

The Department of Energy has, during the summer of 1985, developed a position on retrievability to fully describe and document all design, construction, operation, and maintenance equipment requirements associated with retrievability. An evaluation of the effects of these requirements on the repository design and the associated equipment needs has not been completed at this early stage in the repository design process. These retrieval effects will be analyzed and addressed during the site characterization period and subsequent design phases supporting the license application.

5.1.3.4 Salt Disposal

As the result of mining activities, approximately 8.8 million metric tons (9.665 million tons) of salt mineral will require disposal. The excess salt and salt-laden material brought to the surface during repository construction and operation could be disposed of in the following ways:

- Onsite disposal
- Commercial market
- Ocean disposal
- Great Salt Lake disposal
- Mine disposal
- Offsite (surface) disposal.

Selection of the disposal option will be based on a comparative evaluation of the advantages and disadvantages of all options suitable for a given site. A principal factor in such an evaluation be would the potential for environmental impact. Knowledge gained from testing and experimentation during the site characterization phase will be incorporated in repository design, and will be applied to salt management during repository operations to limit impacts. The primary consideration will be assurance that the quality of the environment in the affected area during this and future generations will be adequately protected in accordance with the criteria set forth in the siting guidelines, especially 10 CFR 960.5-2-5, Environmental Quality. Transportation, with its potential impacts and costs, also will be a significant factor in the evaluation but will be given less weight than environmental impact.

While the repository program has not advanced to the point where the final selection of a disposal method can be made using data specific to the selected site, the significant impacts of the options at potential sites can be reliably anticipated at this time. The following sections summarize the salient features of each option.

5.1.3.4.1 Onsite Disposal. Onsite disposal will require the constructon of a large surface storage area. It would be underlaid and covered by impervious materials.

5.1.3.4.2 Commercial Market. Excavated salt will either be supplied through the General Services Administration (GSA) to buyers or governmental agencies "as is" or after some onsite processing. Because the salt will be removed from the repository site, there will be no potential for long-term impact. Potential for short-term impacts will be limited in duration to the operating period of the repository, and in magnitude to those of a commercial salt production facility.

Because transportation costs may exceed the market price of the salt, the DOE may have to subsidize the sale. The feasibility of this alternative is not fully developed.

5.1.3.4.3 Ocean Disposal. The excess salt could be converted into brine and could be dispersed in ocean waters through outfalls. Disposal of brine would require a significant quantity of fresh water. In addition, transport of either the brine or the solid material from the site to the disposal point would be required.

5.1.3.4.4 Disposal in Great Salt Lake. Excess salt can be transported to the Great Salt Lake and discharged into the lake. Chemical companies are at present withdrawing lake water, extracting potassium and magnesium compounds, and returning concentrated brine to the lake. The amounts of salt disposed of commercially per year are larger than the amounts expected to be disposed of for the repository project.

5.1.3.4.5 Mine Disposal. Excess salt would be transported by rail to existing evaporite mines, transferred underground via a closed conveyor system, and packed into unused sections of the mines. There would be no expected long-term impacts associated with this option.

5.1.3.4.6 Offsite (Surface) Disposal. The disposed salt would be blended into a natural environment composed of evaporite materials, alkali flats and dried saline lake beds, very similar in composition to the material being disposed of.

5.1.3.4.7 Choice of Mine Disposal as Representative Method. The supporting studies for this section identify mine disposal as being environmentally benign and technically feasible. Numerous evaporate mines were available (SCC, 1984a) with capacity to accept waste salt. This study provides assurance that multiple mines with sufficient capacity are available should this alternative be exercised.

Tentative mine sites have been identified within a few hundred miles of the repository site. The resulting transportation costs are relatively modest. This option is the representative disposal option.

Detailed discussion of salt disposal alternatives other than mine disposal are not presented here.

Impacts of the mine disposal option are transportation related, and appear in Section 5.3.5, Salt Disposal.

5.1.3.4.8 Description of Activities Related to Salt Management Method. A general description of the physical activities likely to be performed at the repository site was performed by SCC (1985a). This discussion addressed activities at the disposal site if the salt disposal method selected were to be disposal in an existing mine. Several of these activities are general and would be applicable to other disposal methods.

Salt handling at the repository site. The excavated salt is brought to the surface by the skip hoisting system. The skips discharge into a surge bin near the headframe, and the salt is then conveyed from the surge bin to the site salt stockpile or, if excess salt, to the railroad loadout area.

The excess salt is loaded into railroad cars for shipment to the excess salt disposal site. The handling, loading, unloading, and transporting of salt at the repository and at the excess salt disposal site are performed in a manner to reduce air-borne particulates which avoid adverse impacts to surrounding environments. As far as practical, conveyors, transfer points, and loadout structures will be enclosed and equipped with dust collection equipment to minimize impacts on the environment.

Salt handling at the disposal site. A possible excess salt disposal location for the Davis Canyon site is the Carlsbad area of New Mexico. The excess salt is dumped from the railroad cars into a track hopper and the salt is transported underground into an existing evaporite mine using one of several available conventional materials handling designs. The salt is placed as a backfill in the previously mined rooms.

5.1.3.5 Treatment and Disposal of Other Repository-Generated Wastes

Liquid and solid wastes generated by repository operations are collected and treated on site and disposed of in an appropriate manner. Treatment and disposal is in compliance with applicable local, State, and Federal regulations.

Sanitary wastes are collected and transferred to the waste water treatment facilities by a site sanitary sewage system. The sanitary waste treatment facilities are a packaged system that utilizes both primary and secondary treatment to remove 85 percent to 95 percent of the 5-day biochemical oxygen demand (BOD) and a similar range of suspended solids. Following treatment, liquid effluents are discharged into the treated waste water pond.

Industrial wastes such as used lubricating oil, laboratory chemicals, and nonradioactive cleaning solutions will be collected at the source. Most or all of these wastes will be transported off site to commercial disposal sites or recycling centers. Hazardous industrial wastes will be disposed of at offsite commercial facilities specifically designed for the purpose.

Radiological wastes consist of items generated on site in the course of normal operations; for example, used high-efficiency particulate air (HEPA) filters, anti-contamination clothing, contamination test swipes, and solutions used to remove radioactive contamination. Solid radiological wastes are collected at the source, packaged as contact handled transuranic waste (TRU), and disposed of in the repository. Liquid radiological wastes are collected at the source and taken to the waste water treatment facility in a drain system that is entirely separate from the sanitary sewer system. Radioactive liquid and solid waste system capacities are listed in Table 5-1. All inaccessible radiological waste piping is double-walled to preclude undetected leaks. These radiological waste liquids are solidified on site and packaged as contact handled TRU wastes.

All the ponds (storm water detention, salt stockpile runoff and treated waste water) are designed to contain the inflow from a 100-year or greater, 24-hour storm event. The ponds, when full, will have spillways with the capacity to safely discharge a storm of greater magnitude without overtopping the embankment. All ponds will have an essentially impervious lining to prevent seepage of pond water into the underground aquifer. Each pond will contain facilities to monitor storm water and other effluents from the plant and evaluate them for radioactive and nonradioactive pollutants before being discharged to the existing natural surface drainage courses outside the repository. The total areas of the ponds are listed in Table 5-1.

5.1.4 Decommissioning and Decontamination

After the operational phase, the repository would be decommissioned and decontaminated (D&D). Detailed D&D plans would be developed and provided with the NRC construction application. Although future D&D requirements may differ from current requirements, the general philosophy is to restore the repository site as closely as possible to original site conditions and to completely backfill the underground facilities in order to seal the drifts, haulageways, and shafts. During this period, the radioactively contaminated portions of the waste handling facilities could be cut up, packaged, and placed in the repository subsurface. The remaining open areas of the repository subsurface would be backfilled and sealed using the originally excavated salt material stored on site. The surface facilities would be dismantled and the surface area restored to final reclamation grade. Shaft backfilling would comprise salt and selected materials with seal plugs at predesigned depths.

5.1.4.1 Surface Activities

Decommissioning operations would include decontamination and dismantling of the surface facilities and restoration of the site area to the final reclamation grade, and seeding, if appropriate. Mechanical and chemical decontamination methods would be used to remove radioactive contamination from the WHPF and its support facilities. Contaminated material, not capable of being decontaminated, will be transferred to the subsurface drift areas for emplacement. A final radiation survey of the surface facilities will be performed to ensure that all areas are below radiation levels that allow for unrestricted public access.

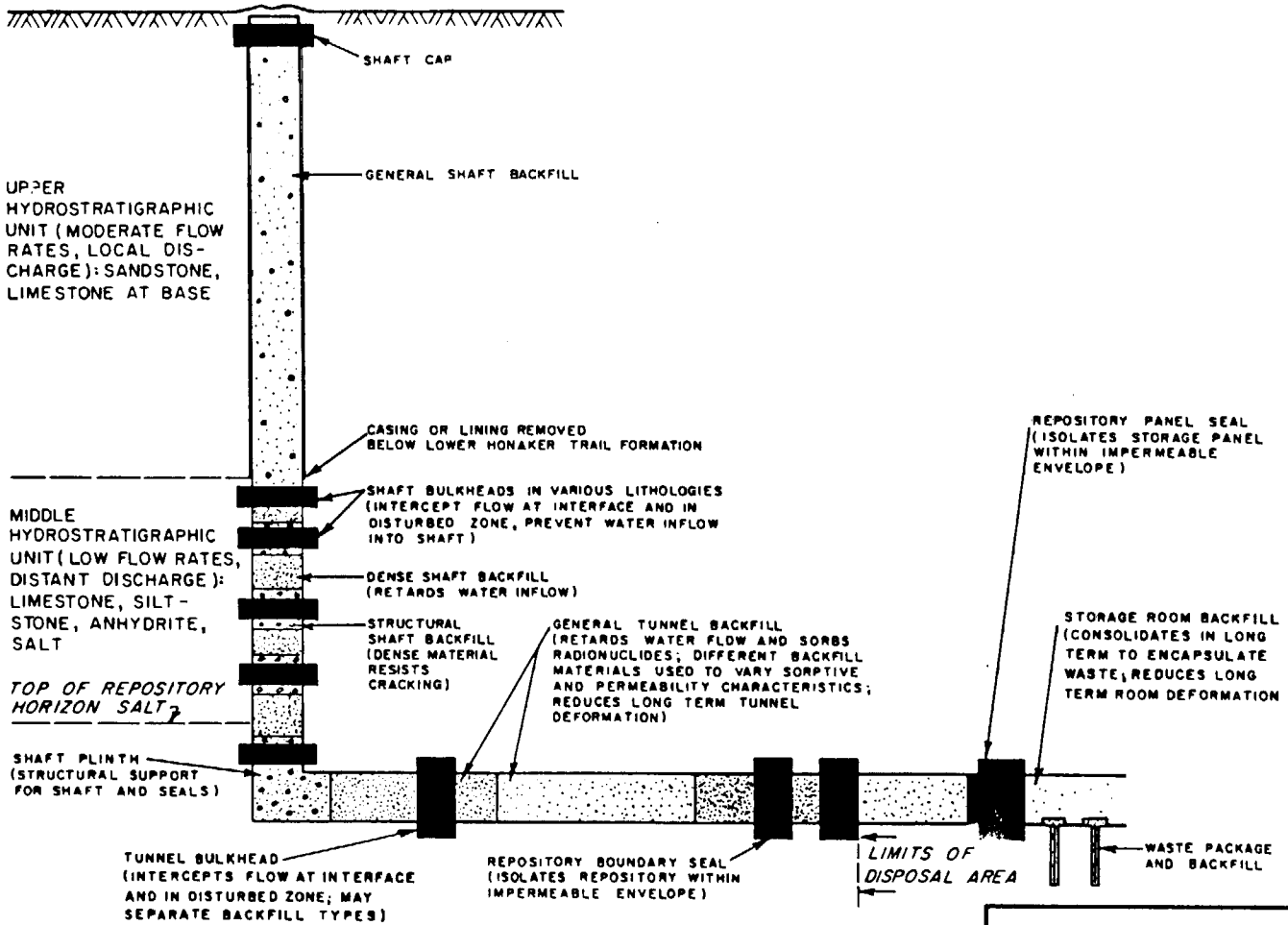
5.1.4.2 Subsurface Activities

After all contaminated materials from surface decommissioning and decontamination are emplaced underground, the repository subsurface facilities will be closed by installing a repository sealing system. The repository seals will consist of subsystems to seal the rooms, drifts and passageways; the shafts; and the boreholes. The repository sealing system components will be designed to withstand the effects of design basis seismic events, anticipated thermal conditions, and expected ground swell or subsidence without unacceptable loss of function. A schematic diagram of the sealing system is shown on Figure 5-13. A comprehensive description of the repository sealing system design and materials studies is contained in Kelsall et al. (1985, BMI/ONWI-563). The sealing system will meet or exceed any applicable State requirements for plugging mine shafts or wells.

5.1.4.2.1 Room, Drift, and Passageway Seals. The bulk of the horizontal openings will be filled with a crushed salt backfill, which under the stress and heat conditions will ultimately (tens to hundreds of years) reform into a solid mass of salt similar to the preemplacement conditions. Groups of rooms, referred to as panels, will be isolated with precompressed salt blocks installed as masonry walls to provide isolation while the crushed salt is compacting. In the passageways connecting the shafts to the main disposal area, multiple concrete bulkheads will be installed. Portions of the drift between concrete bulkheads will be backfilled with an earthen material to provide redundancy.

5.1.4.2.2 Shaft Seals. After the passageways connecting the shafts have been sealed, the base of the shaft will be filled with structural concrete to support the loads imposed by the shaft sealing materials. Most of the shaft volume will be backfilled with the following: crushed salt (in salt horizons only); dense earthen material, a mixture of clay and locally available materials; or general backfill, locally available material such as that removed during shaft sinking. At selected locations along the shaft, bulkheads will be constructed as shown on Figure 5-14.

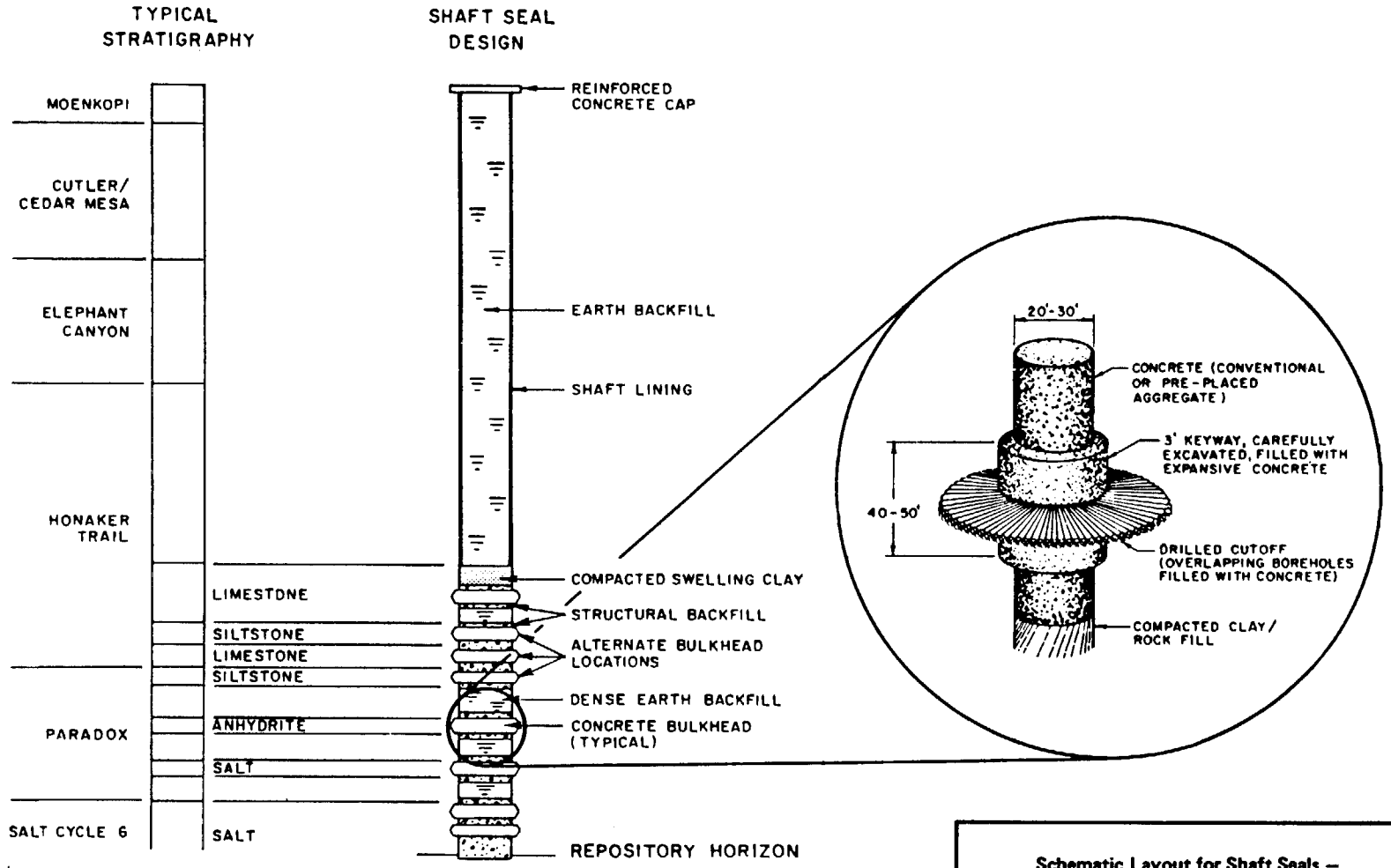
The shaft lining will be removed at these bulkhead locations. These bulkheads will extend into the rock around the shaft to intercept and seal any fracture areas created by the sinking of the shaft and prevent the transport of water outside of the sealed shaft. At the top of the shaft, a shaft-cap of concrete will be placed.



Source: Adapted from Kelsall et al., 1985, BMI/ONWI-563.

Repository Sealing System Schematic — Paradox Basin Repository

Figure 5-13



NOTE

BULKHEAD NUMBER AND LOCATIONS TO BE DETERMINED ACCORDING TO ACTUAL STRATIGRAPHY

Source: Adapted from Kelsall et al., 1985, BMI/ONWI-563.

Schematic Layout for Shaft Seals – Paradox Basin

Figure 5-14

5.1.4.2.3 Borehole Seals. Boreholes from the surface will be plugged as shown on Figure 5-15. Cement grout will be the primary constituent of the seal with a clay layer for material redundancy. Where necessary to seal behind the borehole casing, the casing can be perforated using oil field tools and grout squeezed through the holes into the formation.

5.1.4.3 Salt and Nonnuclear Waste Disposal

Water in the salt pile retention pond will be allowed to evaporate, the liner and salt-contaminated materials will be removed, and the depression will be backfilled to final reclamation grade. Most of the salt in the surface stockpile would be used to backfill subsurface facilities. Salt remaining after this operation will be transported from the repository site and disposed of in a manner similar to the excess salt disposal method used during repository operations.

5.1.4.4 Labor Force

Decommissioning activities will resemble those of the construction phase and require personnel for dismantling, backfilling, and beginning ground surface restoration procedures. The size of the decommissioning-phase labor force would be smaller than the operations labor force, as shown in Table 5-2.

5.1.5 Postclosure Activities

Following the closure of the subsurface areas and decommissioning of the surface facilities, the repository would enter the postclosure phase. Generally, activities at the site would be those necessary for (1) active prevention against repository intrusion, (2) passive prevention against underground intrusion, and (3) possible active monitoring of repository conditions.

5.1.5.1 Active Prevention

At the time of repository closure, the DOE would own surface and subsurface title to the controlled area. After closure, the DOE will maintain an institutional barrier into the foreseeable future. This arrangement will provide active institutional barriers to subsurface exploration that have the potential for affecting the repository.

5.1.5.2 Passive Prevention

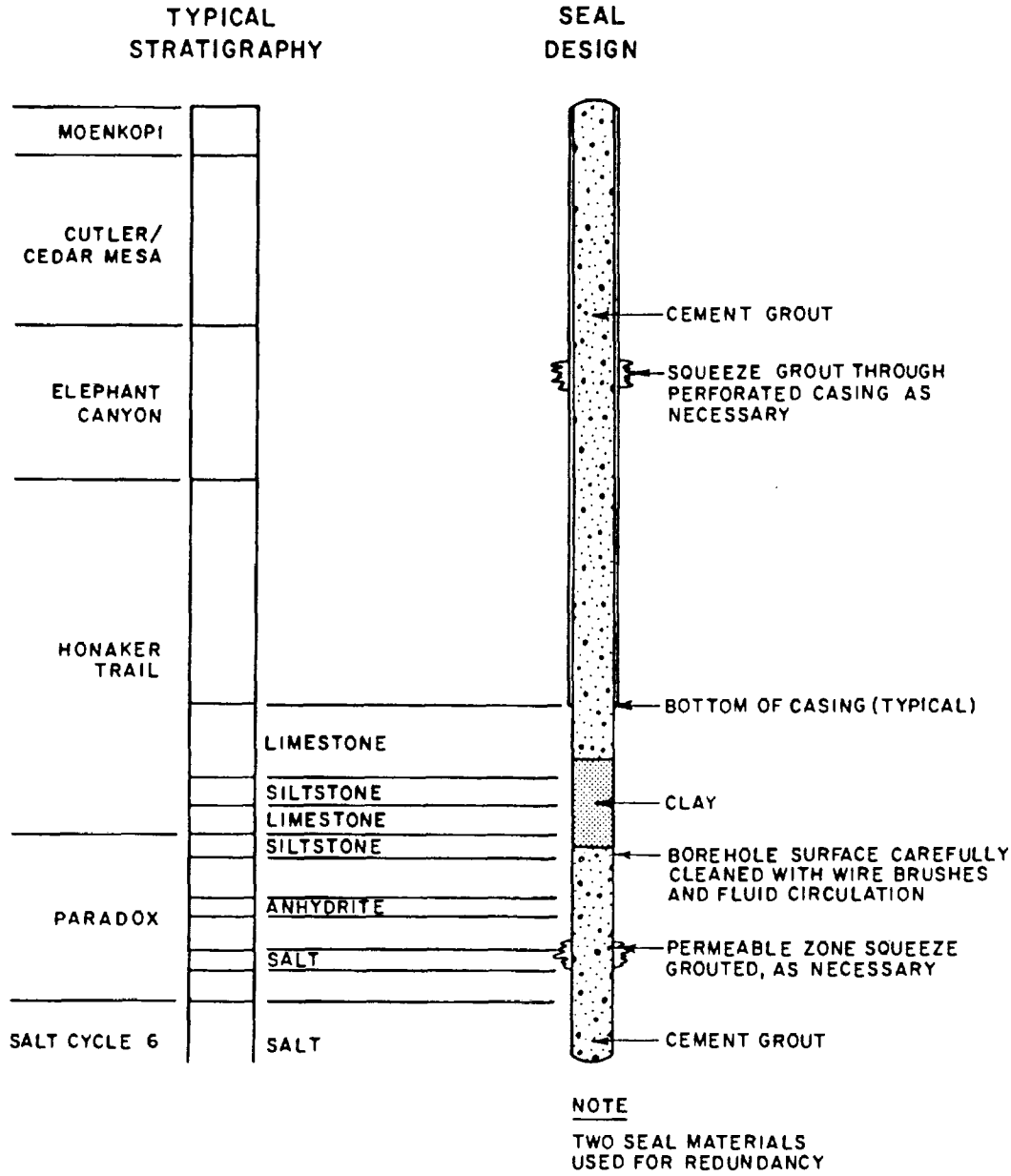
It is possible that institutional barriers and systems of record-keeping and updating may fail in the future. For this reason, a passive barrier system will be used to notify future societies with the technology to excavate or drill to the repository level about the hazards below the surface.

Numerous options for passive barriers being considered by the DOE are listed below (Kaplan, 1982, ONWI-354; Berry, 1983, ONWI-474).

1. A set of 3- to 9-meter (10- to 30-foot)-high peripheral markers may be placed surrounding the outer control zone (the land owned by the DOE). These probably would be monolithic and shaped like tall pyramids. Simple warning symbols will be cast into each face. The markers would be spaced so that a person standing at a given point on the perimeter would be able to view at least two markers.

2. A monument may be created and located over the center of the repository area. This marker would probably be pyramidal in shape and large enough to contain an internal area for accommodating details of the construction and hazards in the subsurface repository.

3. Earthworks large enough to be discernible by site visitors would probably be created. These would probably be constructed around the central monument in the form of warning symbols.



Schematic Design for Sealing Vertical Boreholes in the Paradox Basin

Source: Adapted from Kelsall et al., 1985, BMI/ONWI-563.

Figure 5-15

4. A redundant set of warning symbols may be placed into the ground by tilling magnetite or some other site-anomalous material below the soil surface. These symbols, which may be quite large, would not be apparent to the eye but would be detectable by simple instruments.

The option most likely to be implemented is a set of markers.

5.1.5.3 Active Monitoring

While postclosure monitoring requirements have not been established by the NRC, it is possible that such requirements will be instituted. If postclosure monitoring is required, the DOE would probably retain a small technical staff and one of the small repository building.

5.2 EXPECTED EFFECTS ON THE PHYSICAL ENVIRONMENT

This section addresses the geologic, hydrologic, and environmental effects that are expected to result from locating a repository in Davis Canyon. In addition to the brief discussion in this section, impacts of transportation access-route construction and transportation operations are addressed in more detail in Sections 5.3.2 and 5.3.3. The effects are based on the engineering feasibility studies for constructing and operating a repository at candidate salt sites (SCC, 1984a). This design is currently undergoing revision (Section 5.5) and some impacts could change. However, as indicated in Section 5.5, it is not expected that these design modifications would significantly increase environmental impacts. An impact analysis will be presented in the final environmental impact statement (EIS) if this site is recommended for the repository.

5.2.1 Geologic Conditions

Potential geologic effects on the geology are expected to be limited to local, minor subsidence or uplift of the surface over the repository. As discussed below, these effects should be within allowable limits and any resulting impacts should have acceptable environmental consequences. No other known or expected geologic conditions would be adversely affected by repository construction and operation. Impacts on the lithology and structure of the salt horizon and surrounding sediments are not expected. There will be no significant losses or modification of strata and rock other than the rock and salt actually removed in the process of underground development.

Minor subsidence of the surface may result from subsurface excavation of salt and rock for repository development. Theoretical studies (Weart, 1983, SAND83-0450, p. 18) conclude that salt extracted at the Waste Isolation Pilot Plant (WIPP) site in New Mexico will result in subsidence not exceeding 0.3 meter (1 foot). Subsidence at the Davis Canyon site is expected to be of similar magnitude, because construction techniques, salt extraction ratios, and repository depth would be similar to that of the WIPP site. This magnitude of subsidence is small and is not expected to significantly affect topography, alter ground-water or surface-water flow patterns, or result in the development of major discontinuities. Furthermore, operating procedures call for mechanically backfilling and pneumatically compacting the salt into the chambers, shafts, and drifts as the storage process proceeds. This will reduce void space in the underground openings by 65 percent and further reduce the potential for subsidence.

Once the site has been licensed, the repository design calls for heat-producing radioactive waste to be placed in boreholes drilled into the floor of the underground chambers. Long-term thermal expansion of salt and surrounding strata is expected to cause uplift of the surface. Theoretical studies performed at WIPP suggest that uplift from the waste will be less than 50 centimeters (1.5 feet) over 2,000 years, decreasing to one half of this level after about 6,300 years and decreasing by half again after 16,500 years (Maxwell et al., 1980, SAND79-7111, p. 25). Modeling studies for the Paradox Basin site suggest that thermally induced uplift will be less than 1 meter (3.2 feet) after 1,000 years, decreasing thereafter (Svalstad and Wagner, 1982, pp. 150-152). At the site, the uplift is expected to decrease to

0 within a 3 to 5-kilometer (2 to 3-mile) radius, indicating a maximum change in surface gradient of about 0.03 centimeter per meter (0.004 inch per foot). Because uplift activity spans thousands of years and decreases progressively after about 1,000 years at the site, it should not significantly affect surface drainage gradients or ground-water flow patterns, nor is it expected to reactivate fault structures. Such a minor uplift, spread over a large area and occurring over a long period of time, should not cause major discontinuities in the bedded salt or overlying sediment, which would provide possible pathways for ground-water intrusion. This is substantiated by the DOE (1981, DOE/NWTS-147[2]) and Russell (1979), who found that vertical uplift caused by heating of a repository could be as much as 3 meters (10 feet) and not cause environmental concerns. Data are not sufficient to determine which type of movement (subsidence or uplift) will dominate at any particular time. They are compensating effects, however, and could result in little or no long-term net change in surface elevation.

The interbed between Salt Cycles 5 and 6 contains small amounts of kerogen. Based on pyrolysis analyses from the GD-1 corehole, Hite (1983, Fig. 17) shows that the potential amounts of hydrocarbons in the interbed range up to about 0.004 milliliter per kilogram (1.0 gallon per ton). Hite (1983, Table 3) also reports the amount of organic carbon in the same interbed ranging between 0.11 and 1.41 weight percent, and the amount of hydrocarbons which can be volatilized at 200 to 250 C (392 to 482 F) ranging between 0.030 to 2.909 milligrams of hydrocarbon per gram of organic carbon. The temperature at the salt-overpack interface reaches a maximum of approximately 235 C (455 F) about 10 years after emplacement of commercial high-level waste (CHLW) (Figure 6-6). From this, McNulty (1984) calculated that the maximum 100 C (212 F) isotherm will be reached approximately 50 years after waste emplacement at a distance of about 20 meters (66 feet) above the waste package. Since the salt bed thickness is a minimum of 52 meters (172 feet) and the waste packages will be located in the lower one-half of the salt bed, the 100 C (212 F) isotherm will occur in the salt rather than in the interbed. Hence, interbed temperatures will always be below 100 C (212 F), which is well below the 200 to 250 C (392 to 482 F) needed to generate the amounts of hydrocarbons quoted by Hite (1983, Table 3). Furthermore, the heat impact from the emplaced waste lasts only about 10,000 years, after which the temperature of the salt will return almost to its initial temperature of about 30 C (86 F). This heating period is short relative to the natural heating episodes that produce natural gas and petroleum. Based on the data presented here, any additional overpressuring caused by heat from the emplaced waste is expected to have a minor effect. Since this interbed will have been penetrated by the exploratory shafts and boreholes and subjected to detailed characterization, this may allow for bleeding-off of any overpressures encountered.

The carnallite marker bed, overlying the potential repository horizon, is approximately 40.8 meters (134 feet) thick, based on measurements in the GD-1 corehole which is 5 kilometers (3 miles) north of the site. This marker bed is made up of thin layers of carnallite within the massive halite and averages 2.4 weight percent of carnallite. However, according to Hite (1982, p. 7, Figure 2a) the proposed repository lies outside of the depositional limit of potash salts. Consequently, Salt Cycle 6 should contain lower concentrations of carnallite than those found in GD-1. Calculations by McNulty (1984) show that the temperatures in the carnallite marker bed 15.24 meters (50 feet) above the repository will reach a maximum temperature of 104C (219F) at 40 years and remain above 100 C (212 F) for a period of about 40 years. This maximum temperature is at the high end of the range of 50 to 100 C (122 to 212 F) representing the dehydration temperature of carnallite (Jockwer, 1981, p. 40). Limited data by Pfeifle et al. (1983, ONWI-450, pp. 29, 30, 39, Figure 4.7) suggest that carnallite creeps very much like salt when heated at 200 C (392 F) for 30 days. Pfeifle et al. (1983, ONWI-450, Figure 4.4, Table 5.2) also show that the strength of carnallite varies with temperature in the middle range of possible "strength" data for salt. Consequently, these limited data suggest that carnallite will creep and "yield" very much like salt even at temperatures significantly in excess of the dehydration temperatures. In summary, existing evidence supports the conclusion that geochemical changes due to increased temperatures will not degrade carnallite "strength" in excess of that expected for salt. Furthermore, the similar creep and "yield" behavior of carnallite suggests that carnallite will have many of the self-healing characteristics of salt. Finally, because of the relatively small amounts of carnallite, distance from repository horizon, and low permeability of salt (Tien et al., 1983, NUREG/CR-3129, SAND82-2223), it is unlikely that any water released through dehydration of

carnallite (which should be minimal for expected temperatures) should reach the waste package and increase corrosion.

As addressed in Chapter 3, the probability of seismic activity (Section 3.2.5.2), igneous activity (Section 3.2.5.3), and localized differential uplift or subsidence (Section 3.2.5.4) is low. Repository development is not expected to increase the occurrence of these geologic phenomena beyond present rates. Seismicity observed at underground coal mines and at potash mines in the Colorado Plateau suggests that geological conditions may exist that could lead to the occurrence of similar mining-induced microearthquake activity related to repository development (Wong, 1984, ONWI-492, p. 117). Further evaluation of regional and local seismicity, suspected faults, and regional structure, which might affect site development, are proposed in Section 4.1.1.2. Repository buildings that will contain radioactive materials are designated as Category I structures, and will be designed to perform during and immediately following the design basis earthquake, to be established (Section 5.1).

The rate of salt dissolution in the bedded salt region of Paradox Basin is not known. As discussed in Section 3.2.5.6, salt dissolution features in the basin are known, or suspected, in several areas in the site vicinity. Lockhart and Beef Basins are known areas of dissolution and are located 19 kilometers (12 miles) and 23 kilometers (14 miles), respectively, from the geologic repository operations area. Both Shay Graben and Needles Fault zones are also areas of suspected dissolution and both are located about 16 kilometers (10 miles) from the geologic repository operations area. No salt dissolution features are known at the site. Repository development could potentially increase the natural rate of salt dissolution at the site by providing access pathways to the salt for ground or surface water. Such pathways would include shafts and boreholes and induced structural discontinuities. As discussed above, the creation of major discontinuities is not likely. As discussed in Section 4.1.2.2, appropriate drilling techniques, seals, and plugs will be used to prevent vertical migration of water to the salt. Furthermore, as indicated in Sections 3.3.2 and 5.1, significant ground-water inflow is not expected to occur during construction of the shaft. Hence, the natural rate of salt dissolution should not be adversely affected by repository development.

In the absence of impurity stringers and heat, salt has negligible permeability. In the presence of heat, brine migration occurs. Within crystals, the most probable mechanism is thermal-gradient-induced migration of brine inclusions, in which salt dissolves at the hot interface and precipitates at the cooler interface after diffusing through the inclusion (Jenks and Claiborne, 1981, ORNL-5818, p. 15). This brine moves up the temperature gradient and stops at the crystal boundary. Under high enough temperature gradients, large brine inclusions can move across crystal boundaries, but it is thought that repository gradients are too small to drive this type of migration. Consequently, any significant movement of liquid brine from crystal boundaries towards the emplacement hole must take place through connected pores and microcracks. Such movements could result from pressure gradients, temperature gradients, capillary action along previously unwetted surfaces, and water vapor moving under vapor pressure gradients. Jenks and Claiborne (1981, ORNL-5818, Table 12) calculated maximum rates of brine migration to be about 250 milliliters per year for packages of CHLW in bedded salt, with the total amount of in-migration during the first 100 years after emplacement to be about 25 liters (6.6 gallons). Providing care is taken to locate the emplacement holes in good quality salt containing a minimum amount of inclusions, impurities, and interbeds, brine migration should be limited to the immediate vicinity of the waste canisters. Hence, brine migration is not expected to have any significant effect on the physical environment.

The above discussion on brine inclusions does not consider "brine pockets." Brine pockets are relatively large volumes of entrapped brine which are found in some salt deposits and have accumulated in the intergranular spaces since the formation of the deposit. They should be detected during the site characterization phase and, if they occur, will be dealt with during repository design or operations. With regard to the existence of gas and brine pockets, only minute traces of gas were detected during drilling in the Paradox Basin and no brine pockets of any size were encountered. Nevertheless, a level of uncertainty still exists. In practice, the potential for gas and brine pockets translates to a need for increased care and safety in advancing an excavation heading (e.g., by probing ahead of the face, and bringing up ample ventilation and dewatering capability behind the face).

The thermal pulse from the repository has been estimated to be 1 to 2 C (33.8 to 35.6 F) at the base of the shaft after 1,000 years (Kelsall et al., 1985, BMI/ONWI-564). This small temperature change should have a negligible effect on the stability and the deformation of the shaft, as well as a minimal effect on the shaft seals.

5.2.1.1 Soils

The effects on soils associated with repository development will result primarily from site construction and, to a lesser extent, from site operation. Site decommissioning primarily involves dismantling and restoration activities, which will not have adverse effects on the soil.

5.2.1.1.1 Construction. Construction activities that will affect soils include the following:

- Construction of a rechannelization system to divert drainage around surface facilities
- Clearing, grubbing, and grading the 189-hectare (467-acre) area for surface facilities
- Construction of retention ponds and mud pits
- Onsite storage of salt excavated from the shaft and ancillary subsurface openings
- Construction of access corridors for roads, railroads, and utilities over an area of approximately 654 hectares (1,615 acres) (Section 5.1).

Prior to construction of surface facilities, the entire area will be cleared and graded. Surface drainage will be rechanneled where necessary. The site layout and orientation (Section 5.1) have been designed to minimize earthwork and disturbance of existing surface features. However, local topography and drainage patterns will be changed, an undetermined amount of topsoil will be stripped, and subsoil horizons will be mixed. Stripped topsoil will be stored on site for site restoration activities.

The disturbance of soil horizons and storage of topsoil for future site restoration will have several adverse impacts. These include the following:

1. Removal of vegetation and disturbance of cryptogamic surface layers, if present, will result in a greater potential for wind and water erosion.
2. The mixing of topsoil with less fertile and more alkaline lower soil horizons will reduce soil fertility when topsoil is restored following site closure.
3. Disruption and compaction of soil horizons will reduce permeability, infiltration capacity, and hydraulic conductivity. These changes will result in increased runoff and resultant erosion.
4. Stockpiled topsoil may suffer loss of fertility over long periods of time.

The amount of soil disturbed will vary with site topography and with the amount of cut and fill necessary to prepare the area for construction. Approximately 3,605,000 cubic meters (4,712,000 cubic yards) of excavated and 3,610,000 cubic meters (4,717,000 cubic yards) of fill are estimated to be required (Section 5.1). In some areas, only a portion of the upper soil horizon will be removed, while in others, several horizons may be affected. In areas where fill is required, existing soils will be covered with spoils from excavation or with materials imported to the site for establishing suitable foundation conditions or surfaces.

Construction and site restoration activities will include measures to minimize impacts to soils and aid revegetation efforts in concurrence with and application of BLM reclamation

practices. Soil banking, ridging, and diking, natural vegetation seed sprays, runoff diversion structures, and retention ponds will be used to retard surface runoff and hence reduce soil erosion. In addition, compacted soils will be ripped, disked, and protected from further disturbance to enhance surface water infiltration, reduce erosion, and to promote the reestablishment of cryptogamic communities. Topsoil will be stripped, stockpiled, protected from erosion and salt contamination, and replaced on stripped areas. Soils will be graded to approximately preconstruction contours and soil amendments used to increase soil fertility for revegetation activities.

Approximately 2,951,000 metric tons (3,254,000 tons) of salt excavated from shafts and underground facilities will be stored on site in a 20.3-hectare (50.2-acre) storage area as discussed in Section 5.1.2.3. Possible impacts from the salt handling and transfer during construction will be similar to impacts during operation, which are discussed in Section 5.2.1.1.2.

Three major retention ponds are potential sources of contamination to the underlying and surrounding soil. Each pond will have a liner system to minimize seepage of contaminants into the soil. A monitoring and leakage recovery system will be installed to detect a leak and determine the size and location of the leak. The monitoring system will be designed for site soil conditions and may include observation wells, drains, or unsaturated zone monitors. If leaks are detected, they will be repaired. Any released contaminated water will be recovered by means of pumping wells. Likewise, if oil or fuel spills occur, the contaminated soil will be disposed of in a licensed waste disposal facility.

5.2.1.1.2 Operation. Operation of the repository will require continued maintenance of the salt pile and retention ponds. A ground-water monitoring system will detect seepage of contaminants from these areas into the soil and corrective measures will be taken if necessary.

The potential effects of windborne salt, originating from salt handling operations and deposited in offsite soils, are not expected to be significant (Section 5.2.10). To evaluate the impact of salt on soil, a comparison of the amount and effect of salt deposition on roadside soils receiving salt from roads salted in winter was made with the amount of salt expected to be deposited at the repository site (Section 5.2.5.5).

A typical winter road salt application is between 18 and 23 metric tons (20 to 25 tons) per 1.6 kilometers (1 mile). This rate of salt application equals approximately 4,400 kilograms per hectare (4,000 pounds per acre) for a 30-meter (100-foot) right-of-way (Hutchinson, 1973; Hutchinson and Olson, 1967; Scharpf and Srago, 1974). Roadside salt impacts to soil, however, are generally restricted to a distance of 15 to 18 meters (50 to 60 feet) from salted highways (Hutchinson and Olson, 1967; Prior and Berthouex, 1967).

Maximum salt deposition from the repository site is estimated at 1 kilogram per hectare (0.9 pound per acre) per year, a rate considerably less than that of a typical highway roadside. Although application of road salt in this concentration does damage vegetation, the annual increase in soil salinity due to the repository will be less than 0.2 part per million and it will decline rapidly away from the repository site. Consequently, the effects of windborne salt on the site's soils are believed to be minimal.

Soil salinity will be monitored during repository construction and operation. The monitoring program will include periodic sampling of soils, surface water, and ground water. If salt concentrations approach potentially adverse levels, impacts can be mitigated by adding calcium in the form of gypsum to flush excess sodium from the soil (Buschena and Sucoff, 1980; Leopold and Willing, 1984).

5.2.1.1.3 Decommissioning and Closure. Backfilling and sealing the shafts will include the disposal of wastes not amenable to chemical or mechanical decontamination. The wastes will be entombed by backfilled salt from the salt storage pile. Retention pond liners and the salt pile liners will be removed and emplaced in the repository or shipped off site to a licensed disposal facility. The retention ponds and salt pile areas will then be regraded to

their preconstruction contour. All dikes, soil ridges, artificial drainages, and building foundations will be regraded. Stockpiled topsoil will be regraded over areas stripped of soil. Compacted soils and roads will be ripped and disked to enhance moisture retention, reduce surface runoff and erosion, and promote the reestablishment of cryptogamic communities. All disturbed areas will be mulched, reseeded, and revegetated (Section 5.2.1.1.1) to eventually reduce postclosure erosion. This work will be performed in accordance with a detailed reclamation plan, including continued monitoring and maintenance. Long-term impacts to the environment from soil erosion are not expected.

The site will be monitored. If contamination is detected, fugitive waste and contaminated soil will be removed.

5.2.1.2 Mineral Resources

The primary impact on mineral and hydrocarbon resources will be the exclusion of resource development within the 2,331-hectare (5,760-acre) site. Surface and subsurface mineral rights in the area will be retained by the DOE throughout site construction, operation, and decommissioning. This will continue into the postclosure phase for an as yet undetermined period of time to prevent potential breach of the repository by future mineral exploration and development activities.

Low resource potential was used as a condition for site selection during the site-screening process; therefore, the local and regional effects of the restriction to develop mineral and hydrocarbon resources are expected to be minimal. As discussed in Section 3.2.8, proven mineral resources within the controlled area are limited to small deposits of uranium and vanadium. None of these potential resources are unique to the Davis Canyon area. Known production of uranium and vanadium resources has been small to large, and the remaining potential resources have been estimated to be none to medium. No current commercial production of oil or gas has been reported, and no hydrocarbon reserves have been identified within the controlled area. The depth of halite is prohibitive for its development as a resource.

Much larger undeveloped potash resources exist in both Salt Cycles 13 and 18 elsewhere in the Paradox Basin (in and beyond the candidate area to the north, east, and southeast of the site). It is judged that the impact of prohibiting exploration and potash resource development at and near the site during the institutional-controlled part of the repository lifetime will be minimal.

5.2.2 Hydrology

Hydrologic impacts may potentially result from the development of a repository in Davis Canyon. Impacts on surface and ground-water resources are discussed in this section. Appropriate mitigating measures are also described where applicable.

5.2.2.1 Surface Water

This section discusses impacts on surface water resources resulting from the construction, operation, and decommissioning and closure of the repository. The impact on water quality would be local, affecting primarily Davis Canyon and Indian Creek. The extent and magnitude of these impacts will be determined after site-specific engineering design plans have been finalized. However, the DOE projects it can meet the requirements of both the "Federal Water Pollution Control Act" (33 USC Sections 1251-1376), and the "Water Pollution Control Act of Utah" (Utah Code Ann. Sections 26-11-1-26-11-20 and 26-15-4 [Supp. 1984]) because discharges will be minimal and engineering control measures will be applied to keep effluents within allowable discharge limits. No significant effect on the water quality of the Colorado River is expected because of pollutant control measures, natural impact attenuation factors, and the distances between the site and the river.

5.2.2.1.1 Construction. Impacts on surface water resources resulting from construction of the repository would include the use of surface water resources required for construction activities, potential alteration of surface hydrologic regime, and possible degradation of the

water quality of the adjacent streams and water bodies. The Fish and Wildlife Service has been consulted (Neff, 1984) on the identification, location, and extent of any floodplains in the vicinity of the site that may receive protection under Executive Order 11988 (Protection of Floodplains). Measures to mitigate potential adverse impacts from changes in surface hydrology relate to construction practices for controlling erosion and runoff to receiving waters. These include diversion of runoff to retention basins for solids sedimentation and effluent evaporation.

The water requirements for the repository construction have been identified in Table 5-1. The total demand for raw water would be 1,570,000 cubic meters (416 million gallons) over the period of construction. This includes water for the access road and railroad, concrete batch plant, and potable use on and off site.

A review was performed to evaluate the resources of the area and its allied water rights issues (SCC, 1984a). A variety of potential water sources exist in the area. A likely source of water is the San Juan County Water Conservancy District (SJC-WCD), which has jurisdiction over the project site. SJC-WCD has indicated that it would enter into an agreement for the sale or lease of up to 345,000 cubic meters (280 acre-feet) annually of the waters of the Colorado River or one of its tributaries during construction, and thereafter up to 617,000 cubic meters (500 acre-feet) of water annually for operation of the repository (Nielson, 1984). Other potential sources include purchase or lease of existing private water rights along the Colorado River or one of its tributaries (SCC, 1984a). One alternative being considered is the consolidation of acquired water rights to a single point of diversion of water from the Colorado River downstream of Moab where a pumping station and pipeline could be constructed to the repository site (Section 5.1.2). Such a change in the authorized points of diversion would be subject to appropriate regulations. The maximum annual withdrawal constitutes only about 0.01 percent of the average annual flow of the Colorado River at the Cisco gaging station. While this amount is small, it would contribute to the increasing demand on the region's sparse water resources.

The 100-year floodplain of the unnamed tributary of Davis Canyon in this area will be encroached by some surface facilities of the repository (Section 3.3.1). This encroachment will reduce the flood storage capacity of this reach of the river and could result in higher peak flood flows in the downstream reaches and a subsequent increase in suspended sediment and turbidity. The magnitude and extent of this impact cannot be quantified at this time, however it will be partially offset by the ponding of surface runoff, as discussed below.

Rechannelization will follow recommended procedures (DOT, 1979; Simpson et al., 1982). Due consideration will be given to channel sinuosity, grade, and bank stabilization.

In assessing possible degradation of water quality of adjacent streams and water bodies the following were considered:

- Soil erosion by wind and water from land cleared for construction and by subsequent construction activities
- Stream diversion and channelization
- Runoff and windblown dust from excavated material stockpiles (nonsalt) and from salt handling and transfer
- Accidental spills of fuels, lubricating oils, and other materials.

Site preparation and the construction of onsite and offsite facilities may cause some local and temporary degradation of the water quality. An increase in suspended sediment concentration, turbidity, and nutrient concentration in the adjacent surface waters can be expected.

Indian Creek will be crossed by the access road, utility corridor, and access railroad spur. The unnamed tributary of the Davis Canyon wash will be diverted and rechanneled.

Grading, equipment transport, and related activities will cause erosion of the creek beds and banks, which will result in degradation of water quality in Indian Creek.

Impacts from onsite and offsite construction activities will be minimized by careful construction techniques such as diking, water spraying for dust control, covering the spoil piles, using temporary sedimentation ponds at major disturbed sites, and cofferdams around excavated areas and culverts under roads at stream crossings. The sedimentation ponds will be designed, constructed, and operated to capture and retain surface runoff from the disturbed areas including stockpile areas for excavated material (nonsalt). They will allow the sediments to settle out of the sediment-laden runoff before it is released to the environment. The basins will be sized to provide a one-hour retention for a 13-centimeter (5-inch) rainfall in a 24-hour period. In addition, an overflow containment area will be provided to contain the runoff that could be generated by a 24-hour storm, of a 25-year recurrence interval.

With proposed mitigation measures, the potential impact on water quality in Indian Creek would be small. Since most of the other streams in the area are ephemeral, and since the mean annual runoff amounts to less than 25.4 millimeters (1 inch), the potential impact on water quality on these ephemeral streams, resulting from construction activities, would also be small.

Potential degradation of the water quality of adjacent streams and water bodies caused by windblown salt, if any, would be small. The majority of the salt emission would be deposited within the repository site (Section 5.2.10); runoff from this area will be retained and discharged off site only if it meets environmental discharge standards. The amount of windblown salt deposited in the adjacent watersheds would be less than 1,800 kilograms (2 tons) per year, equivalent to less than 0.5 percent of the present salt loadings carried in the nearby Indian Creek. (The salt load of Indian Creek is estimated to be at least 455,000 kilograms [500 tons] per year from observed flow and water-quality data given in Tables 3-14, 3-16, and 3-17.)

Ponding of surface runoff from disturbed areas and salt pile runoff retention ponds will reduce surface runoff to the streams in the immediate area. The repository plans of Section 5-1 call for the diversion of all surface water drainage from salt contaminated areas of the repository site to a retention pond. Since evaporation greatly exceeds precipitation, excess liquid is expected to evaporate from this pond. As a result, no salt runoff to surface water is expected under normal operating conditions.

Significant degradation of the water quality in Davis Canyon and Indian Creek could potentially result from the catastrophic release of the contaminated runoff from the temporary sedimentation and salt pile runoff retention ponds. Such an event could occur if the embankments were breached by storm runoff exceeding the design event. The magnitude of this potential impact is not precisely known at present due to the uncertainty of final repository design. However, any potential impact would be lessened by the dilution effect of the storm runoff that initiated the impact. Ponds and embankments will be designed and constructed to meet existing Federal and State regulatory requirements.

Based on the water-quality data collected at the Cisco gaging station, the Colorado River carries a salt loading of approximately 3.5 billion kilograms (3.8 million tons) per year. In light of this large salt load, impacts resulting from an increased salinity due to either windblown salt or a catastrophic failure of the salt runoff retention pond are not expected to be significant.

The potential for significant degradation of water quality in the nearby streams from accidental spills of fuels, lubricating oils, and other materials on site is considered to be minor. These materials will be restricted to the construction areas where safeguard measures will be implemented. Emergency clean-up programs will also be formulated to minimize any possible adverse effect to the water quality in this area resulting from accidental spills of these materials.

5.2.2.1.2 Operation. Approximately 185,000 cubic meters (49 million gallons) of water per year will be required for the operation of the repository. Once a water supply system has been established for the construction phase of the repository, no additional environmental impacts are expected.

Like those resulting from construction activities, impacts on the surface water resources resulting from the operations of the repository would also include possible degradation of the water quality of nearby streams. These impacts, however, will be greatly minimized by control measures implemented as part of the operating procedures and by the onsite retention ponds, namely, the salt runoff pond, the treated wastewater holding pond, and stormwater detention ponds (Figures 5-1, 5-2; Section 5.1.2.3).

Impacts from windblown salt particles from salt handling and transfer, and from unlikely releases from retention ponds, should be similar to those encountered during construction (Section 5.2.2.1.1).

5.2.2.1.3 Decommissioning and Closure. Impacts on surface water quality during decommissioning will be similar to those caused by construction activities. Decommissioning impacts, however, should be more moderate because fewer land surface areas are being disturbed during decommissioning. It is unlikely, for example, that bridges and roads will be dismantled. However, some increase in suspended sediment concentration, turbidity, and nutrient concentration in nearby streams can be expected due to decommissioning activities.

Impacts from windblown salt particles from stockpiles, salt handling and transfer, and from windblown releases from retention ponds, should be similar to those encountered during construction (Section 5.2.2.1.1). These impacts will be quantified using data collected during site characterization.

Since all runoff or wastewater retained in onsite retention ponds will be evaporated and proper decommissioning procedures will be followed before final disposal, no significant impacts on surface water resources are expected.

5.2.2.2 Ground Water

This section describes the effects on ground-water resources resulting from the construction, operation, and decommissioning of the repository at Davis Canyon. Effects identified relate primarily to ground-water quality, although some minor effects on the ground-water system may also occur. Most effects will be avoided or mitigated by facility design (e.g., impoundment liners, shaft seals) or restoration measures, which are noted where applicable. The effects are identified based on the repository design described in Section 5.1. Individual site activities that may produce these effects are discussed below.

5.2.2.2.1 Construction. Repository construction includes site preparation, surface facility construction, shaft construction, and repository construction (Section 5.1). Primary activities which may affect ground water include the following:

- Excavation of the repository shafts and ancillary subsurface openings
- Construction of retention ponds and salt storage piles
- Handling and storage of salt.

Excavation of the repository shafts and related subsurface facilities could potentially affect ground water in two ways: (1) the shafts will penetrate several water-bearing units within the Upper and Middle Aquifer systems leading to possible hydraulic connection between aquifers, and (2) removal and storage of salt on the surface will provide a source of contaminants which could be transported to the ground-water system. These potential impacts will be avoided by the design measures described below and thus have a low probability of occurrence.

The shaft-liner design and installation will take into account the site-specific stratigraphy and major aquifers, with seals installed to isolate the aquifers from the waste-storage level and from one another. As a result, hydraulic connection of aquifers and potential dis-

solving of the salt in the lower levels of the shaft will be avoided. Monitoring wells near the shaft will be sampled regularly to detect any aquifer cross-contamination. If results indicate that flow around seals is occurring, remedial measures, such as grouting or pumping, will be implemented. These are largely precautionary measures, however, because as indicated in Sections 3.3.2 and 5.1, significant ground-water inflow is not expected to occur.

Ground-water quality impacts due to infiltration of precipitation through soils contaminated by windblown salt are expected to be minor because of the low deposition of salt outside the repository area, the low precipitation rate, and the deep water table in the site area.

There is a low probability that seepage of contaminants will occur through the salt pile liner, the pond liners, or the fiberglass fuel tank. A double liner with underdrain and a leakage detection system will be installed at the retention ponds and salt pile to provide early detection of ground-water contamination and for collection of seepage in the event of liner failure. The fuel tank monitoring system will be designed on the basis of site soil conditions and could include observation wells, drains, or unsaturated zone monitors. If wells are installed, they could be pumped in the event of a spill in order to prevent offsite migration of contaminants.

Water supply for site construction will be obtained entirely from surface water resources. No effect on local ground-water flow or potentiometric surfaces will occur.

5.2.2.2.2 Operation. Operation of the repository will require a water supply for the heating, ventilation, and air conditioning (HVAC) cooling tower, steam generation, washdown, dust suppression, cement mixing, sanitation, and other miscellaneous uses (see Table 5-1). This water will be obtained from surface water sources. No ground water will be used and no effect on local flow patterns or potentiometric surfaces will occur.

In Section 5.2.1, uplift due to thermal expansion of the repository strata is discussed. Modeling studies show that the maximum thermal uplift at the repository site would be less than 1 meter (3.3 feet), decreasing to zero within a 3- to 5-kilometer (2- to 3-mile) radius. This small amount of uplift will occur slowly over more than 1,000 years. For these reasons, it is concluded that no significant disruption of ground-water flow patterns will occur. As shown in Figure 3-57 and Table 3-24, existing wells and springs are at least 2 kilometers (1.2 miles) from the repository operations area. Wells supplying Canyonlands National Park are located well beyond 5 kilometers (3 miles) from the repository, and therefore would be outside the area affected by thermal uplift.

Changes in ground-water quality due to infiltration of precipitation through soils contaminated by windblown salt are expected to be minor. Model studies of repository operation show that deposition of salt will be on the order of 1 kilogram per hectare (0.9 pound per acre) per year in the repository area, decreasing to 0.1 kilogram per hectare (0.09 pound per acre) per year at a distance of 1 to 2 kilometers (0.6 to 1.2 miles) (see Section 5.2.10). If all of this salt were carried to the ground-water table and distributed in the top 3 meters (10 feet) of the saturated zone, it would represent an annual increase in salinity of about 0.01 to 0.1 milligram per liter in the ground water beneath the site area. Even over the 26-year operating life of the repository, this would represent an increase of less than 3 milligrams per liter. It is very unlikely that even this small increase would ever occur, since some of the salt would be removed by runoff, and the precipitation rate is so low that salts carried down through the unsaturated zone would be removed by natural ground-water flow and dispersion before they could accumulate in the aquifer.

5.2.2.2.3 Decommissioning and Closure. Decommissioning and closure of the repository will include backfilling and sealing the underground facility, backfilling and sealing the shafts, decontaminating and dismantling the surface facilities, removing excess salt, waste, and fluids from the storage pile and retention ponds, and restoring the site to its approximate preconstruction topography, drainage pattern, and vegetation. These activities are described below and will have minimal adverse effects on the ground-water system.

Subsurface reclamation will include backfilling the repository rooms with previously excavated salt. A concrete plug and polymer seal ring will be emplaced in the shaft to prevent ground-water inflow into the repository.

The access shafts will be backfilled with salt to the top of the salt bed, filled with excavated overburden and seals above the salt, and finally capped with a concrete plug up to 1 meter (3.3 feet) below the surface. The final meter (3.3 feet) will be filled with soil. These activities will ensure vertical isolation of aquifers originally penetrated by the shaft.

Excess salt, fluids, and waste from the salt storage pile and retention ponds will be removed to offsite licensed facilities not yet identified. These areas will continue to be monitored into the postclosure phase for an as yet undetermined period of time. Monitoring the site will determine the effectiveness of decommissioning and reclamation activities and detect the occurrence of residual ground-water contamination. If contamination is detected, dewatering and cleanup of the area will be implemented to minimize the impact.

5.2.3 Land Use

Potential impacts on land use during repository construction, operation, and decommissioning are discussed in this section. Land use is discussed for each phase of the repository: construction, operation, and decommissioning and closure. Impacts include a permanent change in the character of the land, disruption of grazing activities, and temporary interruption of access to nearby recreation and dedicated land areas.

Repository development will require that 2,332 hectare (5,760 acres) be either totally owned by the DOE or permanently withdrawn for use by the DOE for the purpose of protection, as discussed in Sections 5.1.1.5 and 6.2.1.3. If the Davis Canyon site is designated for repository development, the DOE will initiate appropriate acquisition actions with respect to Federal, State, and private lands (Section 5.1.1.5).

The DOE will act to remove public land from other uses and designate it for repository purposes. This will require the following actions:

- Land will be permanently withdrawn by Congressional action
- Any mineral leases and mining claims not extinguished during site characterization will now be extinguished through acquisition, or as a last resort, condemnation
- Termination of grazing leases.

The DOE will also secure title to both State and private lands. State land will be acquired through the Utah Board and Division of State Lands. Private land will be acquired through negotiations with individual property owners. Sections 5.1.1.5 and 6.5 set forth the procedures for acquisition of State and private lands.

Currently, land use in the Davis Canyon area is controlled by the Indian Creek-Dry Valley Management Plan for BLM land and the San Juan County Master Plan for State land. Both plans permit multiple uses. As stated above, if the site is selected for development, the land will be permanently withdrawn for the DOE's use. Consequently, continuation of alternative land uses that occur within the nonrestricted portion of the repository-controlled area will be at the DOE's discretion as allowed by the Nuclear Regulatory Commission. The DOE may allow or could permit some uses to occur within the DOE-controlled area as long as they are not incompatible with repository performance and use. No subsurface activities will be allowed. Furthermore, nonrepository activities will not be allowed within the restricted area (the 189 hectares [467 acres] required for repository surface facilities).

5.2.3.1 Construction

Repository construction will occur on 189 hectares (467 acres) of Federal land in Davis Canyon. Construction will have potential land-use impacts on grazing and recreation.

Access routes and utility corridors will traverse 654 hectares (1,615 acres). Section 5.3.2 discusses the access routes in detail. The road access construction will cover a distance of 45 kilometers (25 miles). The four alternative rail routes under investigation range in distance from 60 kilometers (38 miles) to 86 kilometers (54 miles). Utility corridors will traverse a total of 125 kilometers (78 miles) for new corridors. They will consist of 43.5 kilometers (27 miles) of new transmission line, 46.7 kilometers (29 miles) of gas pipeline, and 35.4 kilometers (22 miles) of potential water pipeline. The electric and gas utility corridors will be constructed along the access road right-of-way, while the potential water pipeline will use the rail right-of-way if available in order to minimize land-use impacts. The major land-use impact will be on grazing lands traversed by these access routes and utility corridors, as described below.

5.2.3.1.1 Grazing. Grazing will be prohibited on the 189-hectare (467-acre) construction site. As stated in Section 3.4.1.3, average forage production in Davis Canyon is estimated to be 5.2 hectares (13 acres) of rangeland per animal unit month (AUM). Assuming this rate of production for all areas disturbed for repository surface facilities, approximately 36 AUMS of forage will be permanently lost. This represents 7.2 percent of the 500 AUMs estimated in Davis Canyon.

The Davis Canyon site lies within the BLM Indian Creek grazing allotment of 95,045 hectares (234,680 acres). Total removal of the entire 2,333 hectares (5,760 acres) from grazing will comprise only 2.5 percent of this allotment, or a loss of 443 AUMs. However, the DOE may permit grazing on the area beyond the restricted construction area, which would reduce the loss of AUMs.

Grazing will alsc be disrupted by construction of the access and utility corridors to the site, discussed above. As indicated in Section 5.1, depending on the route selected, the rail corridor will require from 238 hectares (589 acres) to 309 hectares (764 acres) of grazing lands. In addition, the exclusive-use road alternative that will be investigated will require 148 hectares (366 acres); the majority will traverse grazing land (Section 5.3.2). Disturbance to grazing lands will be permanent within the railroad and right-of-ways during the life of the railroad and road corridors. Hence, grazing will gradually be lost in these areas as construction progresses. For example, the fenced right-of-way for rail lines could sever grazing allotments, creating difficulties for livestock management. Transportation improvements may also bisect other grazing lands that are not open range. Cattle crossings will be provided for, as appropriate. The DOE will review with the BLM, pursuant to the "Taylor Grazing Act" (43 USC Sections 315-316o) any grazing plans which may be affected by construction activities in order to minimize impacts (see Section 5.4.2.3 on socioeconomic effects from grazing impacts).

5.2.3.1.2 Salt Impacts. Salt related impacts to land use are expected to be insignificant. Based on examination of salt management practices and results at International Salt Company's Retsof Mine, Texas Gulf's Potash Mine, and Potash Corp. of America's Canadian mine, as well as Project Gnome and WIPP (Parsons-Redpath, 1984), no apparent changes in offsite land use were found. It is therefore reasonable to expect that at Davis Canyon there will be no significant changes. The majority of the windblown salt particulates will be deposited within the construction area and only insignificant levels of salt will collect in the soil. However, based on past studies, the expected build-up will not be great enough to cause significant adverse impacts on the natural vegetation and, hence, on grazing productivity. (See Section 5.4.2.3 for a socioeconomic discussion of grazing impacts.) Land-use impacts resulting from rail transportation of salt from the area are also expected to be negligible. Various enclosures and dust collection equipment will be used to reduce airborne particulates. Section 5.3.5 describes salt impacts in detail and presents the findings from past studies.

5.2.3.1.3 Recreation. Recreational use of Davis Canyon will be impacted during construction of the repository. These impacts can be characterized as (1) the direct impacts created by impaired access and increased visitation, and (2) the indirect impacts created by a change in the status of the land to a single-purpose repository site. Direct impacts on access and visitation will be similar to the construction impacts that will arise with regard to Canyonlands National Park and Newspaper Rock State Historical Monument, as described in detail below in Section 5.2.3.1.4. Indirect impacts are expected to be minimal, as only 189 hectares (467 acres) of land that is not as frequently used for recreation will be removed from use.

5.2.3.1.4 Dedicated Lands. As described in Sections 3.4.1 and 4.2.1.1, the Davis Canyon site is located adjacent to the Canyonlands National Park and is also in the vicinity of three wilderness study areas (WSAs): Butler Wash, Indian Creek, Bridger Jack Mesa, and is also near the Newspaper Rock State Historical Monument. When the DOE acquires the land required for repository purposes, and commences construction, there will not be a change in the status of these dedicated lands. No direct repository activities will occur within these dedicated lands. As will be described below, repository construction activities will not cause a permanent change in the land-use patterns of Canyonlands National Park, pursuant to the Canyonlands National Park General Management Plan and its Statement of Management (see Section 3.4.1).

The proposed wilderness areas within the park (Section 3.4.1) are not expected to be affected to the extent that their value as recreational resources are diminished. The distance of the WSAs from the repository site in combination with the procedures that will be used to minimize construction impacts (Section 5.1) will preclude any adverse direct impacts.

Construction activities will have a direct impact on access to the Needles District of Canyonlands National Park, Newspaper Rock State Historical Monument, and other nearby recreational areas such as Davis and Lavender Canyons, which are all accessed by highway Utah 211. However, this impact will be temporary while the new exclusive-use access road to the site is completed, should this alternative route be selected (Section 5.3.2).

During repository construction, average passenger vehicle round trips are estimated to be 769 per day during peak periods and average 562 for nonpeak periods. In addition, it is estimated that 12 truck round trips per day will occur. During the first year of construction, while the new exclusive-use access road is under construction (if selected), traffic on Utah 211 will increase to 819 vehicles per day (Section 5.3.3.1.1). The average daily traffic count on Utah 211 during 1983 was only 45 vehicles. However, traffic flow on Utah 211 is subject to large seasonal fluctuations. For example, the Utah 211 traffic flow peaked at approximately 1,020 vehicles per day over the 1985 Memorial Day holiday weekend (Parry, 1985). Thus, the degree of impacts on access to Canyonlands National Park, Newspaper Rock State Historical Monument, and the nearby recreational areas that use Utah 211 for access will vary depending on the season and visitation patterns. During the site characterization phase, the DOE will investigate the option of busing repository construction workers to further reduce repository construction traffic volume. Busing, if used, will further minimize access conflicts to these dedicated lands and recreation areas.

The other repository access road alternative under consideration is the upgrade of Utah 211, so that increases in traffic flow can be accommodated (Section 5.3.2). Temporary inconveniences with access to the dedicated and recreation areas mentioned above will arise during the period that highway improvements are made.

Another direct impact on dedicated lands is the potential for increased visitation from the construction work force, especially on the Needles District of Canyonlands National Park and Newspaper Rock State Historical Monument. As indicated in Section 5.6.1.2, it is impossible to estimate how many repository construction workers and their families will visit the parks. As a point of reference, as stated in Section 3.4.1, 51,129 persons visited the Needles District in 1983 and 61,045 persons visited Newspaper Rock State Historical Monument in 1983 (Jensen, 1984). It is estimated that in-migrants will total 4,690 during the period of peak construction (Section 5.4). Based on expected recreational activities of the in-migrants (which will be similar to current residents), it appears that the potential land-use

impact will not be significant. Any land-use impact arising from potential visitations to the Needles District is not expected to change the status of the Canyonlands National Park proposed wilderness areas.

5.2.3.2 Operation

Operation of the repository will result in land-use impacts no greater than those described under repository construction.

5.2.3.2.1 Recreation and Dedicated Lands. It is likely that the recreational and dedicated land-use impacts will be similar in magnitude for the following reasons. First, operation will be less disruptive than construction activities. Therefore, direct impacts regarding access and visitation impacts on recreation and dedicated lands will be less than during construction.

Second, an exclusive-use access road to the site is being considered by the DOE. Access to both the Canyonlands National Park and Newspaper Rock State Historical Monument will not be directly affected in this case since highway Utah 211 will not be used and an overpass over Utah 211 will be provided. Furthermore, the exclusive-use access road will limit visits to the park by repository workers. In addition, traffic control measures may be taken as well as the option of busing repository workers. Rail lines will incorporate the under- and overpasses at Utah 211, in order to eliminate direct crossing over the highway. Hence, rail lines will not conflict with access to the nearby recreation and dedicated land areas.

Third, in-migration during the operation phase, as discussed in Section 5.4.1, should amount to 3,730 people during the peak operations. This is less than during construction. Hence, visitation impacts on recreational and dedicated lands will be less. (See Sections 5.2.10 and 5.4 for additional information on the effects on tourism and visitation.)

5.2.3.2.2 Grazing. Grazing impacts will result from a permanent loss of grazing in the restricted operation area of 189 hectares (467 acres) or approximately 36 AUMs. This represents a loss of 7.2 percent of the 500 AUMs estimated in Davis Canyon. Grazing will be lost within the right-of-way of the railroad during its use. Transportation corridors may bisect grazing lands that are now open range. These corridors may also disrupt grazing patterns and livestock's access to water. Water sources for livestock in this area are as much as 4.8 to 6.4 kilometers (3 to 4 miles) apart, and a transportation corridor may limit livestock access to a water source.

The impact of access to water will be overcome by the conventional solution of providing cattle crossings. The DOE will permit grazing to the extent possible in the controlled area if such activity is allowed by the Nuclear Regulatory Commission. If the entire controlled area of 2,333 hectares (5,760 acres) is removed from grazing, then most of the area (97 percent) accessible to cattle in Davis Canyon will be impacted, a loss of 443 AUMs. However, this represents only 2 percent of the available grazing capacity in the BLM Indian Creek grazing allotment (see also Section 5.4.2.3 on socioeconomic effects).

5.2.3.2.3 Urban and Other. Due to the distance of the repository site from Monticello, Moab, and Blanding, there will be no direct land-use conflicts with these urban centers. It is highly unlikely that smaller communities, such as La Sal, which is about 113 kilometers (70 miles) from the site, will be adversely impacted since expected in-migration to this community will be negligible (see Section 5.4 for a detailed socioeconomic discussion of these impacts). Depending on the rail and road corridors selected, a few of the scattered ranches in the area may be directly affected by repository construction.

Water requirements for repository development will have no significant impact on any of the land uses previously discussed (see Section 5.2.2.1.2). A variety of potential water sources exist in the area. Approximately 185,000 cubic meters (49 million gallons) will be required per year during operations. The maximum annual withdrawal for the repository will amount to approximately 0.01 percent of the average annual flow of the Colorado River at the Cisco gaging station. Water requirements during operation will not adversely impact recreational uses, grazing, or urban use in nearby communities (Section 5.2.2).

Mineral development will be prohibited in the controlled area. The consequent loss of these resources will not be significant. The mineral potential of the area is discussed in Sections 3.2.8 and 5.2.1.2.

5.2.3.2.4 Salt Impacts. Salt will be stored temporarily on site during construction and operation. Salt storage and disposal will have little impact on grazing (Section 5.4.2.3). Deposition of salt will occur primarily within the restricted area. However, the levels of salt that may be deposited are well below the concentration that could cause serious damage, based on studies presented in Section 5.3.5. Rail transport of salt is not expected to affect land use along the routes due to use of various enclosures and the use of dust collection equipment to reduce airborne particulates. A further discussion of potential landfills that may accommodate waste salt and impacts is presented in Sections 4.2.1.1.3 and 5.3.5.

5.2.3.3 Decommissioning

During decommissioning and closure, the land disturbed for repository surface facilities and access routes will be cleared, graded, and revegetated. The salt pile will be reclaimed and topsoil replaced and reseeded. Salt will be backfilled. Additional salt, not backfilled, will be transported and disposed at a licensed landfill (Section 4.2.1.1). Any restrictions on surface and subsurface uses in the controlled area will continue indefinitely. Vehicular traffic will be drastically reduced as decommissioning progresses. Thus, any access conflicts with nearby recreation and dedicated lands that may arise during construction and operation will be substantially reduced to negligible levels.

5.2.3.4 Mitigation

The following specific measures could be taken to mitigate land use impacts:

- Agriculture:
  - BLM procedures (Nodine, 1985) will be followed in restoring surface and vegetation cover to prevent erosion (see Section 5.2)
  - The DOE will consult with grazing allotment leaseholders to minimize disruption of their land use (see Section 5.4.1.4 as well)
  - Cattle crossings will be provided where required.
- Recreation:
  - Separate access road alternative will eliminate access problems to Canyonlands National Park and Newspaper Rock State Historical Monument; an overpass will be used to cross Utah 211
  - Utah 211 improvements alternative could aid in accommodating increases in traffic flow
  - Prudent construction and operating procedures will reduce indirect impact on recreational uses of Canyonlands National Park (Section 5.1)
  - Underpasses and overpasses will be used to eliminate direct rail crossings of Utah 211.
- Salt:
  - Rail transportation vehicles will be enclosed, speed control and salt handling will be closely monitored, and dust collection equipment will be used
  - The area beyond the restricted zone will be monitored to check the impact on vegetation (Section 5.2.4.1) and grazing.

- Other:

  - DOE will consult with mineral-rights owners and landowners, as appropriate.

5.2.3.5 Cumulative and Long-Term Impacts

Three long-term impacts are associated with repository development. First, the status of the land in Davis Canyon will change to a restricted, single-purpose use. Previously, multi-purpose uses have been permitted, including subsurface exploration.

The second impact will be on grazing. This is expected to be small relative to the total acreage available in the Indian Creek grazing allotment. Furthermore, grazing may be allowed in certain portions of the controlled area. Thus, grazing impacts will occur but should be insignificant (Section 5.4.2.3).

Only temporary land-use impacts on recreation and dedicated lands will occur. Following decommissioning, access conflicts to the nearby recreational and dedicated land areas will not occur and visitation impacts on the land use in these areas will be eliminated (Sections 5.2.11, 5.4.2.4, and 5.4.3.7).

5.2.4 Terrestrial and Aquatic Ecosystems

This section contains an evaluation of the potential effects of repository construction, operation, and decommissioning and closure on the terrestrial and aquatic ecosystems and associated biota of the proposed site. The analysis is based primarily on preliminary design, presented in Section 5.1, and on regional biological information, presented in Section 3.4.2.

5.2.4.1 Terrestrial Biota

5.2.4.1.1 Construction. Construction of the surface facility will result in primary impacts to vegetation on the repository site. Approximately 189 hectares (467 acres) will be cleared and graded to accommodate the major planned surface components (buildings, water ponds, salt storage piles, etc.) of the project. Some surface disturbance will also occur with the construction of the necessary transportation and utility systems, including an access road, railroad spur, and pipeline and powerline facilities. Access will be provided by construction of a new road to the site and upgrading of adjoining highways, and by construction of a railroad from the Moab area to Davis Canyon.

Development of the repository areas will eliminate native plant communities and wildlife habitat within the construction zone until the site is decommissioned and restored. Soil removal and grading will destroy most or all of the plant cover. Sedentary wildlife (primarily soil macrofauna, small mammals, and reptiles) will be destroyed, whereas mobile species (such as large mammals and birds) can relocate. Displaced wildlife will compete for resources with organisms in undisturbed areas, leading to additional ecological adjustments and potential mortality. Minor impacts, including potential behavioral changes, are expected from blowing dust, vehicle emissions, vehicle movements, loud and unexpected noises, lighting, and the general presence of humans. The biota affected will be primarily those remaining within close proximity to the construction sites.

The repository construction work force and their families may have secondary impacts on the area. Secondary impacts to the vegetation communities may occur as a result of increases in camping and hiking, both in the Davis Canyon area and Canyonlands National Park. These recreational activities are all actively encouraged by the Canyonlands National Park management. Increased activities of this kind may lead to changes in the vegetation community structure, including the frequency of occurrence of various plant species, percentage of cover, and species composition. It is also possible that certain plant species within walking distance of highways, roads, and facilities may be selectively removed.

Approximately 3.0 million metric tons (3.3 million tons) of salt will be generated and stored on site for up to 26 years. Wildblown salt particles will be dispersed from

ventilation shafts during subsurface mining operations and surface handling. The stabilized surface storage pile is not expected to contribute to windblown salt due to the rapid crusting characteristic of salt in the environment. Dispersion modeling described in Section 5.2.5 of salt deposition suggests that maximum rates of deposition will be 1.0 kilogram per hectare (0.9 pound per acre) less than 0.8 kilometer (0.5 mile) from the source. Deposition rates fall off rapidly from that point (see Section 5.2.10.2).

Although salt deposition will be practically unmeasurable beyond the 2,331-hectare (5,760-acre) controlled area, vegetation within this area may exhibit some symptoms of salt stress over the life of the repository. Plants exposed to elevated salt levels are affected by: (1) osmotic inhibition of water absorption; (2) alteration of mineral nutritional balances in plant tissue; and (3) toxicity of specific ion concentrations, particularly sodium and chloride. Actual plant stress could be a combination of these mechanisms or cumulative. Environmental conditions, including moisture, temperature, and time of day, also influence the effects of salt. Vegetation with a low tolerance for salt is most likely to be adversely affected.

Maas and Hoffman (1977) demonstrate that, in general, grasses tend to be more tolerant to elevated levels of salt in the soil than broad-leaved plants. Some studies on species found in the site vicinity indicate some of the effects salt deposition may have on these species. Four-Wing saltbush (Atriplex canescens) survived and grew at salinities as high as 38 umhos per centimeter (Richardson and McKell, 1980). Four-Wing saltbush, in a greenhouse experiment, tolerated concentrations of salt equivalent to that of seawater (Wallace et al., 1982). However, growth of most species decreases with increasing salinity. One experiment showed a decrease in the biomass and succulence of Distichlis stricta (salt grass) with application of sodium chloride (NaCl) (Tiku, 1976). Section 5.2.10.2.4 discusses the effects of salt in the environment and provides additional details on various design measures that will mitigate any potential salt contamination.

During construction of a repository and associated facilities within Davis Canyon, the wildlife species residing within the area of development will be displaced into adjoining desert shrub habitats. Increased noise levels (see Section 5.2.7) associated with construction of the repository, roads, and railroad will cause additional displacement of wildlife from adjoining habitats. This will result in a temporary increase in competition for food and cover. Some direct mortality may also occur to small mammals and reptiles during construction activities. All birds and large mammal species are highly mobile and should be able to move away from the site and inhabit adjacent areas; however, some road kills may occur. Raptors, including golden eagles, red-tailed hawks, and prairie falcons may be temporarily forced to change their hunting territory due to increased levels of human activity and project-generated light and noise. If potential impacts to migratory birds are identified, mitigation measures will be developed in consultation with the Department of Interior pursuant to the "Migratory Bird Treaty Act" (16 USC Sections 703-711). Following construction, many species will reoccupy habitats adjacent to project facilities.

The U.S. Bureau of Land Management (BLM) estimates that 10 to 15 mule deer presently utilize Davis Canyon for overwintering habitat, with one or two deer possibly residing all year (Sandberg and McClure, 1983). Construction activities and accompanying disturbances associated with the project work force may result in these deer moving into adjacent areas. However, BLM does not consider Davis Canyon a crucial winter range and has documented little deer use of the canyon. The area has been closed to hunting during the past three seasons due to low productivity and low deer populations.

Salt deposition could adversely affect wildlife populations if it caused a decline in the quality or abundance of any essential habitat component, such as forage, food, or cover (California Department of Transportation, 1975). As discussed in previous sections, however, surface-water quality is not expected to be adversely affected and any impacts to vegetation will only occur immediately adjacent to the salt pile. Although direct salt poisoning of wildlife has been reported, these effects were caused by levels of de-icing salt applications much higher than salt deposition rates expected from repository operations (Schraufnagel, 1967). Thus, adverse impacts of salt deposition on wildlife near the Davis Canyon site are not expected.

Secondary impacts to wildlife populations may also result from increases in recreational vehicle activity and other recreational uses of the land within and adjacent to the project area. Wildlife populations may also be affected by increases in harassment and poaching. Any secondary impacts of this type will be discussed with the Fish and Wildlife Service (FWS).

Construction of the proposed repository access road to Davis Canyon could potentially affect black-footed ferrets, peregrine falcons, pronghorn antelope, and mule deer in the area. The tie-in to U.S. 191 crosses a known prairie dog colony, which is a potential habitat for the endangered black-footed ferret. Surveys for ferrets will be performed prior to construction and if found, the roads will be rerouted. Peregrine falcon habitat (cliff areas) occurs in Harts Draw along the route, and these areas will also be surveyed and avoided if necessary. The proposed route crosses known mule deer winter habitat and pronghorn antelope range. Construction of the access road will be scheduled to avoid critical life history periods such as migration, breeding, and fawning. If site-characterization studies reveal significant year-around antelope range along the proposed corridor, other route alignments will be investigated.

Construction of the proposed Utah State Highway 211 (Utah 211) bypass around Newspaper Rock State Historical Monument may impact a number of important fish and wildlife resources known in the area, including Yellowstone cutthroat trout, mule deer, mountain lions, and golden eagles.

Harts Point is an important mule deer wintering area. Construction of the proposed bypass around Newspaper Rock could affect traditional annual movement patterns to and from Harts Point. Significant adverse impact to this deer herd is not expected due to the temporary nature of this construction (less than 1 year) and the ability to limit construction disturbances to nonmigratory periods.

Impacts to mountain lions and golden eagles are not likely to result from bypass construction. Lions occur in the general area, but are wide ranging in activity and no dens or concentrations are known around Newspaper Rock. The historical golden eagle nest located over 0.8 kilometer (0.5 mile) south of Kelly Ranch may or may not be active during construction. If it is, and depending on the presence of buffers, construction activity may be limited during the March through April critical nesting period, as required. Results of site-specific field studies and continued consultation with the FWS under the Bald and Golden Eagle Protection Act (16 USC Section 668-668d) will determine the extent of any adverse impacts to nesting golden eagles and appropriate mitigative measures.

Impacts to terrestrial biota will result from construction of any one of the four alternative rail routes to the Davis Canyon site (see Table 5-4). The Colorado River rail routes A and B would potentially impact similar resources, specifically, desert bighorn sheep, peregrine falcons, bald eagles, and rare plants (BNI, 1984; BNI, 1985b). Bighorn sheep habitat (Figure 3-73) would be bisected by the Colorado River routes, possibly forming a behavioral barrier to sheep movements between vital cliff and riverine habitat. Cliff areas would be destroyed and approached closely in some areas, possibly disrupting nesting peregrine falcons (Figure 3-72) and golden eagles, and sheep habitat. The Colorado River is approached closely and crossed at Potash; thus, this rail route construction would be potentially disruptive to wintering bald eagles. To minimize impacts to the important species mentioned above, construction of the railroad will be scheduled to avoid critical life history periods (lambing, nesting, etc.).

Construction of Kane Springs alternative rail route would potentially affect the same important wildlife and plant species identified for the Colorado River routes A and B. However, less bighorn sheep and rare plant habitat would be affected along the Kane Springs route (BNI, 1984). Similarly fewer possible impacts to wintering bald eagles would occur along the Colorado River as the result of less disturbances adjacent to the river.

The Spanish Valley route was ranked to have the least potential biological sensitivity among six preliminary rail alternatives under investigation (BNI, 1984). This route crosses few areas known to harbor important species or their habitats. The proposed tunnels through

Hatch Point and Harts Point should avoid impacts to pronghorn antelope and mule deer, respectively (Figure 3-73).

The majority of the utility corridors for both the natural gas pipeline and 115 kilovolt electric transmission lines will be adjacent to transportation corridors. Some additional land and habitat will be disturbed. Since electrical transmission lines can be a hazard to birds, particularly raptors, by collision during poor visibility or by electrocution, the transmission towers can be designed to be more visible to avoid proximity to preferred habitats for birds such as waterfowl, and to minimize the potential for electrocution.

Water demands during repository construction and operation are 1.54×10^9 and 9.27×10^9 liters (0.42×10^9 and 2.45×10^9 gallons), respectively (Table 5-1). Two water supply options under consideration include construction of a pump station and pipeline from the Colorado River, and use of existing water allotments in the region. Construction of the 20-centimeter (8-inch) water pipeline over 35.4 kilometers (22 miles) could affect local populations of desert bighorn sheep, golden eagles, and peregrine falcons depending on the final routing (Figure 5-10). Site characterization studies will determine the presence of peregrines, golden eagles, and bighorn sheep along the proposed pipeline corridor. Cliff nesting habitat for peregrines and eagles will be surveyed. Temporary impacts to sheep will include possible displacement and avoidance behaviors during the construction period.

5.2.4.1.2 Operation. Operation of the repository will entail minor impacts to terrestrial biota. Vehicular activities, noise, lights, and other human activities will result in some temporary disturbance to wildlife in adjacent areas. Many species will acclimate to the increased human activity, while others may be forced into less disturbed areas. Vegetation impacts from windblown salt should be similar to those encountered during construction. Secondary human activities (e.g., hunting) not directly associated with site operation may also disturb nearby wildlife habitats and populations.

Operation of the repository access road should cause no significant impact to fish and wildlife in the area. Avoidance of sensitive habitats during final routing and construction will have prevented most impacts. Although some road kills are likely, strict enforcement of a reasonable speed limit into the project site will help to limit these. The access road is not likely to cause long-term effects on the Harts Point mule deer herd. This access route should not present a behavioral barrier to deer winter migrations as Utah 211 is routinely crossed in the same area. Operation of the Utah 211 bypass should have no significant impact on fish and wildlife resources in the area. Deer herds currently cross Utah 211 without significant effect.

5.2.4.1.3 Decommissioning and Closure. With reclamation and revegetation of the site, wildlife habitat will be restored and wildlife should repopulate the closed site. Sites will be restored in conformance with BLM standards, following consultation with appropriate Federal and State agencies. The selection of seed mixes, soil conditions, and other measures including a thorough study of site-specific conditions such as elevation, slope, aspect, and soil chemistry, will aid in successful site restoration. Typical seed mixes for various conditions are available from BLM (1985). A detailed reclamation plan is described in Section 5.2.1.1. BLM experience in the area is that grasses and forbs can generally be reestablished to predisturbance density and vigor in 2 to 4 years (BLM, 1982). Windblown salt will continue to be a possible source of impact until salt transfer operations are completed. Wildlife populations should return to preconstruction levels and may benefit from the increased habitat availability and diversity associated with the reclaimed site.

5.2.4.2 Aquatic Biota

5.2.4.2.1 Construction. Repository construction activities in Davis Canyon will have negligible impacts on existing aquatic biota. This is because the drainages in Davis Canyon are ephemeral and intermittent and, as such, support no viable aquatic communities (Johnson, 1984).

Impacts to wetlands (riparian zones) resulting from offsite (access roads and railroads) development would be similar to those discussed for the site characterization phase of the project (Section 4.2.1.2.4). In addition, construction of the rail corridor would temporarily impact a number of riparian zones, depending on the route finally selected. Because almost all drainages crossed are ephemeral desert washes, very limited vegetation, water quality, or wildlife impacts are expected. However, removal of water by pipeline from the Colorado River for repository development (and operation) may jeopardize the endangered Colorado squawfish. If so, the DOE will continue discussions with the FWS to develop an acceptable means to reduce or eliminate any potential impacts.

Construction of the proposed transportation corridors across various streams and drainages will result in minor short-term increases in the turbidity of waters associated with these drainages. Installation of powerlines across streams will create minor and temporary impacts only, associated with construction of access across these ecosystems. Stream impacts may include insignificant, temporary increases in turbidity downstream of culvert (or equipment crossings) installations. Installations may require temporary road construction for access, which, if properly installed with adequate cross drainage, will impact a small percentage of plants present, until construction is complete and the road material is removed. No significant or long-term impacts to aquatic biota are expected in drainages crossed by the transportation route.

Although no population of fishes is known to be present at the proposed site access route crossing of Indian Creek (BNI, 1984), upstream portions of Indian Creek support a self-sustaining, naturally reproducing Yellowstone cutthroat trout population and has been classified as a high priority fishery (BNI, 1984). Construction of the Utah 211 bypass would involve some channel realignment of Indian Creek. The DOE will continue to consult with the FWS and Utah Division of Fish and Game under the Fish and Wildlife Coordination Act in conducting studies to determine if the Yellowstone cutthroat trout is present in this stretch of the stream. Should the Utah 211 bypass be developed, the DOE will implement appropriate mitigative measures in cooperation with these agencies.

Indian Creek may also be subject to secondary impacts from any influx of people into the area with resultant increased demands on fisheries and other recreational resources.

5.2.4.2.2 Operation. Davis Canyon contains essentially no aquatic habitat, thus no significant impacts on aquatic biota would be associated with operation of the repository facilities. During operation of the repository, measures designed to reduce water contamination from surface runoff, sewage effluent, and salt pile runoff will protect the water quality of adjacent aquatic systems. No impacts on aquatic biota in Indian Creek or the Colorado River are expected since projected deposition rates described and assessed in Section 5.2.10.2 will be practically unmeasurable more than 1.6 kilometers (1 mile) from the site. Runoff outside the controlled area is expected to contribute less than a 0.4 percent increase in the salt loading of Indian Creek and no measurable increase to the Colorado River. If salt accumulates over the lifetime of the repository and then washes into either water body, the total would be substantially less than present base loads of salinity (see Section 5.2.2.1). Water utilization at the repository will be based on a philosophy of maximum wastewater reuse through treatment. The only discharges leaving the facility will be sewage treatment plant sludge and dewatered clarifier and softener sludge, both of which will be disposed of in authorized landfills. Surface runoff will be diverted to and contained within separate evaporation and retention ponds. All ponds will be lined to minimize water loss into the ground. The salt stockpiles will also be lined.

5.2.4.2.3 Decommissioning and Closure. Decommissioning and closure of the site will result in little disturbance to aquatic ecosystems. Storm events during decommissioning may result in a temporary increase in turbidity and sediment loads of site runoff. These effluents will be controlled by the protection measures installed for construction and operation. Reclamation and revegetation of the site will ultimately stabilize the soils of any disturbed areas resulting in decreased erosion potential. Secondary impacts to aquatic resources, such as increased fishing may continue throughout site decommissioning activities.

5.2.4.3 Threatened and Endangered Species

The presence of species protected under the Endangered Species Act of 1973 (16 USC Sections 1531-1543) will be confirmed during site characterization studies (described in Section 4.1.3.1.2). If, in continuing consultation with the FWS, it is determined that repository development may adversely affect a protected species, the DOE will initiate appropriate measures to avoid the impact. Species of particular concern include the endangered peregrine falcon (nesting and foraging among cliff habitats of the region), bald eagles (winter roosts), black-footed ferret (associated with prairie dog colonies), the Colorado squawfish (Colorado River and tributaries), and two species of plants, the endangered *Echinocereus triglochidiatus* var. *inermis* and the threatened *Sclerocactus glaucus*.

5.2.4.3.1 Construction. Based on past field studies (BNI, 1984), repository construction activities are not expected to significantly impact any threatened or endangered species. Potential impacts to peregrine falcons, bald eagles, and black-footed ferrets from the development of highway access routes, rail corridors, and a water pipeline from the Colorado River to the repository, have been previously discussed in Section 5.2.4.1.1. Impacts to the Colorado squawfish could potentially occur during construction of one of the four alternative rail routes or from construction of the pipeline.

The Colorado routes A and B potentially have the greatest probability of adversely affecting the Colorado squawfish. In either route alternative, the Colorado River is approached closely and crossed at Potash, near Colorado squawfish nursery areas. However, railroad river crossings will be selected and constructed so as not to physically disturb any squawfish nursery area. Construction of either the Kane Springs or the Spanish Valley routes involve less direct approaches to the Colorado River, except at the river crossings. Any of the alternative routes can be constructed at a time of the year and by such methods so as to avoid any significant impacts to Colorado squawfish nursery areas.

Construction of a water intake structure along the Colorado River may affect Colorado squawfish habitat (particularly nursery areas). Detailed baseline studies and consultation with the FWS will confirm the presence of the fish in the proposed area as well as assist in a final pipeline location. Use of good engineering and drainage and erosion control practices should prevent any possible impacts to Colorado squawfish from increased siltation or sedimentation.

The possible depletion of 10.86 million cubic meters (2.87 billion gallons) of water (construction and operation) from the Colorado River would require consultation with the FWS to develop avoidance or replacement measures. Use of existing allotments of water in lieu of a new pipeline, should cause no impacts to fish and wildlife in the area unless those allotments are exceeded.

5.2.4.3.2 Operation. Subject to final field survey results, no threatened or endangered plant or animal species are expected to be impacted by the operation of the repository in Davis Canyon. No threatened or endangered plant species have been found on or adjacent to the repository site (BGI, 1983, ONWI-470, pp. 5-1, 5-2). The endangered bald eagle and peregrine falcon have been observed approximately 16 to 24 kilometers (10 to 15 miles) from the repository site but they have not been known to nest, roost, or concentrate at the proposed repository site (BGI, 1983, ONWI-470, pp. 4-4, 4-7). No impacts to the endangered fish of the Colorado River will occur since no significant measurable changes in river flow, sediment level, or salinity will result from operational activities; however, because of withdrawal of water from the Colorado River and the presence of endangered species in the river, there will be consultations with the FWS regarding potential impacts.

5.2.4.3.3 Decommissioning and Closure. Decommissioning and closure activities will include a cessation of repository operations, initiation of land reclamation, and other positive impacts upon endangered species and their habitats in the area. A gradual return of extirpated wildlife to the project area will begin at this time.

5.2.5 Air Quality

Repository construction, operation, and decommissioning and closure activities will affect air quality as a result of earthmoving equipment, stationary and mobile diesel-powered equipment, a concrete batch plant, a natural gas-fired steam plant, mine ventilation exhausts, salt handling activities, and windblown dust. This section assesses potential air quality impacts by comparison with National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50). Project-related emissions analyzed are particulates, oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO). To determine compliance with the appropriate NAAQS, particulate and NO_x emissions and their impacts are examined in detail. Effects on air quality-related values (AQRVs) are also considered. Estimated short-term concentrations of SO_2 and CO, based on very conservative analyses, are less than the respective NAAQS (BNI, 1985c). Other than their possible effects on AQRVs (Section 5.2.5.3.4), SO_2 and CO are not considered further.

5.2.5.1 Activities and Emissions

The repository project consists of three periods of activities: (1) construction, which includes the site clearing, surface construction, and underground development phases; (2) operations phase; and (3) decommissioning and closure. Summaries of particulate and NO_x emissions are presented in Tables 5-8 and 5-9, respectively, for the three construction phases and the operations phase (BNI, 1985c). These are the expected maximum annual emission rates based on available engineering descriptions (Sections 5.1.1 through 5.1.4). Source inventory has been changed since the modeling analysis discussed below was performed. The implications of these changes are evaluated in "Evaluation of Air Quality and Noise Impacts Assessments - Davis Canyon" (ONWI, 1986). Although small differences exist, conclusions remain as stated.

5.2.5.1.1 Construction. The primary source of particulate emissions (fugitive dust) during the three repository construction phases is earthmoving activity. Particulate emissions from engine exhausts are included on the earthmoving fugitive dust emission rates. The maximum annual particulate emission is 246 metric tons (271 tons) per year, occurring during the site-clearing phase. As the repository site is developed, emissions from earthmoving activities become progressively less. At the same time, as shown in Table 5-8, other sources of particulate emissions become active. During the underground development phase, emissions of salt particulates occur from load-in and maintenance of the salt storage pile and from two mine vent exhausts.

Particulate emissions due to wind erosion from disturbed areas of the site and from active areas of the salt storage pile are not included in Table 5-8 but are considered in estimating project-related impacts. Maximum annual emissions from disturbed areas and the salt pile are estimated to be 588 and 2 tons per year, respectively. Wind erosion contributes little to the worst case conditions since such conditions are associated with low wind speeds. The determination and application of these emissions is discussed further in Section 5.2.5.2.

Erosion potential from disturbed areas is expected to peak during the site-clearing phase and decrease as the site is developed. During the underground development phase, wind erosion is expected to be minimal because the many surface structures and equipment laydown areas would act as wind breaks. Furthermore, revegetation and paving of most of the remaining exposed areas is planned. Maximum erosion potential from the salt pile is expected from the actively developed areas of the pile, beginning during the underground development phase and lasting about 5 years. (Wind erosion of the small salt pile remaining after site characterization is expected to be negligible because the pile will be covered.)

NO_x emissions increase slightly during the three phases of repository construction due to increased vehicle and other mobile equipment (e.g., graders) activity. Maximum annual NO_x emissions occur during the underground development phase with the initiation of steam plant operations (see Table 5-9).

Table 5-8. Maximum Repository Particulate Emission Rates (tons per year)

Source	Site Clearing[a]	Surface Construction[b]	Underground Development[c]	Operations[d]
Earthmoving (fugitive dust)	271	79	67	21
Concrete Batch Plant	0	15	10	0
Material Handling	0	10	10	3
Salt Handling[e]	0	0	15	15
Mine Vent Exhaust[f] (salt)	0	0	1	9
Mine Vent Exhaust[f] (diesel)	0	0	0	1
Steam Plant	0	0	7	7
Total	271	104	110	56

Note: Emissions from the concrete batch plant, the two mine vent exhausts, and the steam plant are considered to be point sources. All other sources are considered to be area sources.

(a) Maximum emission rate occurs during year 1.
(b) Maximum emission rate occurs during year 3.
(c) Maximum emission rate occurs during years 5, 6, and 7.
(d) Maximum emission rate occurs during years 8 through 26.
(e) Estimate due to salt dumping and equipment working on the pile.
(f) Emissions presented are total mine vent exhaust emissions and are apportioned as follows: 36 percent of the emissions are from the confinement air exhaust stack; 64 percent are released from the unexposed air exhaust filter building.

Source: BNI, 1985c.

Table 5-9. Maximum Repository NO_x Emission Rates (tons per year)

Source	Site Clearing[a]	Surface Construction[b]	Underground Development[c]	Operations[d]
Steam Plant	0	0	100[e]	100[e]
Diesel Equipment, Vehicles	414	448	435	49
Mine Vent Exhaust[f]	0	0	0	20
Total	414	448	535	169

Note: Emissions from the two mine vent exhausts and the steam plant are considered to be point sources. Vehicle emissions are considered to be an area source.

(a) Maximum emission rate occurs during year 1.
(b) Maximum emission rate occurs during year 3.
(c) Maximum emission rate occurs during years 5, 6, and 7.
(d) Maximum emission rate occurs during years 8 through 26.
(e) Calculated at 100-percent utilization and for conventional burners. Burners of newer design would decrease emissions to about 50 tons per year; expected utilization will decrease emissions further, to about 20 tons per year.
(f) Emissions presented are total mine vent exhaust emissions and are apportioned as follows: 36 percent of the emissions are from the confinement air exhaust stack; 64 percent are released from the unexposed air exhaust filter building.

Source: BNI, 1985c.

5.2.5.1.2 Operation. Particulate emissions during the operations phase are similar to those of the underground development phase except that earthmoving equipment fugitives are much smaller than those projected for underground development (see Table 5-8). Wind erosion of disturbed areas is expected to be negligible. Wind erosion from active areas of the salt pile would occur until the pile is filled to capacity, probably in the first year or two. The pile would be covered thereafter. NO_x emissions are noticably less during this phase, primarily due to decreased vehicle and mobile equipment activity (see Table 5-9).

5.2.5.1.3 Decommissioning and Closure. Particulate emissions during repository decommissioning will result from earthmoving equipment, stockpile removal, transport of salt, and fracturing of concrete structures and other facilities. Impacts from decomissioning are not modeled. Water sprays will be used to contain fugitive dust during decommissioning; disturbed areas will be revegetated and reclined as described in Section 5.1.4.1. It is expected that these activities can be scheduled and emissions controlled, to the extent necessary to prevent exceedances of the NAAQS.

Particulate and NO_x emissions are expected to be insignificant during repository closure, and they are not modeled.

5.2.5.1.4 Mitigation. The mitigation measures for fugitive dust and mobile NO_x emissions discussed in Section 4.2.1.3.1 will be taken during the repository phases. The control program has established a goal of 90 percent for fugitive dust, to be accomplished primarily by the application of water and chemical suppressants to disturbed areas and haul roads. Additional controls may be applied such as speed controls on earthmoving vehicles and haul trucks, paving haul roads, minimizing the size of disturbed areas, and covering storage piles. Control of NO_x emissions from diesel exhaust will be as required of manufacturers by federal regulations. Inspection and maintenance of these controls by contractors will be a project requirement.

Mitigative measures are required to reduce the amount of particulate salt emissions associated with the salt storage pile. Salt will be conveyed from the service shaft to the pile in a totally enclosed conveyor/transfer system. Salt pile load-in emissions will be reduced by using a wind guard to minimize the drop height of salt through the free air. Wind erosion emissions from the salt pile will be reduced due to the natural crusting tendency of salt (Ver Planck, 1958). Crusting will be promoted by daily watering of the pile. Inactive areas of the salt pile will be covered (e.g., with dirt or asphalt). The application of these control measures is accounted for in the modeling of total suspended particulates (TSP) and salt deposition impacts in BNI (1985c). After the salt pile is filled to design capacity, hauling of excess salt to offsite disposal areas will require load-in of railcars and trucks. These activities will occur in enclosed areas. Transport vehicles will be covered.

5.2.5.2 Methodology

The EPA Industrial Source Complex Dispersion Model (ISC) (Bowers et al., 1979) was used to estimate atmospheric concentrations of TSP and NO_2, and deposition of salt particles around the site area. ISCST (short-term) was used to estimate 24-hour average TSP concentrations. ISCLT (long-term) was used to estimate annual average TSP and NO_2 concentrations and total annual salt deposition. The rationale for selecting this model, the meteorological input data, and the background TSP and NO_2 concentrations for determining air quality impacts (21 and 10 micrograms per cubic meter, respectively) are discussed in Section 4.2.1.3.2.

Emissions during the site clearing and operations phases (Table 5-8) were used to model 24-hour and annual TSP impacts. Emissions during the underground development and operations phases (Table 5-9) were used to model annual NO_x impacts. The site clearing and underground development phases represent the periods of maximum expected impacts during the repository project for TSP and NO_2, respectively.

Emissions during the operations phase (Table 5-8) were used to model annual salt deposition rates around the site area. Similar impacts are expected during the subsurface development phase as discussed below.

5.2.5.2.1 Construction. Particulate emissions during site clearing were modeled as area sources (BNI, 1985c). On a 24-hour basis, fugitive emissions due to earthmoving and related activities were assumed to occur over a disturbed area of 40.5 hectares (100 acres) on any given day (10.1 hectares [25 acres] are considered to be actively scraped and compacted; the remaining 30.4 hectares [75 acres] are less active with hauling and related equipment activities). For modeling purposes, a nominal repository site area of 163.8 hectares (405 acres) was represented by a square 1,280 meters (4,200 feet) on a side. Wind erosion emissions were conservatively assumed to occur over the entire repository site area, which implies the entire site had been previously disturbed. Wind erosion was assumed to occur only when the wind speed at the eroding surface exceeded the threshold of 12 miles per hour (EPA, 1978).

On an annual basis, both earthmoving and wind erosion fugitive particulate emissions were assumed to occur over the entire 163.8-hectare (405-acre) modeled area as site clearing activities progress during the year.

Wind erosion emissions from disturbed areas were calculated using a predictive emission factor equation (EPA, 1978). The emissions are a function of surface erodibility, soil silt content precipitation-evaporation index, and wind speeds above the threshold value given above.

The ISC model allows input of a particle size distribution to account for the variable effects of deposition in estimating both concentrations and total deposition. The distribution used in these analyses is adapted from the results of fugitive dust measurements at western surface coal mines and is discussed in BNI (1985c). This distribution was used for all sources of particulate emissions (fugitive dust and salt).

Annual NO_x emissions from mobile sources were assumed to occur over the 163.8-hectare (405-acre) modeled area during the underground development phase. The steam plant was modeled as a buoyant, elevated point source (BNI, 1985c).

5.2.5.2.2 Operation. Particulate emissions were modeled as a combination of area and point sources (BNI, 1985c). On a 24-hour basis, emissions due to vehicle movement and materials handling activities were assumed to occur over the 163.8-hectare (405-acre) modeled area. Salt handling emissions were modeled as an area source and assumed to occur over 10 percent of the total surface area of the salt pile (or about 5 acres), on any given day. This represents a reasonable estimate of the area which would be subject to wind erosion; that is, the active area over which freshly loaded salt may be moved as the pile is built. The remainder of the pile will be either covered or undeveloped. Mine vent exhausts from the confinement and unexposed air exhaust filter buildings were modeled as point sources. Salt and particulate emissions were combined and apportioned to each of the mine vent exhaust points as discussed in Table 5-8. The steam plant was modeled as a buoyant, elevated point source.

Annual particulate emissions from these sources were modeled in the same manner except for salt handling and wind erosion of the active salt pile area. Emissions from these sources were assumed to occur over 20 percent of the total surface area of the salt pile; this represents one-fifth of the 5-year period required to fill the salt pile to capacity.

Wind erosion emissions from active areas of the salt pile were calculated using a predictive emission factor equation for active storage piles (EPA, 1983). The emissions are a function of salt content, the frequency of precipitation, and wind speeds above the threshold value of 12 miles per hour at the eroding surface.

Annual NO_x emissions from the steam plant and from mine vent exhausts were treated as point sources. Table 5-9 describes the apportionment of emissions between the two mine vent exhaust points. NO_x emissions from vehicle exhausts were assumed to occur over the 163.8-hectare (405-acre) modeled area (BNI, 1985c).

Because of the elevated sources (steam plant and mine vent exhaust), the Valley Model was used to model NO_x emissions during the operations phase. The Valley Model was developed for the analysis of impacts of elevated sources in complex terrain. In such situations, maximum concentrations are likely to occur on elevated terrain during periods of stable atmospheric conditions.

5.2.5.3 Air Quality Impacts

This section addresses the results of the air quality modeling analyses. Additional details appear in BNI (1985c).

5.2.5.3.1 Regulatory Review. The threshold criterion in determining prevention of significant deterioration (PSD) applicability is whether a facility is a "major source" of criteria air pollutants. The sources of particulate and NO_x emissions discussed earlier are not included in the list of 28 major stationary sources subject to an emission limitation of 90.8 metric tons (100 tons) per year. To be considered a major source, project-related stationary-source emissions would have to be greater than 227 metric tons (250 tons) per year. (See Utah Air Conservation Regulations, Section 1.1.75).

Stationary sources of particulate emissions during repository construction and operation include the concrete batch plant, the mine vent exhausts, and the steam plant. All other particulate emissions are fugitive emissions and are therefore not considered in the major source determination (see 40 CFR 52.21[b][1][iii]).

Stationary sources of NO_x emissions during repository construction and operation include the steam plant and mine vent exhausts. All other NO_x emissions are due to nonstationary mobile sources. Table 5-9 indicates that stationary emissions reach a maximum of only 120 tons per year during repository operation and are less during all other phases.

The DOE concludes that the repository project is not subject to PSD requirements because stationary-source emissions do not exceed the threshold limit of 227 metric tons (250 tons) per year.

Utah Air Conservation Regulations (UACR) require the following:

1. The State must be provided with a notice of intent prior to construction of a facility.

2. Because the site is located adjacent to a national park, the Federal Land Manager (FLM) will be provided an opportunity to prepare an analysis of whether the proposed repository construction and operation activities will have an adverse impact on the AQRVs of Canyonlands National Park.

3. The FLM will review the extent, duration, magnitude, and frequency of impacts to AQRVs from project emissions.

4. If the FLM finds adverse impacts from project emissions and the UBAQ agrees, the UBAQ will not issue an approval order for the project.

The Davis Canyon site area has been designated by the EPA as "attainment" for particulates. Consequently, all new major sources are subject to a PSD review. This review includes demonstrating that the applicable SO_2 and TSP increments are not exceeded. In the State of Utah, once the baseline for the area has been "triggered," nonmajor sources are also required to demonstrate compliance with the increments. However, the baseline in the Davis Canyon site area has not been triggered because no approval order for a major source has been issued by the State for this area. Furthermore, the repository project itself is not a major source. In a regulatory sense, project-related particulate concentrations would add to the existing baseline rather than consume increment. The above discussion applies to the evaluation of applicability of PSD increments to both the repository construction and operation phase.

In permit review, the State of Utah does not normally require that construction-related fugitive dust be included in its computation of increment consumption. By excluding construction-related fugitives, the DOE estimates that the 24-hour maximum TSP increase at the park boundary would be much less than the 10 micrograms per cubic meter permitted at the boundary of a Class I area for all phases of repository construction. Consequently, the PSD increment at the park boundary (even if applicable) would not be violated during repository construction. This discussion of the treatment of construction-related fugitives does not apply to the operation phase.

In the interpretation of the modeling results presented below, air quality impacts are considered to be significant if (1) the NAAQS are exceeded, i.e., those ambient concentrations which "...allowing an adequate margin of safety, are requisite to protect the public health" and those levels which "...are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air" (EPA, 1971); (2) there are adverse effects on air-quality-related values; or (3) there are detectable increases in ambient concentrations of criteria pollutants within Canyonlands National park.

5.2.5.3.2 Uncertainties. Prior to discussing modeling results, it is important to point out that there are uncertainties associated with the air quality impact analysis:

1. Particulate Emission Rates. Emission factors, particle size distributions, and control factors used to estimate particulate emission rates are drawn from the published literature. While the DOE considers that these data are the best available for use in the impact analysis, the DOE recognizes that there are uncertainties inherent in their use. For example, fugitive dust emission factors are based on limited measurements at other locations and for other types of earth-moving activities where natural soil characteristics such as silt and moisture content are different from those existing at the site. Particle size distributions from studies of western coal mines were used for both fugitive dust and salt emissions. Dust control efficiency values (50 percent using water application and vehicle speed limits, and 90 percent using chemical suppressant application and vehicle speed limits) can involve errors. The DOE believes the values used herein are achievable with a well designed and carefully conducted mitigation program. Uncertainties inherent in emission rate estimates have not been quantified; they could result in either higher or lower air quality impacts.

2. Offsite Meteorological Data. The meteorological data are from off site, and while the Salt Wash Tower is located in an area similar to that of Davis Canyon, because meteorological conditions are complicated at both locations by different complex terrain, there are limitations to their representativeness. The DOE believes that the Salt Wash Tower data are reasonably representative and the best available for use in the impact analysis. Uncertainties inherent in the use of offsite meterological data have not been quantified; they could result in either higher or lower air quality impacts.

5.2.5.3.3 Estimated Concentrations. The highest and second-highest 24-hour TSP concentrations offsite were estimated. The second-highest offsite values are reported as maximums for comparison with the 24-hour NAAQS, which are not to be exceeded more than once per year. EPA recommends the use of the highest offsite 24-hour TSP concentrations for comparison with the applicable NAAQS standard whenever 1 year of meteorological data is used (as opposed to the second highest value when 5 years of data are employed). This comparison is presented in "Evaluation of Air Quality and Noise Impact Assessments - Davis Canyon" (ONWI, 1986). It will be seen in that report that the conclusions presented here remain unchanged as a result of that comparison.

The highest annual offsite concentrations of TSP and NO_2 are also reported. "Offsite" refers to points at or beyond the controlled area boundary (CAB), as presented in Figure 5-2. Maximum concentrations at the Canyonlands National Park boundary were also estimated.

Maximum 24-hour TSP, and annual-average TSP and NO_2 concentrations at the CAB and at the park boundary are summarized in Table 5-10. Values presented include background values identified in Section 3.4.3.1.

Impacts of NO_2 were modeled with the Valley Model as well as ISC to determine the maximum impact associated with the steam plant (elevated point source) during the operations phase. As expected, maximum concentrations estimated by the Valley Model were from impact of the elevated plume on high terrain at the CAB and the park boundary. The maximum offsite annual average NO_2 concentration is estimated to be 22 micrograms per cubic meter (0.62 microgram per cubic foot). The corresponding value at the nearest park boundary is 13 micrograms per cubic meter.

5.2.5.3.4 Estimated Salt Deposition. Annual salt deposition rates were estimated using the methodology discussed in Section 5.2.5.2. Estimated salt deposition approximately 1 kilogram per hectare (0.9 pound per acre) at approximately 700 meters (2,300 feet) from the salt pile on an annual basis. Deposition rates diminish rapidly with distance, to approximately 0.1 kilogram per hectare (0.09 pound per acre) 1 to 2 kilometers (0.6 to 1.2 miles) from the salt pile. A more detailed discussion of the results is presented in BNI (1985c). Impacts resulting from these deposition rates are discussed in Section 5.2.10.

A qualitative evaluation has been made of the potential effects on the dispersion of salt from a tornado striking the salt storage pile. The amount of salt transported by a tornado would depend on the size, intensity, and speed of the tornado; state or condition of the salt pile; and threshold velocity at which salt aggregate would be lifted from the pile.

In the Davis Canyon site area, the recurrence interval for a tornado striking any point is once in 13,000 years (see Section 3.4.3.3). Considering that the salt pile will be developed to its capacity in about 5 years, and will be covered thereafter, the likelihood of a tornado's damaging the pile is quite small. However, should such an event occur, maximum deposition may occur anywhere from 10 to 60 kilometers (about 6 to 37 miles) downwind of the site (BPNL, 1979, DOE/ET-0029, Vol. 1). Point deposition values within this area may be significantly greater than the maximum annual deposition rate reported above for normal meteorological conditions.

5.2.5.3.5 Impact on Park AQRVs. The National Park Service, through the FLM, will review the frequency, duration, extent, and magnitude of impacts on AQRVs when evaluating the proposed project (NPS, 1982). AQRVs include: visibility, odor, night sky brightness (skyglow), flora, fauna, soils; and archaeological, historical, cultural, geological, and water quality resources (NPS, 1983).

Visibility. Section 169A of the Clean Air Act requires visibility protection for mandatory Class I areas where it has been determined that visibility is an important value (42 USC Section 7491). Canyonlands National Park, a Class I area, is less than 1.6 kilometers (1 mile) west of the Davis Canyon site. A Level-2 visibility analysis was performed to assess visibility impairment to the park (BNI, 1985c). Specifically, this analysis quantifies visual impairment in terms of atmospheric discoloration from NO_x, particulates, and secondary aerosols, and visual range reduction (increased haze from particulates and sulfates). The analysis was performed in accordance with the technical guidance provided in EPA (1980).

The Level-2 analysis considers: worst case atmospheric conditions ("1% meteorology"), particulate size distribution, and topography. The worst case 1 percent meteorology chosen was "F" stability and 1 meter-per-second wind speed.

The particle size distribution assumed is the same as was used in the air quality analysis (BNI, 1985c) and is representative of fugitive dust emitted from site clearing and construction activities.

Table 5-10. Air Quality Impacts During Repository Construction and Operation, Davis Canyon

Pollutant	Averaging Time	Location	Maximum Concentrations (micrograms per cubic meter)		NAAQS (micrograms per cubic meter)
			Construction	Operation	
TSP	24-hour	CAB[a]	124[b]	30	260/150[d]
		Park boundary	64[b]	29	260/150[d]
TSP	Annual	CAB	30[b]	22	75
		Park boundary	24[b]	22	75
NO_2	Annual	CAB	38[c]	22	100
		Park boundary	22[c]	13	100

Note: Background TSP value is 21 micrograms per cubic meter.
Background NO_2 value is 10 micrograms per cubic meter.

(a) Controlled area boundary (see Figure 5-2).
(b) Site clearing phase.
(c) Underground development phase.
(d) Primary standard/secondary standard.

Sources: BNI, 1985c; 40 CFR Part 50.

Other conservative assumptions made in the analysis were:

1. All vistas were assumed to be potentially impacted at all times of the day.

2. A range of scattering angles covering backscatter, forward scatter, and side lighting of the plume were used.

3. There was no gravitational settling of particulates.

4. Given the rather large size of the fugitive particulates (greater than 1.5 microns) scattering coefficients show little wavelength of light was considered.

5. All nitrogen oxide emissions were assumed to be converted to the obscuring compound NO_2.

6. The assumed geometry has the observer located at the boundary of Canyonlands National Park looking out toward Davis Canyon through a "plume" of maximum construction emissions.

The results of the Level-2 analysis indicate that visibility impacts (atmospheric discoloration) would probably be imperceptible for the Davis Canyon site, i.e., the absolute value of the Level-2 derived plume contrast index, or contrast reduction value, is less than the threshold value for visibility impairment, 0.1.

Night Skyglow. Field measurements of luminance around the horizon from various locations in the Canyonlands area were made in the summer of 1985 (BNI, 1985c). The purpose of the study was to determine existing levels of night skyglow. Luminous sources such as Moab were found to be barely visible during moonless conditions, 25 to 50 percent above natural background levels (BNI, 1985c).

A reasonable acceptability criterion for an additional luminous source, such as the repository, is that its magnitude be no more than that of existing sources. Planned illumination levels from repository operations would be designed to meet this criterion by implementing mitigation techniques such as infrared surveillance of large open areas (BNI, 1985c).

Two work shifts (16 hours per day) are scheduled for repository construction. Construction lighting will be used for a few hours each day at twilight. The requirement will be least during the summer season when days are longest. Construction lighting would be dimmed during the 8-hour period of greatest darkness, centered around midnight. Impacts on night sky brightness (skyglow) from this source have not been quantified. Impacts on night sky brightness would, however, be limited to brief periods each day, only during repository construction.

Other Impacts. Except for engine exhaust near equipment, no odorous emissions are expected during repository construction and operation.

The only emissions with potential to impact soils and vegetation in the park are salt particles from salt handling and wind erosion of the salt pile. Salt handling impacts are discussed in Section 5.3.5. Impacts from project air emissions on vegetation, flora, fauna, and soils are expected to be negligible (BNI, 1985c).

Impacts of air emissions to archaeological, historical, cultural, and water quality resources are projected and discussed in Sections 5.2.8 and 5.2.2.

Conclusions. The results indicate that the primary and secondary 24-hour NAAQS for TSP, and the annual NAAQS for TSP and NO_2, will be met during repository construction, operation, and decommissioning and closure. The primary NAAQS were established to protect the public health with an extra margin for safety. The secondary NAAQS were established to protect the public welfare (e.g., environmental and economic interests, visibility and climate, and personal comfort).

There will be significant impacts on air quality in the park, such as temporarily increased ambient levels of TSP and NO_2, particularly during site clearing. The particulate emissions will consist mainly of native soils, and impacts will be temporary. Salt impacts are expected to be negligible. Except for possible temporary impacts from construction lighting, night skyglow from project luminous sources should be no more than that from existing sources.

On this basis, the DOE concludes that the repository project will not have a significant impact on air quality in general, but will have significant but temporary impacts on the air quality in the park.

5.2.6 Aesthetic Conditions

This section contains a discussion of the potential impacts on the visual character of the landscape from the introduction of large structures and associated development into the Davis Canyon area. Potential project facilities affecting aesthetic conditions include waste handling facilities, mine support facilities (headframes, salt storage pile, ventilation exhaust, and supply buildings, etc.); administration and support buildings; utilities and utility support facilities; and rail and access road corridors (see Section 5.1).

5.2.6.1 Construction

During construction, activities potentially affecting aesthetic conditions include surface preparation and grading as well as erection of the repository surface facilities. Major buildings will be constructed of steel and concrete. Fugitive dust emissions will result from activities such as excavation, movement of major equipment, and traffic on unpaved roads. However, this dust will be visible from offsite vantage points for short periods and they will dissipate before reaching offsite locations. State-of-the-art dust control methods will be used to control dust.

Apart from normal earthmoving machinery, the most visible features during construction will be the concrete batch plant and cranes. However, activities requiring this machinery will be temporary and visual impacts will be of short duration. Impacts to air quality and night lighting are discussed in Section 5.2.5.1.

5.2.6.2 Operation

The visibility and visual contrast of repository activities, the access road, and the four railroad route alternatives are presented in this section. As discussed in Section 4.2.1.7, these analyses were based on the Bureau of Land Management's (BLM) Visual Resource Management (VRM) program and the United States Forest Service (USFS) VIEWIT computer program. Using the VIEWIT Program the potential visibility, or line-of-sight, of specific structures or features are mapped from selected viewing positions (Travis et al., 1975). Visual contrast ratings were developed following determination of potential visibility (BLM, 1985). A description of the specific methodologies used is described in Section 4.2.1.7.

As discussed in that section, the VRM classes in the project area had already been determined by the BLM according to scenic quality, distance zone and sensitivity level. The proposed repository site is classified as Class B scenery, is within the foreground/middle-ground distance zone, and has a high sensitivity level, qualifying it for VRM Class II. The VRM class inventory for the railroad routes is presented in Table 5-11 and Figure 5-16.

5.2.6.2.1 Viewshed Analysis. Viewsheds of repository structures and activities were plotted using the VIEWIT computer program to identify land surface from which they could be potentially seen. For the access road and the railroad routes, viewsheds covering the entire length of each were mapped from 18 key observation points (KOPs) selected to determine how much of these linear features would be seen from the KOPs. The KOPs, their locations, and the VRM Class in which they are located, are listed in Table 4-25 and shown in Figure 5-16.

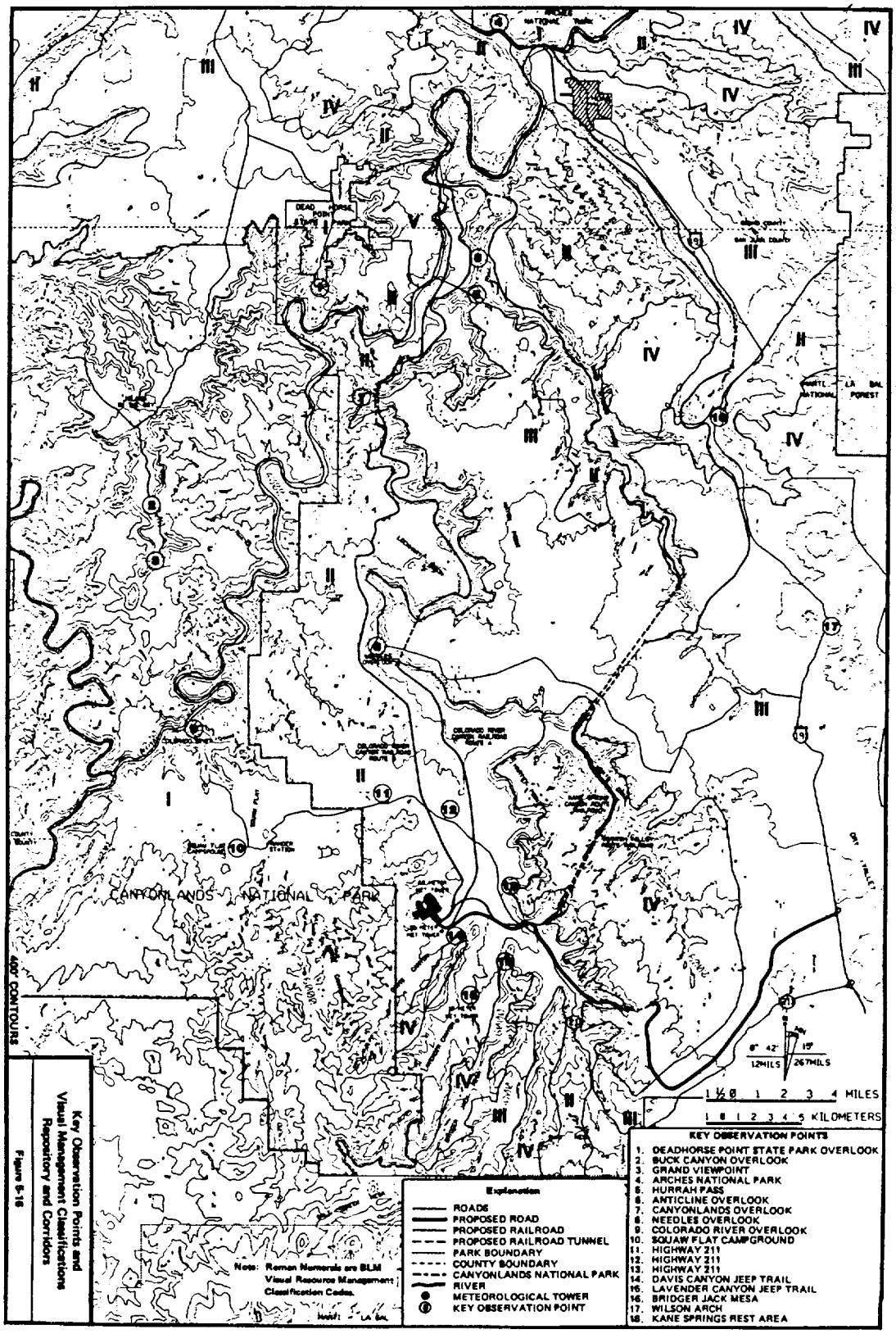
Table 5-11. Summary of VRM Inventory Data for Railroad Route Alternatives from Potash, Davis Canyon Site

Railroad Route (feet)[a]	Scenic Quality[b] Class	Distance Zone[c]	Sensitivity[b] Level	VRM Class[c]
Colorado River Canyon Route A				
0-2,000	A	FG/MG	High	II
2,000-199,000	A	FG/MG	High	II
Colorado River Canyon Route B				
0-9,000	B	FG/MG	High	V
9,000-204,600	A	FG/MG	High	II
Spanish Valley Route				
0-19,000	B	FG/MG	High	II
19,000-118,000	C	FG/MG	High	III
118,000-140,000	B	FG/MG	High	II
140,000-202,000	C	FG/MG	High	III
202,000-250,000	C	FG/MG	Low	IV
250,000-285,000	B	FG/MG	High	II
Kane Springs Route				
0-9,000	B	FG/MG	High	V
9,000-92,000	B	FG/MG	High	II
92,000-131,000	B	SS	High	II
131,000-163,000	C	FG/MG	High	III
163,000-210,000	C	SS	Low	IV
210,000-244,100	B	FG/MG	High	II

(a) Potash Branch connection is Station 0.
(b) See Section 3.4.5 (Aesthetic Resources) for description of term.
(c) See Section 4.2.1.7 (Table 4-24) for description of term.

Sources: Meiiji Resource Consultants, 1980; Environmental Associates, 1978; BLM, 1985.

A larger reproduction of this figure appears at the back of this volume.



Key Observation Points and Visual Management Classifications Repository and Corridors

Figure 5-16

Three structures, the salt stockpile, and the site itself were selected for the repository viewshed mapping, because they incorporate the full range of vertical structures and horizontal area covered by the facility:

- 80.8-meter (265-foot) service shaft headframe
- 54.9-meter (180-foot) waste shaft headframe
- 21.3-meter (70-foot) waste packaging facility
- 11-meter (34.7-foot) salt stockpile
- Repository ground-level activities.

The 60-meter (197-foot) and 10-meter (33-foot) meteorological towers were also selected for viewshed mapping. Their viewsheds are displayed in Figures 4-30 through 4-34 and discussions concerning their visibility are in Section 4.2.1.7.

The repository viewsheds listed below are displayed as figures in this section:

Figure 5-17 Composite Viewshed: Service and Waste Shaft Headframes
Figure 5-18 Viewshed: Waste Packaging Facility
Figure 5-19 Viewshed: Salt Stockpile
Figure 5-20 Viewshed: Ground Level Activities.

The shaded areas on these figures represent the area(s) from which the particular repository activity can be seen. As an example, in Figure 5-18, a person standing any place within the shaded area, could potentially see some portion of the waste packaging facility. Since only key observation point #14 (Davis Canyon Jeep Trail) is in the shaded area, the waste packaging facility is only potentially visible from this key observation point.

Of the viewsheds mapped from KOPs #1 through #18, and used in assessing the visibility of the proposed access road and the four proposed rail routes, two were selected to illustrate the viewshed process:

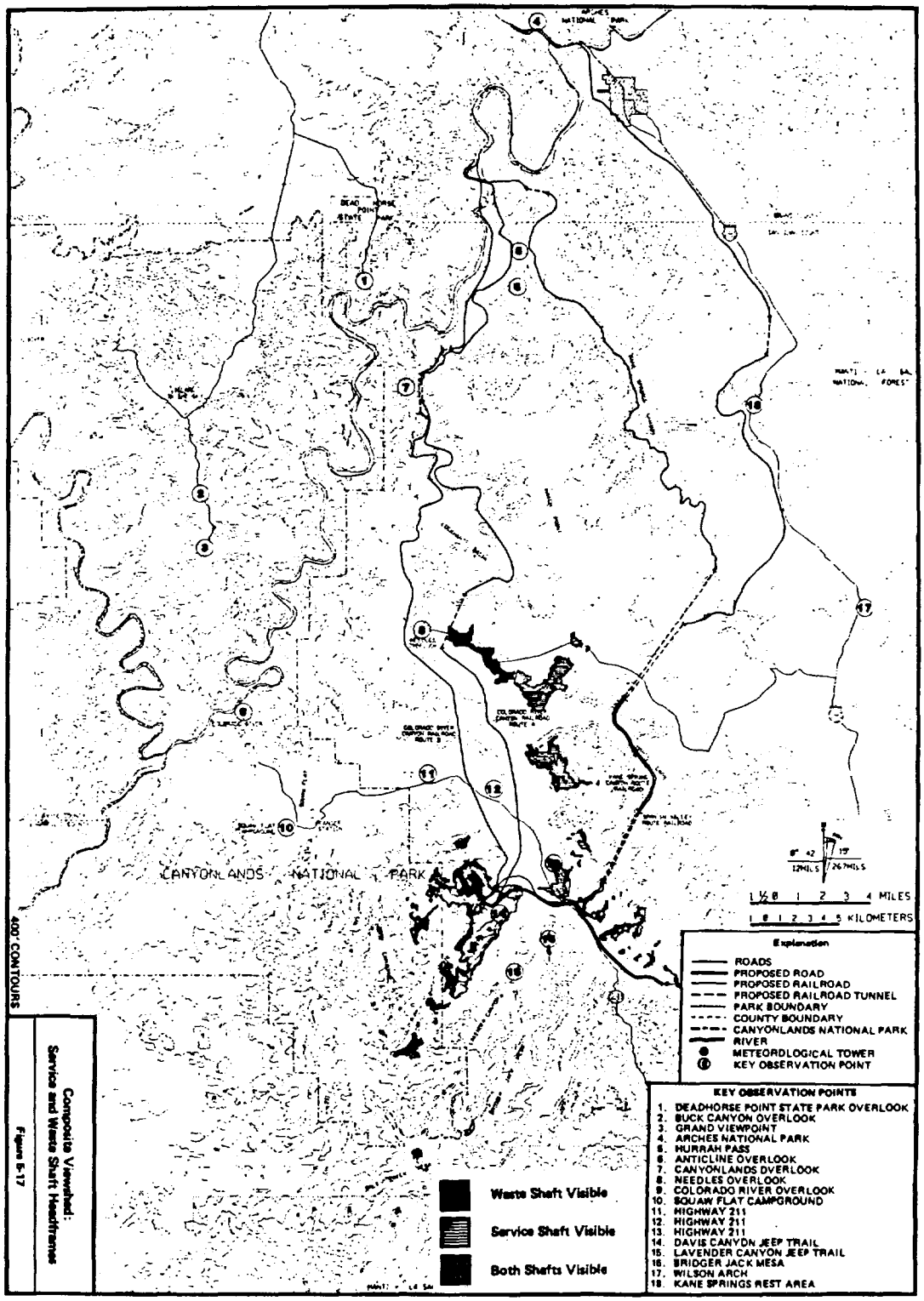
Figure 5-21 Viewshed: Dead Horse Point Overlook (KOP #1)
Figure 5-22 Viewshed: Needles Overlook (KOP #8).

These KOPs were chosen because they are two of the more popular viewpoints due to their accessibility and topographic prominence. The figures illustrate the areas potentially visible if one were standing at these key observation points. Both figures indicate that none of the repository activities evaluated in this analysis are visible from the Dead Horse Point Overlook nor the Needles Overlook.

Repository Visibility. The repository facility is potentially visible from three KOPs: Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16). As discussed below, individual repository activities are potentially visible from limited areas within Canyonlands National Park. These areas receive little visitor use because there are not designated hiking or jeep trails leading to or within them. Table 5-12 shows the specific repository facility activities visible from these KOPs.

Visibility of Individual Repository Activities: The service shaft headframe is potentially visible from a total area of 36.3 square kilometers (14.0 square miles); and the waste shaft headframe from 26.7 square kilometers (10.3 square miles) (Table 5-13, Figure 5-17), including: the Davis Canyon Jeep Trail (KOP #14); the northern tip of Bridger Jack Mesa (KOP #16); portions of the northwestern and southewestern edge of Harts Point; portions of the southern edge of Hatch Point, with some adjacent land in Harts Draw; approximately 3.6 kilometers (2.2 miles) of the access road to Needles Overlook; and two isolated areas of high ground within Canyonlands National Park (one around the head of the north fork of the wash in Davis Canyon; the other on the north side of Cedar Mesa), where visitor use is minimal.

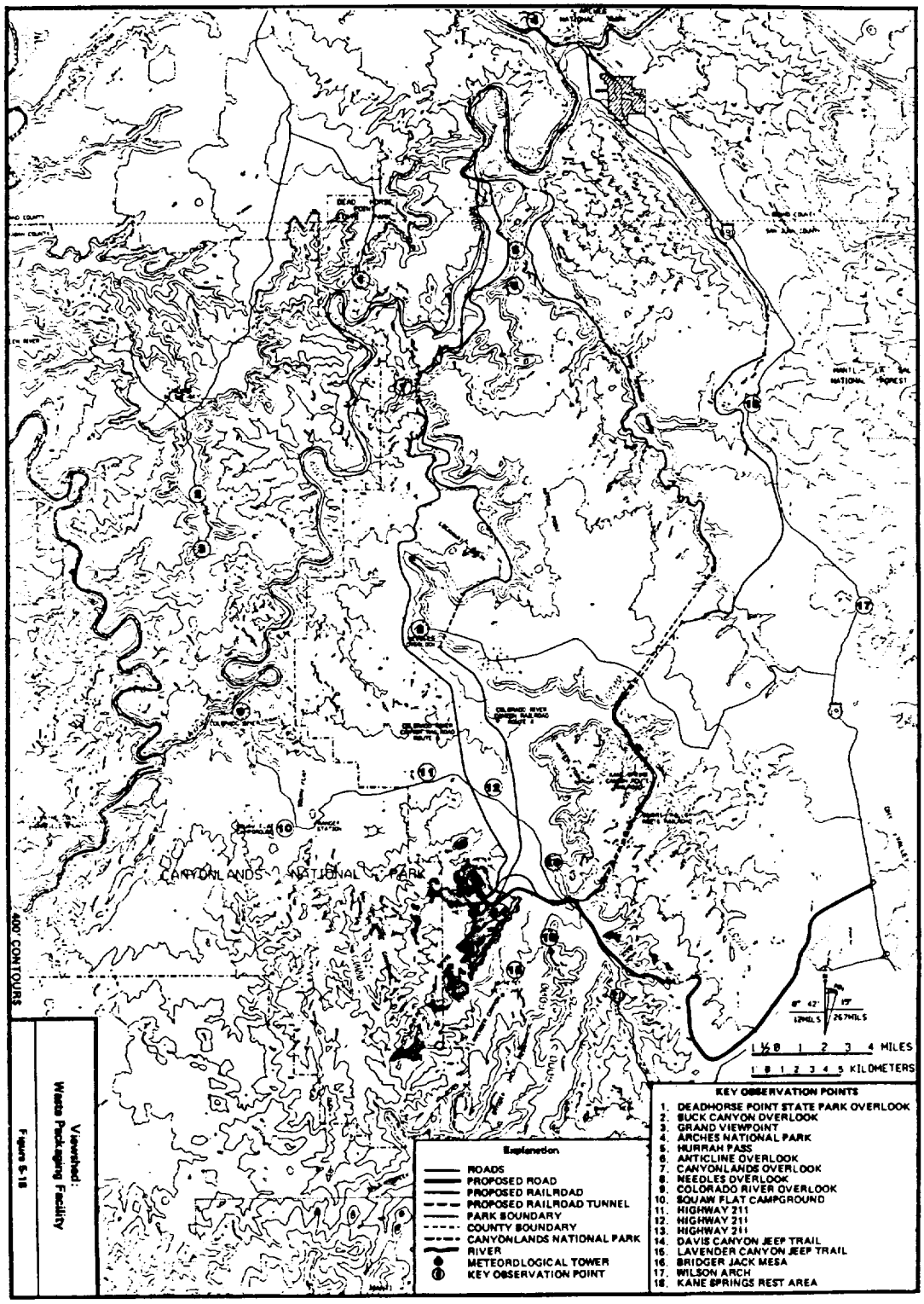
A larger reproduction of this figure appears at the back of this volume.



Composite Viewshed: Service and Waste Shaft Headframes

Figure 5-17

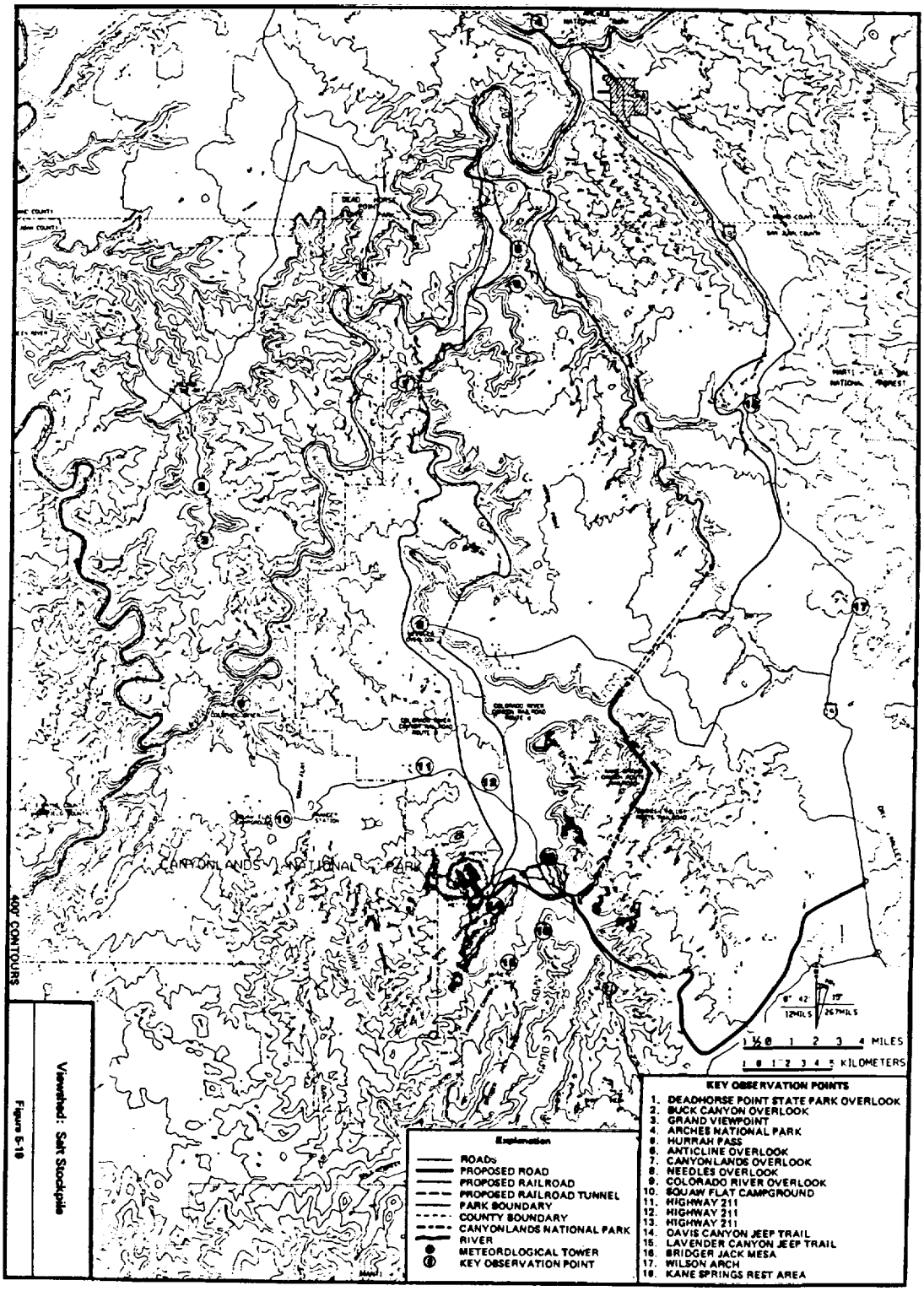
A larger reproduction of this figure appears at the back of this volume.



Viewshed: Waste Packaging Facility

Figure 5-18

A larger reproduction of this figure appears at the back of this volume.



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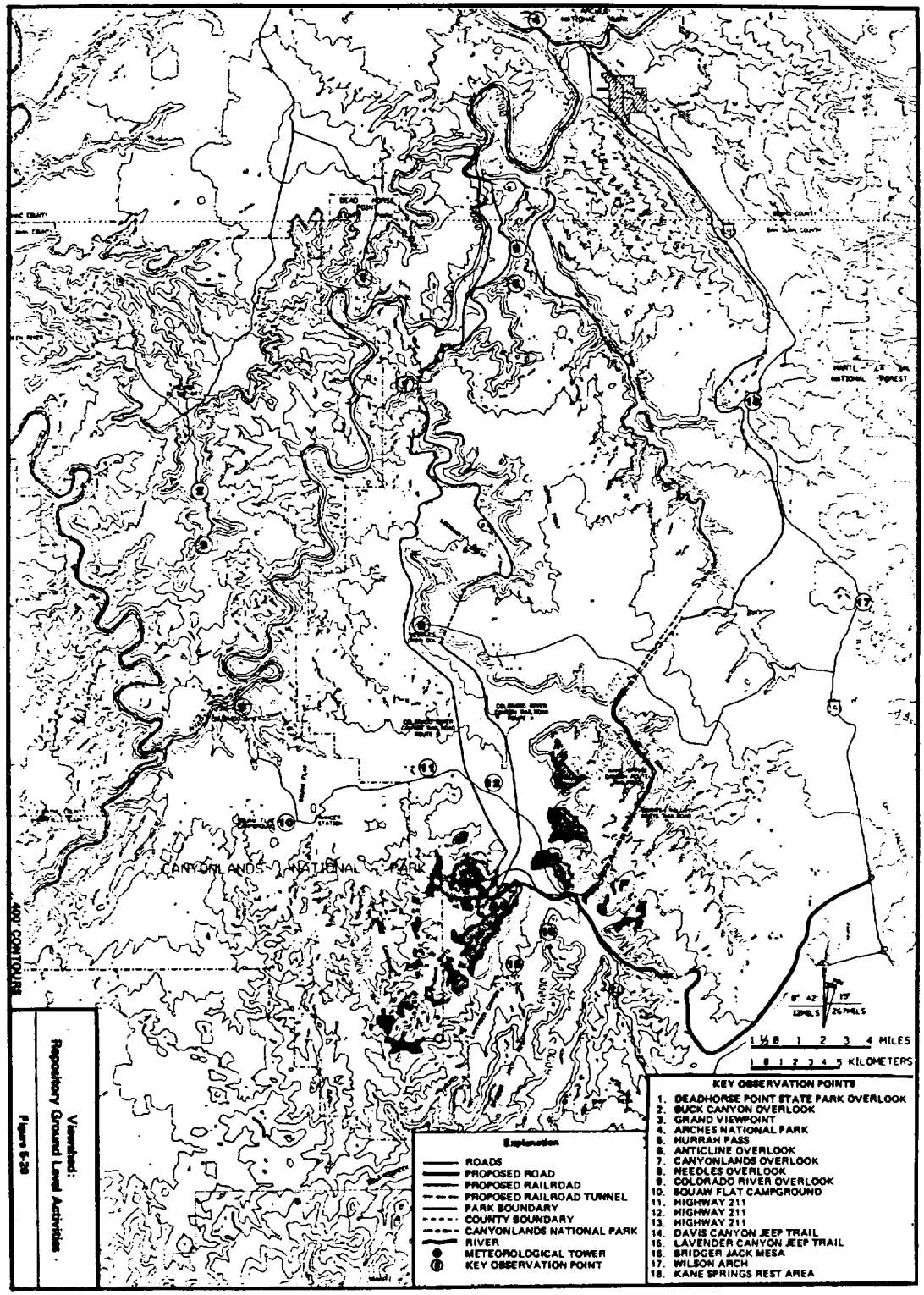

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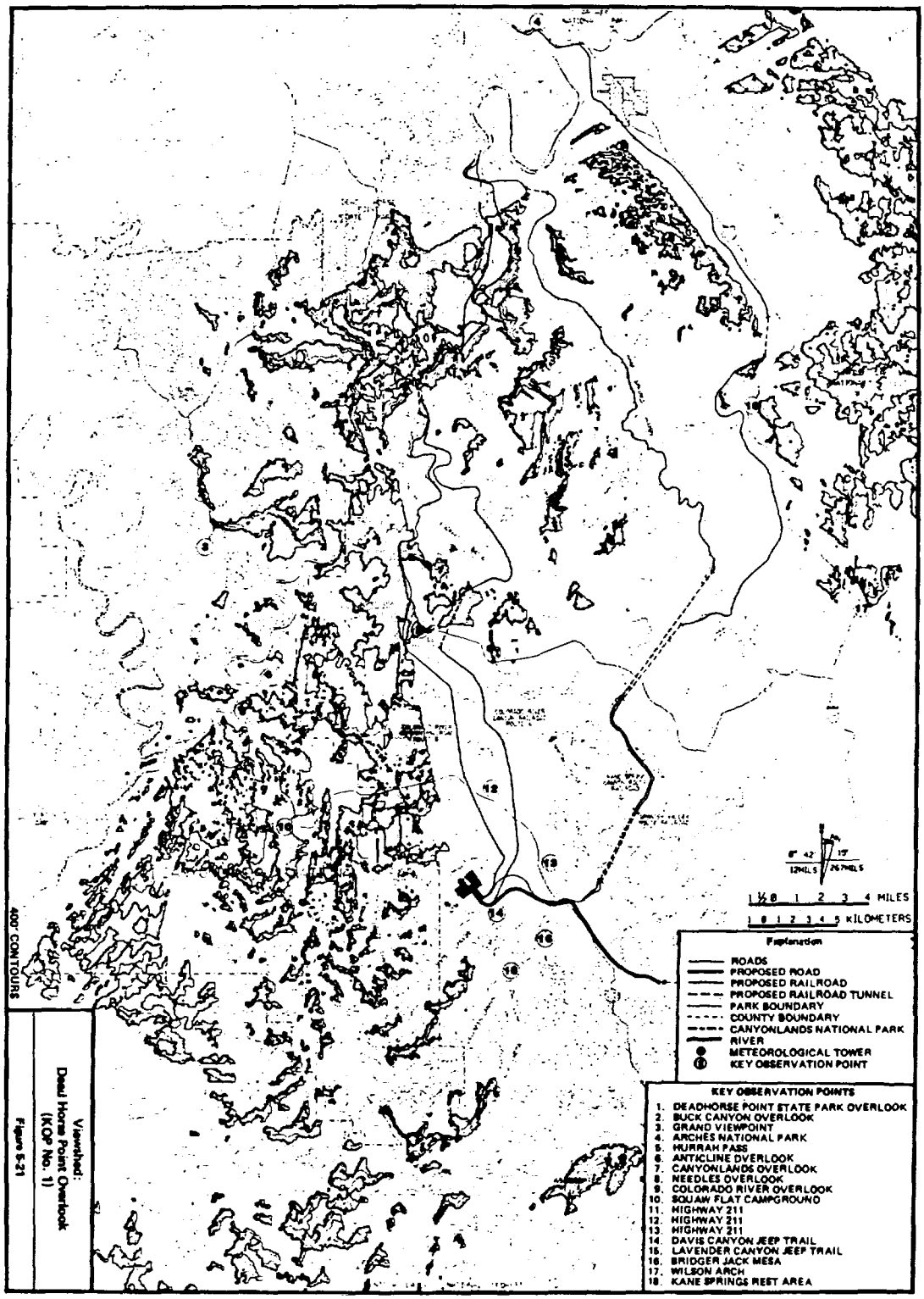

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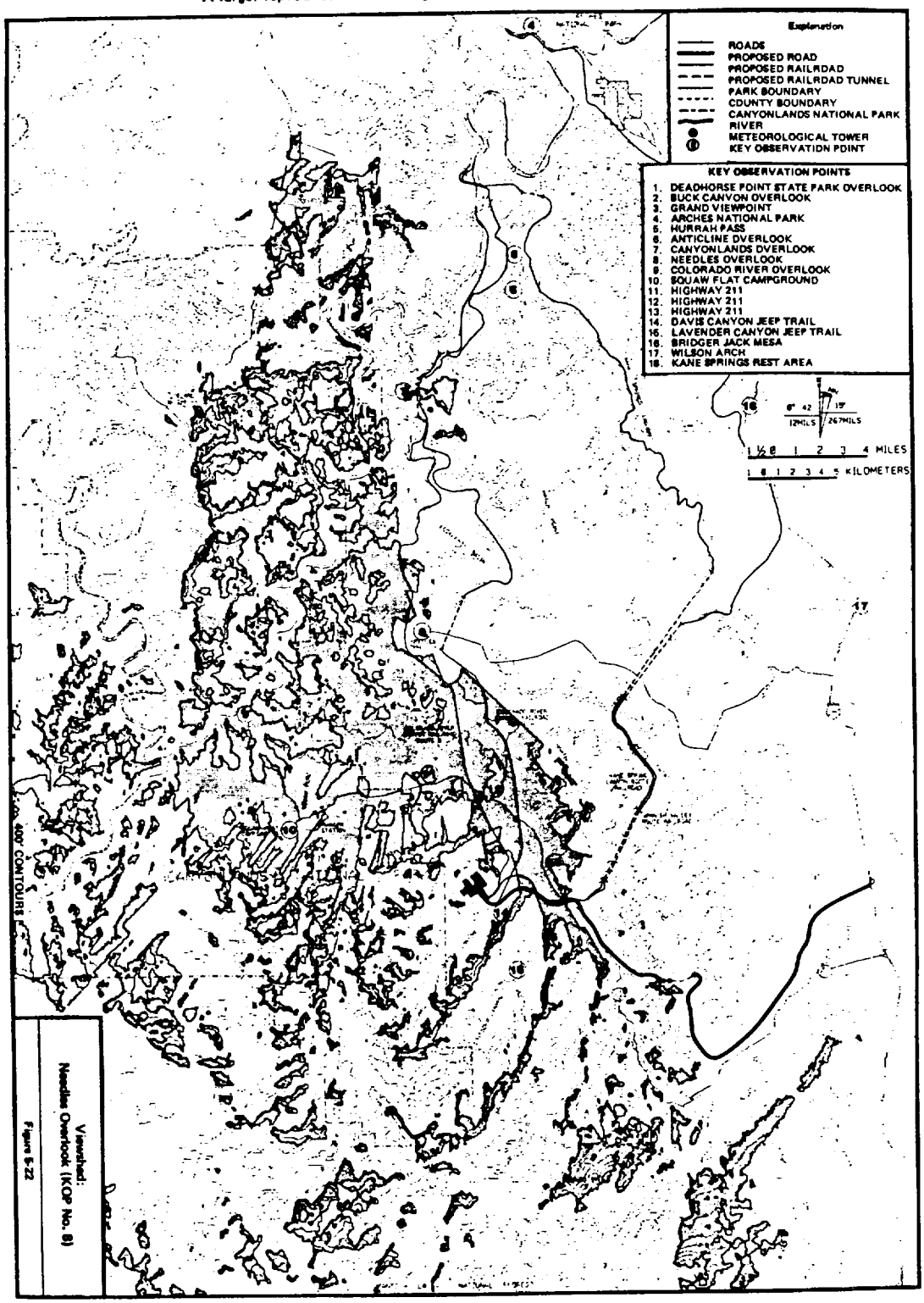


Table 5-12. Potential Visibility of Repository Facility from Key Observation Points

KOP No.	KOP Name	Service Shaft Headframe	Waste Shaft Headframe	Waste Packaging Facility	Salt Stockpile	Ground Level Activities
1	Dead Horse Point Overlook					
2	Buck Canyon Overlook (CNP)					
3	Grand View Point Overlook (CNP)					
4	Arches N.P. Visitor Center					
5	Hurrah Pass					
6	Anticline Overlook					
7	Canyonlands Overlook					
8	Needles Overlook					
9	Colorado River Overlook					
10	Squaw Flat Campground (CNP)					
11	Utah 211 at Canyonlands N.P.					
12	Utah 211 at Corral Pocket					
13	Utah 211 at So. Six-Shooter Peak				X	X
14	Davis Canyon Jeep Trail	X	X	X	X	X
15	Lavender Canyon Jeep Trail					
16	Bridger Jack Mesa	X				X
17	Wilson Arch Viewpoint					
18	Kane Springs Rest Area					

Note: X = Activity is visible from that KOP; all other activities are not visible.

Table 5-13. Potential Visibility by Area

Activity	Total Square Kilometers (Square Miles) From Which This Facility is Potentially Seen	Total Square Kilometers (Square Miles) Within Canyonlands National Park From Which This Facility is Potentially Seen
1. Service Shaft Headframe (see Figure 5-17)	36.3 (14.0)	2.7 (1.0)
2. Waste Shaft Headframe (see Figure 5-17)	26.7 (10.3)	2.9 (1.1)
3. Waste Packaging Facility (see Figure 5-18)	20.2 (7.8)	2.8 (1.1)
4. Salt Stockpile (see Figure 5-19)	23.1 (8.9)	1.4 (0.5)
5. Repository Ground Level Activities (see Figure 5-20)	32.8 (12.7)	5.5 (2.1)

Note: While individual repository activities are potentially visible within limited areas of Canyonlands National Park, these areas receive little visitor use.

The 262 by 131 by 21-meter (860 by 430 by 70-foot) waste packaging facility (building #29) is potentially visible from a total area of 20.2 square kilometers (7.8 square miles) (Table 5-13, Figure 5-18), including: the Davis Canyon Jeep Trail (KOP #14); limited, scattered areas on Bridger Jack Mesa and the southwestern edge of Harts Point; and several small areas within Canyonlands National Park, particularly around Cedar Mesa, where visitation is low.

The approximately 671 by 305 by 11-meter (2,200 by 1,000 by 35-foot) salt stockpile is potentially visible from a total area of 23.13 square kilometers (8.9 square miles) (Table 5-13, Figure 5-19), including: Davis Canyon Jeep Trail (KOP #14); widely scattered areas on the southwestern edge of Harts Point; 1.22 kilometers (0.8 miles) of Utah 211 including KOP #13; and a small area of Canyonlands National Park, running for approximately 3.2 kilometers (2 miles) along the eastern park boundary just west of south Six-Shooter Peak, where visitor use is slight.

The ground plane of the repository facility is potentially visible from a total area of 32.84 kilometers (12.7 square miles) (Table 5-13, Figure 5-20). The area of visibility includes: the Davis Canyon Jeep Trail (KOP #14); portions of the western and southwestern edge of Harts Point with adjacent valley floor; 1.2 kilometers (0.8 miles) of Utah 211 including KOP #13; approximately two acres of Bridger Jack Mesa, including KOP #16; and scattered high ground approximately 3.2 kilometers (2 miles) of the Canyonlands National Park eastern border (concentrated between All American Man and Cedar Mesa), where visitation is limited as a result of no established access.

Visibility From Roads: No individual repository feature is potentially visible from designated jeep trails or other roads within Canyonlands National Park. Of the activities which were examined, all but the waste shaft headframe and the waste packaging facility will be visible for short distances along Utah 211, a total of 3.5 kilometers (1.9 miles), in the vicinity of KOP #13 (Table 5-14). The repository facility will be potentially visible from sections of the jeep trails through Davis and Lavender Canyons, from the Harts Point area and from the access road to Needles Overlook, all of which are outside of the park.

Access Road Visibility. The access road from U.S. 191 to the repository facility is potentially visible from seven KOPs: Buck Canyon Overlook (#2) and Grand View Point (#3) in Canyonlands National Park; Needles Overlook (#8); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); Bridger Jack Mesa (#16); and Wilson Arch Viewpoint (#17) on U.S. 191.

Table 5-15 shows the length of access road that is potentially visible from each KOP, the distance zones from which the access road segments are visible and the VRM class in which these potential road segments are located. Viewing distances are categorized by foreground/middleground (0-8 kilometers, 0-5 miles); background (8-24 kilometers; 5-15 miles) and seldom seen (24+ kilometers; 15+ miles) in this analysis. As an example, Table 5-15 illustrates the following about the potential visibility of the access road from the Buck Canyon Overlook (key observation point #2): (1) 3.1 kilometer (1.9 mile) of the access road is potentially visible from the Buck Canyon Overlook; (2) these access roads segments are only visible in the background distance zone (i.e., distances greater than 24 kilometers (15 miles); and (3) all of the potentially visible segments of the road are located in VRM Class II.

Visibility From Roads: The proposed access road is potentially visible from Utah 211 and the road to Needles Overlook. Within Canyonlands National Park, the access road is seen from the road to Grand View Point in the Island-in-the-Sky District.

Rail Route Visibility. Even though Kane Springs Canyon and Spanish Valley alternatives are both upland, and the Colorado River Canyon alternatives are both located in the same valley, all four routes differ measurably in their visibility.

Table 5-14. Potential Visibility From Utah 211

Activity	Total Road Kilometers (Miles) From Which This Activity is Potentially Seen
1. Service Shaft Headframe	1.1 (0.4)
2. Waste Shaft Headframe	Not Visible From Utah 211
3. Waste Packaging Facility	Not Visible From Utah 211
4. Salt Stockpile	1.2 (0.8)
5. Ground Level Activities	1.2 (0.8)

Table 5-15. Potentially Visible Miles of Access Road by Distance Zone from Key Observation Points (KOPs)

KOP No.	Length of Access Road Visible From Key Observation Points in Various Distance Zones			Total Length of Road in VRM Class, Kilometers (Miles)
	Foreground/ Middleground, Kilometers (Miles)	Background, Kilometers (Miles)	Seldom Seen, Kilometers (Miles)	
2	--	--	3.1 (1.9)	3.1 (1.9)-II
3	--	--	4.8 (3.0)	4.8 (3.0)-II
8	--	3.0 (1.9)	--	3.0 (1.9)-II
13	3.07 (1.9)	0.02 (0.01)	--	3.1 (1.9)-II
14	0.77 (0.5)	--	--	0.8 (0.5)-II
16	7.50 (4.7)	--	--	7.5 (4.7)-II
17	--	--	2.57 (1.6)	2.6 (1.6)-III
	--	--	2.29 (1.4)	2.3 (1.4)-IV

Note: Access road cannot be seen from any Key Observation Point which is not listed above.

Tables 5-16 through 5-19 show the actual length of each rail route alternative that is potentially visible from each KOP. The tables also distribute those visible portions by VRM class and by distance from each KOP. Table 5-20 is a summary table, designed so that comparisons can be easily made among the alternative rail routes. It should be noted that the full range of visible rail route distance was divided equally into three categories to indicate the relative amount of visibility.

Visibility of Individual Rail Routes: This section focuses on each of the route alternatives, describing the affected KOPs from varying distances, the affected land classification, the range in visible length, and the visibility of the tunnel portals.

The Colorado River Canyon Route "A" Alternative (Table 5-16) is potentially seen from: Dead Horse Point Overlook (#1); Buck Canyon (#2); Grand View Point Overlook (#3); Hurrah Pass (#5); Canyonlands Overlook (#7); Needles Overlook (#8); Colorado River Overlook (#9); Squaw Flat Campground (#10); Utah 211 at Canyonlands National Park (#11); Utah 211 at Corral Pocket (#12); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16). This route is potentially visible from a distance of less than 8 kilometers (5 miles) from eight KOPs.

Table 5-16 shows that the lengths of the Colorado River Canyon Route "A" alternative potentially seen range from 0.3 kilometers (0.2 miles) to 19.0 kilometers (11.8 miles), and are located in only VRM Class II lands. Hatch Point tunnel portals are seen from: Dead Horse Point Overlook (#1); Squaw Flat Campgrounds (#10); and Utah 211 at Canyonlands National Park (#11). The western portal or this alternative at Hatch Point is potentially seen from Bridger Jack Mesa (#16).

The Colorado Canyon Route "B" alternative, which is situated closest to Canyonlands National Park (Table 5-17), is potentially seen from: Dead Horse Point Overlook (#1); Buck Canyon Overlook (#2); Grand View Point Overlook (#3); Anticline Overlook (#6); Canyonlands Overlook (#7); Needles Overlook (#8); Utah 211 at Canyonlands National Park Peak (#11); Utah 211 at Corral Pocket (#12); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16). The route is potentially visible from less than 8 kilometers (5 miles) distance from nine of these KOPs.

Table 5-17 shows that the lengths of the Colorado River Canyon Route "B" alternative potentially seen range from 0.10 kilometers (0.1 miles) to 27.5 kilometers (17.2 miles), and are located in VRM Class II and V lands. One of the tunnel portals for this alternative in Hatch Point is potentially visible from KOP #1, Dead Horse Point Overlook.

The Kane Springs Canyon Route alternative (Table 5-18) is potentially visible from: Buck Canyon Overlook (#2); Grand View Point Overlook (#3); Hurrah Pass (#5); Anticline Overlook (#6); Canyonlands Overlook (#7); Needles Overlook (#8); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16). This route is potentially visible only beyond 24 kilometers (15 miles) from Buck Canyon Overlook (#2) and Grand View Point (#3) in Canyonlands National Park; and from six KOPs, it is potentially visible from less than 8 kilometers (5 miles) distance.

As indicated in Table 5-18, the lengths of the Kane Springs Canyon alternative potentially seen range from 0.1 kilometers (0.1 miles) to 5.2 kilometers (3.2 miles), and are located in only VRM Class II and V lands. The tunnel portal above the Utah 211 grade crossing will be visible from Bridger Jack Mesa (KOP #16).

The Spanish Valley Route alternative (Table 5-19) is potentially visible from: Dead Horse Point Overlook (#1); Grand View Point Overlook (#3); Arches National Park Visitor Center (#4); Anticline Overlook (#6); Canyonlands Overlook (#7); Needles Overlook (#8); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); Bridger Jack Mesa (#16); Wilson Arch Viewpoint (#17); and Kane Springs Rest Area (#18). This route is potentially visible only beyond 24 kilometers (15 miles) from two of those KOPs, Dead Horse Point Overlook (#1) in

Table 5-16. Potentially Visible Miles of Rail Line by Distance Zone from Key Observation Points (Colorado River Canyon Route "A")

KOP No.	Lengths of Rail Line Visible From Key Observation Points in Various Distance Zones: Foreground/ Middleground, Kilometers (Miles)	Background, Kilometers (Miles)	Seldom Seen, Kilometers (Miles)	Total Length of Road in VRM Class, Kilometers (Miles)
1	5.3 (3.3)	2.9 (1.8)	--	8.1 (5.1)-II
2	--	15.3 (9.5)	3.7 (2.32)	19.0 (11.8)-II
3	--	18.1 (11.2)	0.9 (0.5)	19.0 (11.8)-II
5	1.8 (1.1)	--	--	1.8 (1.1)-II
7	--	7.0 (4.4)	--	7.0 (4.2)-II
8	3.2 (2.0)	9.0 (5.6)	--	12.3 (7.6)-II
9	--	3.5 (2.2)	--	3.5 (2.2)-II
10	--	2.4 (1.5)	--	2.4 (1.5)-II
11	4.3 (2.7)	1.1 (0.7)	--	5.4 (3.3)-II
12	1.1 (0.7)	--	--	1.1 (0.7)-II
13	2.6 (1.6)	--	--	2.6 (1.6)-II
14	0.2 (0.2)	--	--	0.2 (0.2)-II
16	0.7 (0.4)	--	--	0.7 (0.4)-II

Note: The Colorado River Canyon Route "A" cannot be seen from any key observation point that is not listed above.

Table 5-17. Potentially Visible Miles of Rail Line by Distance Zone from Key Observation Points (Colorado River Canyon Route "B")

KOP No.	Lengths of Rail Line Visible From Key Observation Points in Various Distance Zones: Foreground/ Middleground, Kilometers (Miles)	Background, Kilometers (Miles)	Seldom Seen, Kilometers (Miles)	Total Length of Road in VRM Class, Kilometers (Miles)
1	6.8 (4.3)	10.1 (6.2)	0.1 (0.1)	17.0 (10.6)-II
2	--	24.8 (15.4)	2.7 (1.7)	27.5 (17.1)-II
3	--	23.0 (14.3)	--	23.0 (14.3)-II
6	1.4 (0.9)	--	--	1.4 (0.9)-II
	0.2 (0.1)	0.6 (0.4)	--	0.8 (0.5)-V
7	0.2 (0.1)	3.3 (2.1)	--	3.5 (2.8)-II
8	9.1 (5.6)	6.5 (4.1)	--	15.6 (9.7)-II
11	4.1 (2.6)	--	--	4.1 (2.6)-II
12	0.1 (0.1)	--	--	0.1 (0.1)-II
13	3.9 (2.5)	--	--	3.9 (2.5)-II
14	0.9 (0.6)	--	--	0.9 (0.6)-II
16	1.1 (0.7)	--	--	1.1 (0.7)-II

Note: The Colorado River Canyon Route "B" cannot be seen from any key observation point that is not listed above.

Table 5-18. Potentially Visible Miles of Rail Line by Distance Zone from Key Observation Points (Kane Springs Canyon Route)

KOP No.	Lengths of Rail Line Visible From Key Observation Points in Various Distance Zones: Foreground/ Middleground, Kilometers (Miles)	Background, Kilometers (Miles)	Seldom Seen, Kilometers (Miles)	Total Length of Road in VRM Class, Kilometers (Miles)
2	--	--	0.6 (0.4)	0.6 (0.4)-II
3	--	--	0.2 (0.1)	0.9 (0.1)-II
5	2.2 (1.4)	--	--	2.2 (1.4)-II
6	1.7 (1.1)	--	--	1.7 (1.1)-II
	0.4 (0.2)	0.9 (0.6)	--	1.3 (0.8)-V
7	1.5 (0.9)	1.5 (0.9)	--	3.0 (1.8)-II
8	--	4.0 (2.5)	--	4.0 (2.5)-II
13	5.2 (3.2)	--	--	5.2 (3.2)-II
14	0.1 (0.1)	--	--	0.1 (0.1)-II
16	2.2 (1.3)	--	--	2.2 (1.3)-II

Note: The Kane Springs Canyon Route cannot be seen from any key observation point that is not listed above.

Table 5-19. Potentially Visible Miles of Rail Line by Distance Zone from Key Observation Points (Spanish Valley Route)

KOP No.	Lengths of Rail Line Visible From Key Observation Points in Various Distance Zones: Foreground/ Middleground, Kilometers (Miles)	Background, Kilometers (Miles)	Seldom Seen, Kilometers (Miles)	Total Length of Road in VRM Class, Kilometers (Miles)
1	--	--	0.6 (0.4)	0.6 (0.4)-III
3	--	--	0.2 (0.1)	0.2 (0.1)-II
4	2.5 (1.5)	--	--	2.5 (1.5)-II
	3.2 (2.0)	0.6 (0.4)	--	3.8 (2.4)-III
6	--	3.3 (2.0)	--	3.3 (2.0)-III
7	--	1.2 (0.7)	--	1.2 (0.8)-III
8	--	4.0 (2.5)	--	4.0 (2.5)-II
13	5.1 (3.2)	--	--	5.1 (3.2)-II
14	0.05 (0.03)	--	--	0.05 (0.03)-II
16	2.2 (1.4)	--	--	2.2 (1.4)-II
17	--	0.2 (0.1)	--	0.2 (0.1)-II
18	1.4 (0.9)	--	--	1.4 (0.9)-II

Note: The Spanish Valley Route cannot be seen from any key observation point which is not listed above.

Table 5-20. Potential Visibility Summary of Rail Route Alternatives by Distance Zones from Key Observation Points (KOPs)

Key Observation Points		Colorado Canyon Route "A"			Colorado Canyon Route "B"			Kane Springs Route			Spanish Valley Route			Number of Routes Potentially Seen From Each Key Observation Point
No.	Name	0-8 km. (0-5 mi.)	8-24 km. (5-15 mi.)	24+ km. (15+ mi.)	0-8 km. (0-5 mi.)	8-24 km. (5-15 mi.)	24+ km. (15+ mi.)	0-8 km. (0-5 mi.)	8-24 km. (5-15 mi.)	24+ km. (15+ mi.)	0-8 km. (0-5 mi.)	8-24 km. (5-15 mi.)	24+ km. (15+ mi.)	
1	Dead Horse Point Overlook	L	L	-	L	L	L	-	-	-	-	-	L	3
2	Buck Canyon Overlook (CNP)	-	M	L	-	H	L	-	-	L	-	-	-	3
3	Grand View Point Overlook (CNP)	-	H	L	-	H	-	-	-	L	-	-	L	4
4	Arches N.P. Visitor Center	-	-	-	-	-	-	-	-	-	L	-	-	1
5	Burrah Pass	L	-	-	-	-	-	L	-	-	-	-	-	2
6	Anticline Overlook	-	-	-	L	L	-	L	-	-	-	L	-	3
7	Canyonlands Overlook	-	L	-	L	L	-	L	L	-	-	L	-	4
8	Needles Overlook	L	M	-	M	L	-	-	L	-	-	L	-	4
9	Colorado River Overlook	-	L	-	-	-	-	-	-	-	-	-	-	1
10	Squaw Flat Campground (CNP)	-	L	-	-	-	-	-	-	-	-	-	-	1
11	Utah 211 at Canyonlands N.P.	L	L	-	L	-	-	-	-	-	-	-	-	2
12	Utah 211 at Corral Pocket	L	-	-	L	-	-	-	-	-	-	-	-	2
13	Utah 211 at So. Six-Shooter Peak	L	-	-	L	-	-	L	-	-	L	-	-	4
14	Davis Canyon Jeep Trail	L	-	-	L	-	-	L	-	-	L	-	-	4
15	Lavender Canyon Jeep Trail	-	-	-	-	-	-	-	-	-	-	-	-	0
16	Bridger Jack Mesa	L	-	-	L	-	-	L	-	-	L	-	-	4
17	Wilson Arch Viewpoint	-	-	-	-	-	-	-	-	-	-	L	-	1
18	Kane Springs Rest Area	-	-	-	-	-	-	-	-	-	L	-	-	1
	Number of KOPs from which each alternative can potentially be seen		13			11			9			11		

Notes: L = 0.05-8.29 kilometers (0.03-5.15 miles) length of rail route alternative potentially seen within distance zone. (Low amount seen.)
M = 8.29-16.53 kilometers (5.15-10.27 miles) length of rail route alternative potentially seen within distance zone. (Moderate amount seen.)
H = 16.53-24.77 kilometers (10.27-15.39 miles) length of rail route alternative potentially seen within distance zone. (High amount seen.)
- = Rail route alternative unseen within distance zone. (No amount seen.)

Dead Horse Point State Park and Grand View Point Overlook (#3) in Canyonlands National Park. This alternative is potentially seen from five KOPs from less than 8 kilometers (5 miles) distance.

As shown in Table 5-19, the lengths of the Spanish Valley alternative potentially seen range from 0.05 kilometers (0.03 miles) to 5.1 kilometers (3.2 miles), and are located in both VRM Class II and III lands. Tunnel portals for this alternative are potentially visible from KOP #17 (the north portal at Three Mile Creek) and KOP #16 (west portal above Utah 211.)

Visibility from Roads: Each of the four rail route alternatives are potentially seen from Utah 211, since they each cross it. The Spanish Valley Route alternative parallels U.S. 191, and is potentially visible from the entrance road to Arches National Park. All four alternatives can potentially be seen from within the Island-in-the-Sky District of Canyonlands National Park, along the road to Grand View Point, but none of the routes are seen from the designated jeep and hiking trails in the Needles District of the park.

Visibility from Key Observation Points: This section summarizes the number of rail route alternatives which are potentially visible from the various KOPs (Table 5-20).

Only one KOP, Lavender Canyon Jeep Trail (#15) has no view of any of the rail route alternatives. five KOPs have only one route each within their viewsheds: Arches National Park Visitor Center (#4); Colorado River Overlook (#9) and Squaw Flat Campground (#10) within Canyonlands National Park; and Wilson Arch Viewpoint (#17) and Kane Springs Rest Area (#18) on U.S. 191. Only two routes are potentially visible from three KOPs: Hurrah Pass (#5); Utah 211 at Canyonlands National Park (#11); and at Corral Overlook (#1) in Dead Horse Point State Park, and Buck Canyon Overlook (#2) in Canyonlands National Park, as well as Anticline Overlook (#6). All four routes are potentially visible from: Grand View Point (#3) and Canyonlands Overlook (#7) in Canyonlands National Park; Needles Overlook (#8); Utah 211 at South Six-Shooter Peak (#13); Davis Canyon Jeep Trail (#14); and Bridger Jack Mesa (#16).

Visual Contrast Ratings. Visual contrast evaluations were completed for those features of the repository (service and waste shaft headframe, waste packaging facility, salt stockpile, and repository ground level activities) included in the viewshed analysis. However, separate contrast ratings were not conducted for each individual activity, but for the entire facility. Visual contrast ratings were also done for the four railroad alternatives, but not for the proposed access road.

Utility lines (i.e., waste, gas, electrical) were not evaluated for visual contrast. Impacts from the underground placement of the water, gas, and power lines along the railroad access are considered as part of the railroad visual contrast. The proposed utility corridor for the gas and electrical lines (where it deviates from the railroad access to U.S. 191) would not be visible except along U.S. 191. The results of these visual contrast evaluations are presented below.

Repository. The visual contrast of the repository was evaluated from Utah 211 at South Six-Shooter Peak (KOP #13) and Davis Canyon Jeep Trail (KOP #14). Since only the top of the waste shaft is potentially visible from limited areas of Bridger Jack Mesa (KOP #16), contrast ratings were not calculated for this isolated location.

The repository will create significant short and long term impacts from KOP #13 at a normal observer position and at a distance of 4.0 kilometers (2.5 miles) east of the repository. The visibility of the salt stockpile form and color is the major contributor to the visual impact.

The repository also creates significant short and long term impacts from KOP #14 at an inferior position 1.6 kilometer (1 mile) south of the repository. From this KOP, the form of the buildings is the major contributor to the visual impact.

Visual contrast of the repository was also evaluated from the eastern boundary of Canyonlands National Park 1.6 kilometers (1 mile) west of the repository from a superior position.

The color of the salt stockpile contributes to the high contrast. However, this area of Canyonlands National Park is isolated high ground where visitation is low and is not a KOP.

Railroad Route Alternatives. Table 5-21 summarizes the contrast rating results for the railroad route alternatives as potentially seen from KOPs. Observer positions, lengths of routes which are visible, the VRM class through which those visible sections pass and the degree of impact are all included in the table.

Contrast ratings were conducted for KOPs identified in Table 5-21. Some of the route sections designated as potentially visible through computer manipulation of terrain data were not rated for contrast becausé the field team did not believe they were visible due to distance or topographic and vegetative screening. If there is some minor visibility, the visual impact is likely to be insignificant. In contrast computer viewsheds indicated no visibility from Hurrah Pass and Anticline Overlook for two particular sections of rail route. However, where the field team noted that visibility was in fact possible within the general vicinity of those viewpoints where topography does not restrict the line-of-sight. In these two cases, the contrast ratings were retained.

Pothole Point, Bowtie Arch and Newspaper Rock State Historical Monument were considered for visual impact analysis but discarded because none of the railroads alternatives are visible from these viewpoints.

Viewsheds were not mapped from the southern tip of Behind the Rocks or Indian Creek Wilderness Study areas or from U.S. 191 one mile north of La Sal Junction, but contrast ratings were compiled at these locations for the rail alternatives. It was determined that only the Spanish Valley Route would have a significant visual impact, from only Behind the Rocks Wilderness Study Area and U.S. 191, at those particular locations.

5.2.6.3 Decommissioning and Closure

After final emplacement of nuclear waste canisters, the repository will be decommissioned, closed and decontaminated. All structures including meteorological towers and shaft headframes will be dismantled and transported off site, and the landscape will be graded and revegetated to blend with surrounding topography. Transportation and utility facilities may be decommissioned and converted to other uses. Postclosure activities will include markers or monuments, and small building to be used as a monitoring station (see Section 5.1.1). The aesthetic impacts of these monuments or markers will depend upon the final design or type of passive prevention barrier selected.

5.2.6.4 Mitigation Techniques

Mitigation measures were developed for those contrast rating scores which exceeded the requirements for the assigned VRM class as well as those which met the class, but can be further reduced. Mitigation measures may be used to significantly reduce visual impacts.

In developing mitigation, three basic principles are used: the concepts of (1) strategic location (in less visible and less sensitive areas), (2) minimizing disturbance, and (3) repetition of the basic landscape elements (form, line, color, texture).

The mitigation techniques listed below have been separated into two categories: (1) general, which are basic for all sites of each identified activity, and (2) site-specific, which are limited in application to one site. Implementation of any of the mitigation measures listed below would be made in consultation with the BLM.

5.2.6.4.1 Repository.

General

- All rock cuts could be sprayed with a product to simulate desert varnish

Table 5-21. Summary of Visual Resource Contrast Rating Results for Railroad Route Alternatives as Seen from Key Observation Points

Key Observation Points		Colorado River Canyon Route A					Colorado River Canyon Route B				Kane Springs Canyon Route				Spanish Valley Route			
No.	Name	Observer Position	Length Visible, km (mi.)[a]		VRM Class[a]	Impact[c]	Observer Position	Length Visible, km (mi.)	VRM Class	Impact	Observer Position	Length Visible, km (mi.)	VRM Class	Impact	Observer Position	Length Visible, km (mi.)	VRM Class	Impact
1	Dead Horse Point Overlook	Superior	8.1	(5.0)	II	Insig.	Superior	17.0 (10.6)	II	Insig.	—			N/V		0.6 (0.3)	III	
2	Buck Canyon Overlook	Superior	19.0	(11.8)	II	Insig.	Superior	27.5 (17.1)	II	Insig.		0.6 (0.4)	II		—		N/V	
3	Grandview Overlook	Superior	19.0	(11.8)	II	Insig.	Superior	23.0 (14.3)	II	Insig.		0.2 (0.1)	II			0.2 (0.1)	II	
4	Arches National Park Visitor Center	—				N/V	—			N/V	—			N/V		2.5 (1.5) 3.8 (2.4)	II III	Sig.
5	Hurrah Pass	Superior	1.8	(1.1)	II	Sig.	Superior		II	Sig.[b]	Superior	2.2 (1.4)	II	Sig.	—			N/V
6	Anticline Overlook	Superior			II	Sig.[b]	Superior	1.4 (0.9) 1.0 (0.5)	II IV	Sig.	Superior	1.7 (1.1) 1.3 (0.8)	II V	Sig.		3.3 (2.0)	III	
7	Canyonlands Overlook	Superior	7.0	(4.4)	II	Insig.	Superior	3.5 (2.2)	II	Insig.		3.0 (1.8)	II			1.2 (0.8)	III	
8	Needles Overlook	Superior	12.3	(7.6)	II	Sig.	Superior	15.6 (9.7)	Ii	Sig.		4.0 (2.5)	II			4.0 (2.5)	II	
9	Colorado River Overlook	Normal	3.5	(2.2)	II	Insig.	—			N/V	—			N/V	—			N/V
10	Squaw Flat Campground		2.4	(1.5)	II		—			N/V	—			N/V	—			N/V
17	Wilson Arch Viewpoint	—				N/V	—			N/V	—			N/V	—			N/V
18	Kane Springs Rest Area	—				N/V	—			N/V	—			N/V	—			N/V

Notes: Insig. = (Insignificant) VRM Class requirements not exceeded, Sig. = (Significant) VRM Class requirements exceeded, and N/V = Not Visible.

(a) From Tables 5-6 to 5-9.

(b) Although computer manipulation of terrain data indicated no visibility from this very specific viewpoint, field observation from the general vicinity suggests that some visibility of the proposed route will occur near that viewpoint.

(c) Wherever blanks occur in the column containing impacts, contrast ratings were not computed for that rail route from that KOP. Because the field team did not believe it was visible due to distance or topographic/vegetative screening.

Source: BLM, 1985.

- All exposed concrete (i.e., building and tower foundations, etc.) could either be tinted or sprayed to match the existing soil color

- All permanent structures (i.e., buildings, meteorological towers, fences, bridges, etc.) could be painted a uniform, noncontrasting (flat or semi-gloss) environmental color (brick red or dark brown).

Site-Specific

- Either of two alternatives could be considered to eliminate the high contrast from salt stockpile color as seen from Utah 211: (1) switch the locations of the salt and topsoil stockpiles, or (2) cover the salt stockpiles with soil.

5.2.6.4.2 Railroad Route Alternatives.

General

- Red ballast could be used for the railroad route

- For railroad bridges, all steel girders and trusses could either be painted a dark brown color or constructed of "self-weathering" steel

- End sections of multiplate arches for railroad bridges and culverts for roads could either be cut to match embankment slopes, painted, or sprayed to reduce color contrasts.

Site-Specific

- Colorado River Canyon Route A. Steel trusses on the bridge over the Colorado River (Station 0+15) could be painted dark red or constructed of "self-weathering" steel. The cut through rock (Station 90+00) could be blasted in 9.1 meter (30 feet) terraces with broken faces (instead of sheer walled) to simulate naturally occurring rock terraces indigenous to the area.

- Colorado River Canyon Route B. The cut through rock (Stations 220+00 and 390+00) could be blasted in 30 feet terraces with broken faces (instead of sheer walled) to simulate naturally occurring rock terraces indigenous to the area.

- The cut through rock (Station 365+00) could be blasted as sheer walls.

- Spanish Valley Route. Concrete or portal entrances (Stations 915+00 to 1000+00) could be tinted or sprayed light red.

- The cut through rock (Station 1060+00) could be blasted with broken faces.

- The cut through rock (Station 1100+00) could be blasted with sheer walls.

5.2.6.5 Summary

Viewshed analyses and visual contrast ratings of each railroad route alternative have been summarized as follows.

5.2.6.5.1 Repository. The repository facility is located in two adjacent side canyons of Davis Canyon, where it is screened by the bulk of South Six-Shooter Peak and other high ground. therefore, repository activities, excluding the three meteorological towers from the ESF phase, are potentially visible from a total area of 55.7 square kilometers (21.5 square miles). Of this sum, 7.2 square kilometers (2.8 square miles) are scattered within the eastern boundary of the Needles District of Canyonlands National Park on high ground, where visitation is low, primarily because of the lack of access. With the three meteorological towers, the repository is potentially seen from a total area of 81.3 square kilometers (31.4 square miles), 10.9 square kilometers (4.2 square miles) of which are located within the park.

The number of structures and the complexity of the repository layout is similar to the ESF, but due to its slightly larger size, the magnitude of contrast is also slightly greater. There will be significant short and long term visual impacts from two KOPs, #13 and #14.

Mitigation techniques, such as providing a color finish to the structures, will help blend in with the surrounding landscape and minimize visual impacts.

In conclusion, overall visual impacts will not be significant except possibly within the immediate vicinity of the proposed repository, which are outside of Canyonlands National Park. Visual impacts from Bridger Jack Mesa are insignificant primarily because of limited visibility. From the eastern boundary of Canyonlands National Park contiguous to the site, the visual impact is significant. However, visitation is low and no KOP is located in this area. None of the analyzed KOPs within Canyonlands National Park will be visually impacted because the activities are not visible.

5.2.6.5.2 Access Road. The proposed access road is primarily visible for the four to five miles from its junction with Utah 211, to where it enters the side canyon on the southwestern edge of Harts Point.

No contrast ratings were calculated for the access road, so impacts and mitigation cannot be addressed.

5.2.6.5.3 Railroad Route Alternatives. The Kane Springs Route alternative is potentially seen from nine KOPs for short distances, making it the least visible of the four alternative rail routes. The Colorado Canyon Route "A" alternative is potentially seen from the most KOPs (thirteen) at close distances, for long stretches, and with many tunnel portals exposed. The Spanish Valley Route alternative and the Colorado River Route "B" alternative are both visible from eleven KOPs, but the former route is seen in shorter lengths and less often at the 0 to 8 kilometers (0 to 5 miles) and 8 to 24 kilometers (5 to 15 miles) distance categories than the latter; thus the Spanish Valley Route is the second least visible rail route alternative.

Colorado River Route "A" is potentially visible from more KOPs than Colorado River Route "B". However, the potential visibility of "A" and "B" appear to be very close.

Colorado River Routes "A" and "B" and the Spanish Valley Route have only three significant long term impacts each from the KOPs analyzed. Kane Springs Route has two significant long term impacts, making it the least visually impacting. Long term impacts of this alternative could be minimized by applying red-colored ballast, and at appropriate points, by blasting rock cuts to create natural appearing land forms.

In conclusion, overall visual impacts of all rail corridors were rated insignificant from analyzed KOPs inside of the Canyonlands National Park because of the distance and low visibility.

5.2.7 Noise

Increased noise levels resulting from repository construction, operation, and decommissioning and closure will intrude into the normally quiet environment of Davis Canyon. Noise from project activities will be produced from fixed electrically-powered equipment and mobile diesel-powered equipment. Additionally, infrequent blasting noise will occur, but only for short durations.

In order to accurately assess noise impacts, computer modeling is employed to predict noise levels during periods of peak activities. Results of the predictive modeling are presented as noise isopleths (contours) on topographic maps. Noise criteria presented in Section 4.2.1.6.1 are used to assess noise impacts. Impacts and possible mitigative measures are described. Also included are discussions of impulsive noise and ground vibration from blasting.

5.2.7.1 Noise Criteria

There are no Federal, State, or local noise regulations applicable to the repository site. However, the Department of Energy (DOE) intends to follow U.S. Environmental Protection Agency (EPA) noise criteria, with appropriate abatement, to achieve compliance with the Noise Control Act of 1972 as amended by the Quiet Communities Act of 1978 (42 USC Section 4901-4918).

As discussed in Section 4.2.1.6.1, two indicators of broadband environmental noise impact are used here. They include the following:

- The level above the Threshold of Audibility used for assessing impacts to park and wilderness areas (Fidell and Horonjeff, 1982)
- Energy equivalent day/night sound level, L_{dn}, used to protect the public from the effects of noise (EPA, 1974).

The EPA has also set criteria to protect against hearing loss. The details, application, and interpretation of these criteria are discussed in Section 4.2.1.6.1.

5.2.7.2 Methodology

Potential noise impacts were determined by modeling a representative day during the peak activity period occurring over the initial 2 to 4 years of construction (BNI, 1985d). Source inventory (including the traffic volume) has been changed since the modeling analysis discussed below was performed. The implications of these changes are evaluated in ONWI (1986). Although small differences exist, conclusions remain as stated. Onsite activities that were modeled for repository construction include general site preparation and facilities development, which is described in Section 5.1.2. Types of construction equipment will be similar to that used during site characterization, tabulated in Section 4.1. Offsite transportation corridor construction was also modeled and included preparation of the proposed repository access road from U.S. Highway 191 (U.S. 191). Several rail routes are being considered (Section 5.3.2). Near the vicinity of the proposed site the Spanish Valley route and the Kane Springs route follow the same corridor. Rail construction activities for this corridor were modeled assuming representative construction equipment deployed along the initial 16 kilometer (10 mile) segment leading from the proposed site. Activities along the corridor were assumed to include cut and fill, bridge construction, and rail bed preparation. Construction traffic on Utah 211 and the site access road were also considered in the modeling. Section 5.1.2 describes the proposed repository construction activities.

Typical onsite operational activities, described in Section 5.1.3, were modeled to represent noise levels during repository operation. These activities include onsite salt handling and rail yard operations, project traffic along the access road from U.S. 191, and the daily round trip by train between Moab and the site.

For construction, transportation, and operational equipment inventories for each phase of activity, one-third octave band sound power levels, duty cycles, and loading conditions were derived using vendor-furnished data for quieted equipment or published reports as described in Section 4.2.1.6.4 (BNI, 1985d). In cases where data were incomplete or unavailable, levels were synthesized from related data, known characteristics of comparable equipment, and published standards. All stationary equipment and facilties described in Table 5-1 were assumed to be enclosed and quieted to the background level at the park boundary, while onsite mobile equipment was assumed to be fitted with the best available noise control features. Source locations were selected based upon the figures and activities described in Section 5.1. The noise prediction model and the conservative modeling methodology are described in Section 4.2.1.6.4.

5.2.7.3 Noise Impacts

The impacts due to construction, operation, and decommissioning and closure are discussed below. Audibility isopleths are presented which provide a conservative estimate of the highest one-third octave bar project increment above the masking level (Section 3.4.4) during the peak hour of activity. Audibility isopleths are presented in 5 dB increments starting at 0 db and increasing to 20 dB. Within the 20 dB audibility isopleth, the project's sounds will be heard continuously and energy equivalent sound levels become a better indicator of noise. L_{dn} isopleths starting at 35 dBA and increasing by 10 dB to 55 dBA are also presented. Measured L_{dn} values ranged from 28 dBA in Canyonlands National Park to 46 dBA near Dugout Ranch (Section 3.4.4). The discussion appearing in Section 4.2.1.6.5 on impacts for tonal noise also applies to the repository.

It is believed by the DOE that the noise modeling carried out in this section was based on the best available meteorological data, the latest literature on sound emission levels, and state-of-the-art noise modeling techniques. However, uncertainties do exist in this modeling and are caused largely by:

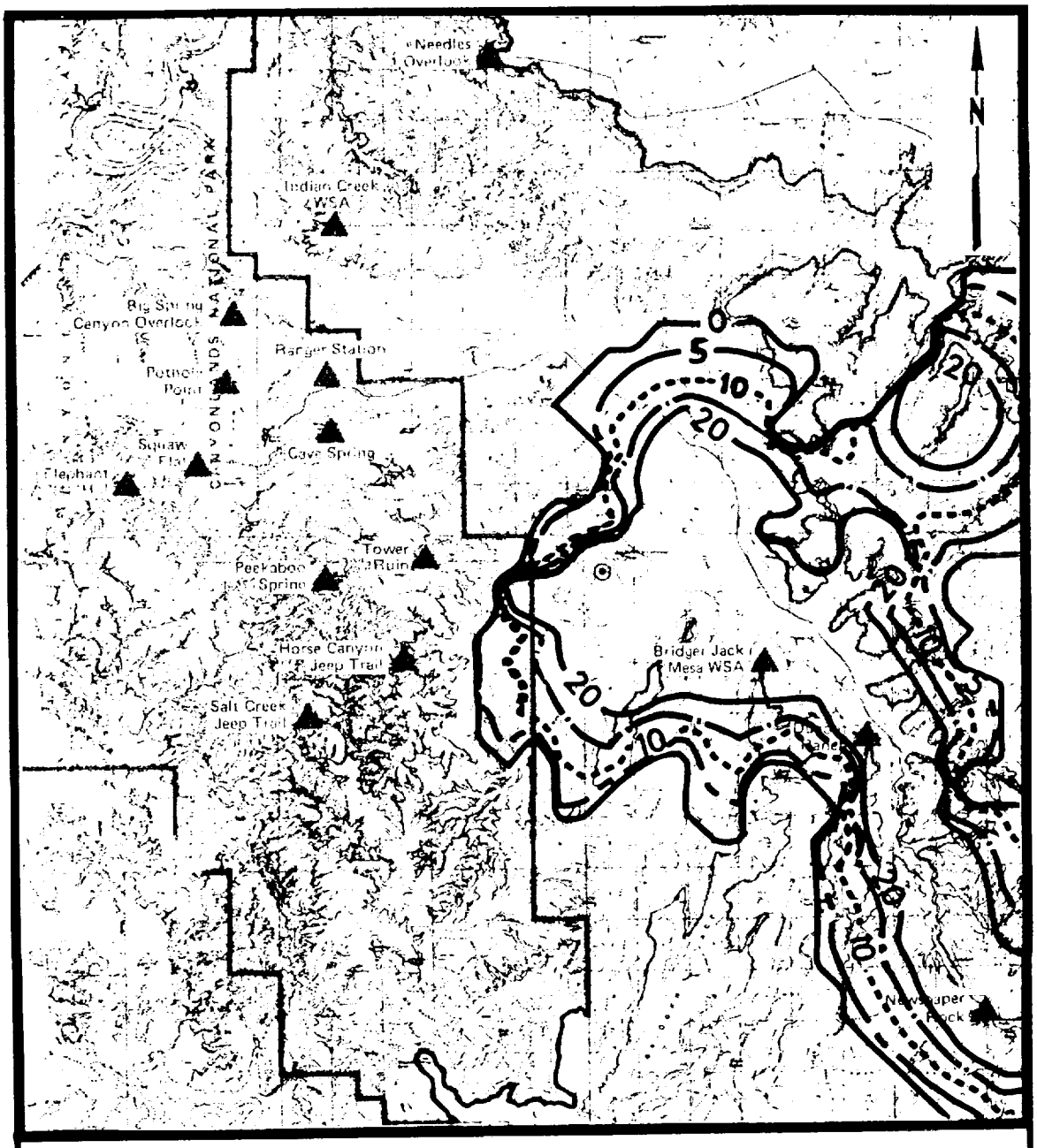
- Uncertainties in sound emission levels to approximately $\pm$ 5 dB
- The precise amount of quieting of the equipment to be used. It is estimated that a 2 to 5 dB reduction in noise levels remains possible for some sources
- The choice of degree of conservatism in the noise analysis. The selection of another value for typical intrusive noise [e.g., L(10) instead of L(eq)] would make the predictions more conservative
- Consideration of wind and temperature gradient effects on noise propagation. Unfavorable gradients (when occurring) can significantly increase noise propagation into the park whereas favorable gradients can significantly reduce such impacts.

The accumulated effects of these uncertainties can be large at any point and at any time outside the site boundary.

5.2.7.3.1 Construction. Noise levels during the peak period of repository construction are shown graphically in Figures 5-23 and 5-24 for audibility and L_{dn} levels, respectively. These results represent the potential noise impacts throughout the initial 2 to 4 years of construction when road and railroad construction activities occur. After 4 years, as these corridors become operational, noise levels will approach those presented in Section 5.2.7.3.2.

Equipment noise levels resulting from repository construction may be audible 2.4 kilometers (1.5 miles) into Canyonlands National Park. Table 5-22 summarizes the predicted levels and the corresponding criteria for 16 sensitive receptors. Of the 16 sensitive receptors listed, 4 will experience audible levels. Noise levels will not be audible at 10 of 11 receptors within the park. Noise levels at the park boundary closest to the site will be 25 dB above the Threshold of Audibility, which represents a strong likelihood of individual complaints. Peekaboo Spring Campground will not experience audible levels. At Newspaper Rock State Historical Monument, little likelihood of individual complaints (2 decibels [dB] above acceptable levels) is expected from peak hour traffic on Utah 211. The estimated L_{dn} at Dugout Ranch is 43 A-weighted decibels (dBA). This is within the EPA guideline of 55 dBA (Section 4.2.1.6.1).

Isopleths (contours) shown in Figures 5-23 and 5-24 reveal that construction of both the railroad and new access route, and traffic along Utah 211 and the site access road account for a large portion of the noise impacts. Traffic along Utah 211 and the site access route extend the L_{dn} 55 dBA value to 0.2 kilometer (0.1 mile) on either side of the road. Intervening canyon walls will decrease these distances. Noise from surface blasting associated with construction of vertical shafts and rail tunnels will be similar to that described in Section 4.2.1.6 and will occur over a period of 6 to 12 days near the end of the first year of construction.



Noise Isopleths in dB Above Masking Level

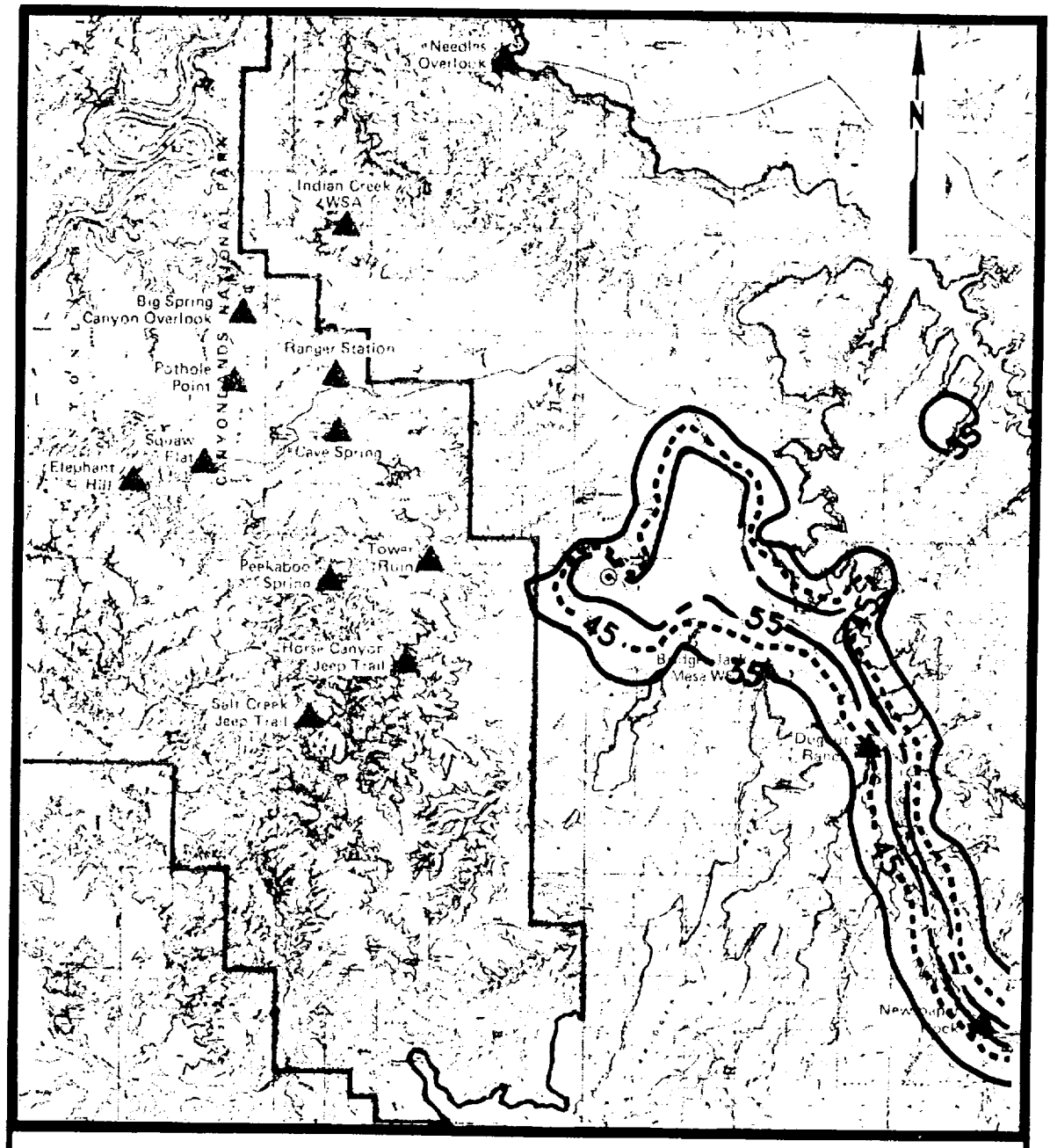
Sensitive Receptor

Site

Source: BNI, 1985d.

Davis Canyon Repository Construction Audibility Contours

Figure 5-23



Scale
0 1 2 Mi
0 1 2 3 4 Km

Noise Isopleths in dBA

Sensitive Receptor

Site

Source: BNI, 1985d.

Davis Canyon Repository Construction Day/Night Sound Level

Figure 5-24

Table 5-22. Noise Impacts to Sensitive Receptors - Davis Canyon, Repository Construction

	Audibility Level		L_{dn} Level[b]	
	Predicted (dB above Threshold)[a]	Acceptable (dB above Threshold)	Predicted (dBA)[c]	Acceptable[d] (dBA)
Dugout Ranch Residence	27	--	43	55
Needles Overlook	NA	20	24	--
Newspaper Rock State Historical Monument	22	20	35	--
Indian Creek Wilderness Study Area	NA	0	24	--
Bridger Jack Mesa Wilderness Study Area	29	0	38	--
Canyonlands National Park Sites:				
Nearest Park Boundary	25	10	36	--
Peekaboo Spring Campground	NA	5	24	--
Squaw Flat Campground	NA	10	24	--
Tower Ruin	NA	10	24	--
Ranger Station	NA	20	24	--
Elephant Hill	NA	10	24	--
Pothole Point	NA	20	24	--
Big Spring Canyon Overlook	NA	20	24	--
Horse Canyon Jeep Trail	NA	10	24	--
Salt Creek Jeep Trail	NA	10	24	--
Cavespring	NA	20	24	--

(a) NA = Not Audible (below Threshold of Audibility).
(b) L_{dn} represents combined project and background noise.
(c) 24 represents the residual background levels defined in Section 3.4.4 with a 10-dB nighttime weighting.
(d) -- = No criteria have been identified.

The peak pressure level from repository shaft blasting will be essentially the same as for ESF shafts, however, there may be more charges per blast, depending on shaft diameter. Peak levels from blasting will be audible at distances up to 47 kilometers (29 miles) if blasting occurs during the infrequent meteorological conditions favorable to sound propagation (Section 4.2.1.6.4). This distance will be much shorter, on the order of 24 kilometers (15 miles), when the wind is blowing from the park toward the site and there is a normal temperature lapse. The conditions favorable to the greater propagation distance are not expected to occur infrequently (Section 3.4.2.4; Figure 3-72). Schedule delays to avoid blasting at such times would not have a noticeable effect on the overall project (Section 3.4.3.4).

Cumulative effects of blasting noise have been considered. Each of three blasts per day for a total of 12 days will consist of 15 impulses separated by 0.5 second. The highest peak sound pressure level will be below 90 dB at 1.0 kilometer (0.6 mile). These conditions are well below the criteria given in Section 4.2.1.6 and cumulative adverse health effects to the general public are not expected.

Projections of ground motion due to blasting of shafts and tunnels are below 2 millimeters (0.08 inch) per second. The resulting vibration levels at Canyonlands National Park boundary are below the threshold of perception for humans and will not be sensed. No impact to the delicate rock formations in the park is expected as a result of blasting (see Section 4.2.1.6.1).

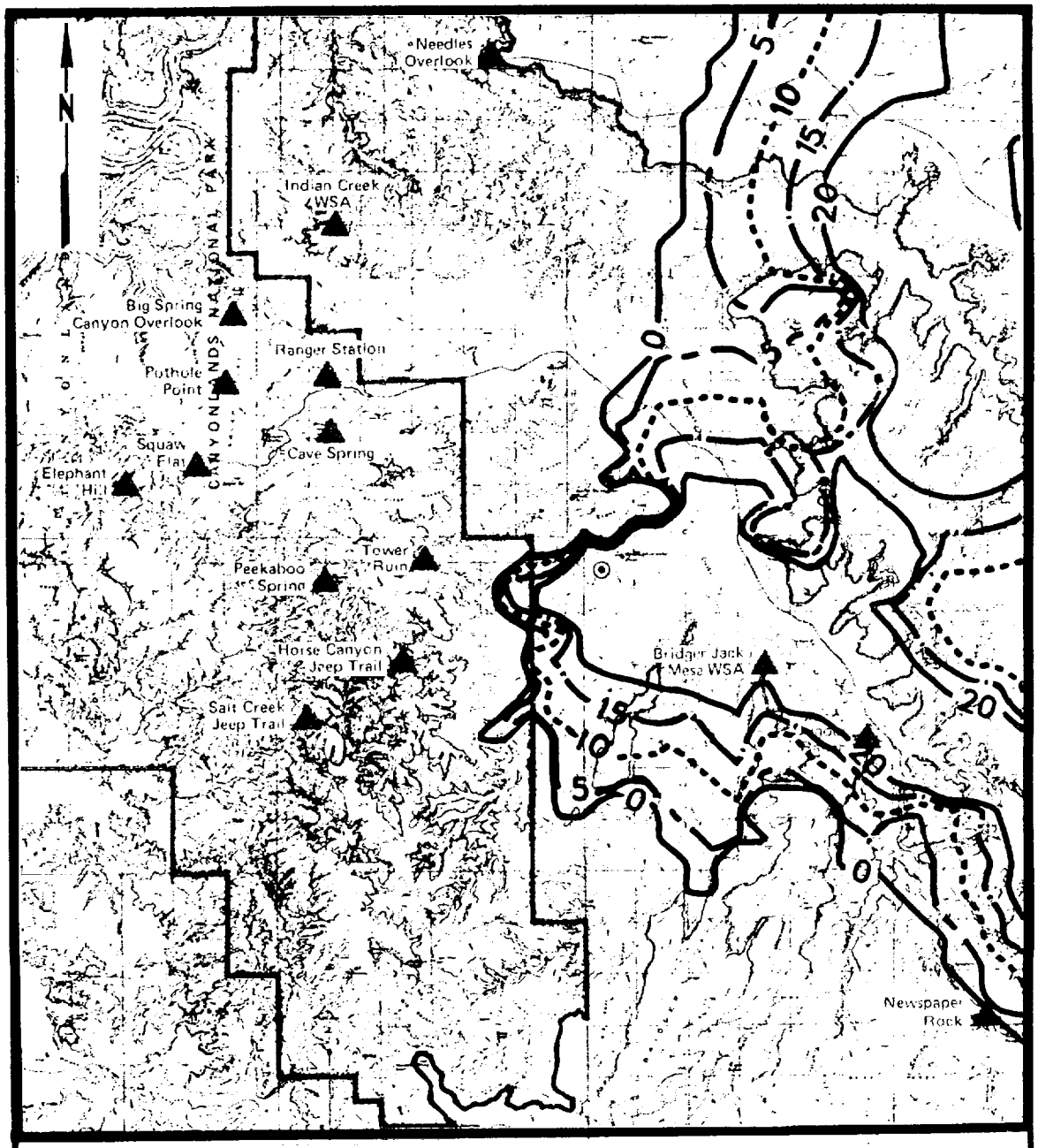
In summary, potential local impacts during the initial 2 to 4 years of repository construction will vary from day to day, depending on construction activities, but will usually include the following:

- Equipment noise audible 2.4 kilometers (1.5 miles) into Canyonlands National Park
- Increased noise levels from construction of the rail route and the site access road resulting in increased noise levels at Dugout Ranch
- Strong likelihood of individual complaints in the area along the nearest Canyonlands National Park boundary (25 dB above the threshold of audibility)
- Little likelihood of individual complaints at Newspaper Rock State Historical Monument (22 dB above the threshold of audibility)
- Strong likelihood of individual complaints at Bridger Jack Mesa Wilderness Study Area as a result of daily peak hour traffic (29 dB above the threshold of audibility)
- Blasting levels (with the wind blowing from the park) audible up to 24 kilometers (15 miles) 3 to 6 times per day for approximately 6 to 12 days.

5.2.7.3.2 Operation. Results of modeling repository operation are presented graphically in Figures 5-25 and 5-26 for audibility and composite L_{dn} values, respectively. Table 5-23 shows predicted levels above the Threshold of Audibility at 16 sensitive receptors, and the acceptable audible levels based upon Table 4-22. Table 5-23 also presents composite L_{dn} values.

The audibility levels shown on the figure and the table represent the maximum difference between the one-third octave band energy average levels during the loudest hour during the day at each receptor and the masking sound. For most receptors the loudest hour occurs when the train passes. For two to four hours each day the zero-audibility contour (Threshold of Audibility) will extend 8 kilometers (5 miles) from the rail line. Near the site, the loudest hour will include the effects of site activities (switch engine), peak hour traffic, and the locomotives.

Of the 16 sensitive receptors listed on Table 5-23, 3 will experience audible project-related levels. Noise levels at the park boundary nearest the site will be 19 dB above the



Scale 0 1 2 Mi 0 1 2 3 4 Km

Noise Isopleths in dB Above Masking Level

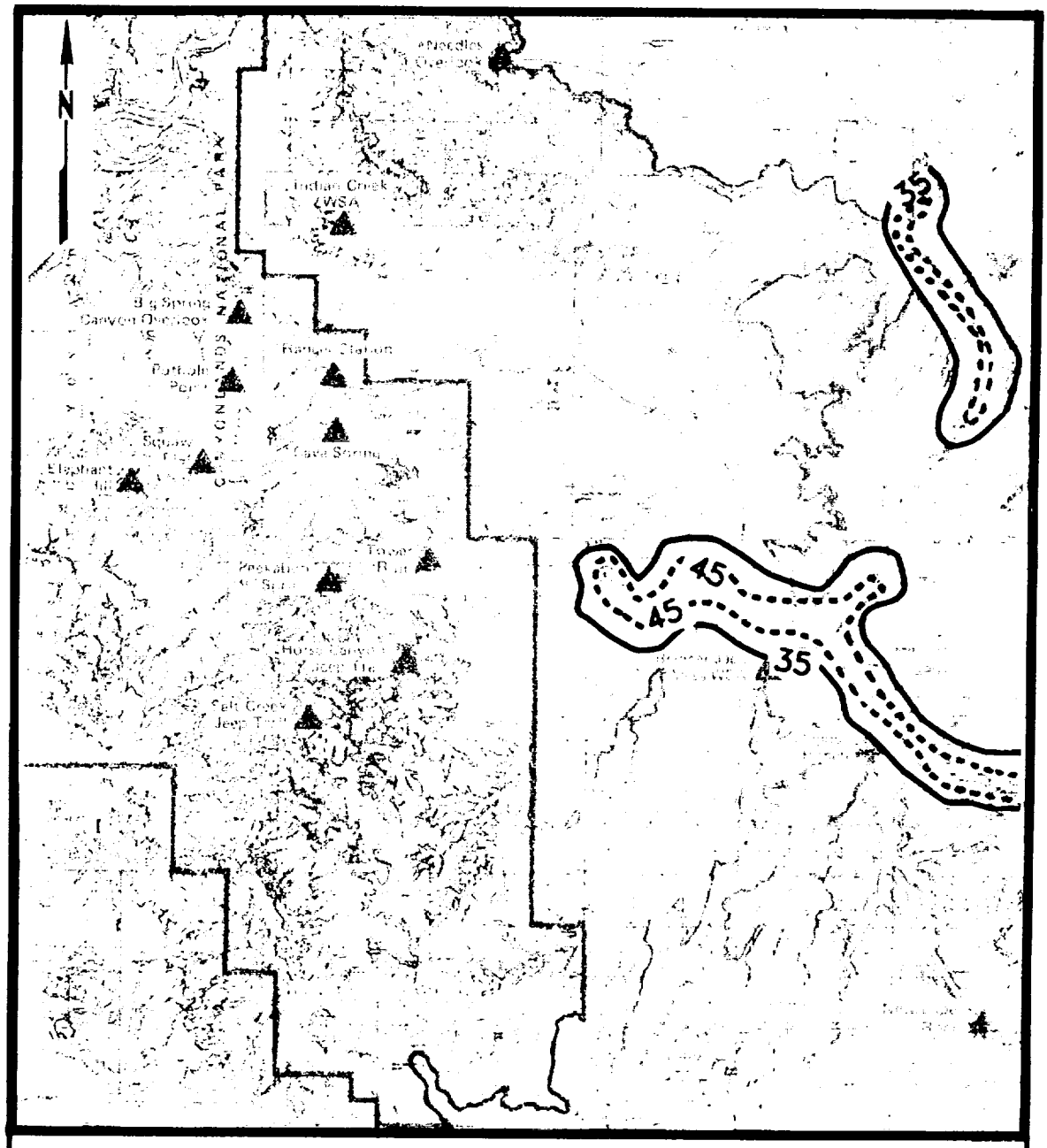
Sensitive Receptor

Site

Source: BNI, 1985d.

Davis Canyon Repository Operation Audibility Contours

Figure 5-25



Scale
0 1 2 Mi
0 1 2 3 4 Km

Noise Isopleths in dBA

Sensitive Receptor

Site

Source: BNI, 1985d.

Davis Canyon
Repository Operation
Day/Night Sound Level

Figure 5-26

Table 5-23. Noise Impacts to Sensitive Receptors - Davis Canyon, Repository Operation

	Audibility Level		L_{dn} Level[b]	
	Predicted (dB above Threshold)[a]	Acceptable (dB above Threshold)	Predicted (dBA)[c]	Acceptable[d] (dBA)
Dugout Ranch Residence	25	--	32	55
Needles Overlook	NA	20	24	--
Newspaper Rock State Historical Monument	NA	20	24	--
Indian Creek Wilderness Study Area	NA	0	24	--
Bridger Jack Mesa Wilderness Study Area	31	0	32	--
Canyonlands National Park Sites:				
Nearest Park Boundary	19	10	27	--
Peekaboo Spring Campground	NA	5	24	--
Squaw Flat Campground	NA	10	24	--
Tower Ruin	NA	10	24	--
Ranger Station	NA	20	24	--
Elephant Hill	NA	10	24	--
Pothole Point	NA	20	24	--
Big Spring Canyon Overlook	NA	20	24	--
Horse Canyon Jeep Trail	NA	10	24	--
Salt Creek Jeep Trail	NA	10	24	--
Cavespring	NA	20	24	--

(a) NA = Not Audible (below Threshold of Audibility).
(b) L_{dn} represents combined project and background noise.
(c) 24 represents the residual background levels defined in Section 3.4.4 with a 10-dB nighttime weighting.
(d) -- = No criteria have been identified.

threshold of audibility, which is 9 dB above acceptable levels. According to the criteria in Table 4-23, there is some likelihood of individual complaints. The L_{dn} value at the park boundary will be 27 dBA. The composite L_{dn} at Dugout Ranch is 32 dBA which is well below the U.S. EPA guidelines of 55 dBA.

The isopleths (contours) shown in Figures 5-25 and 5-26 reveal that traffic noise from the rail routes and the new site access road described in Section 5.1.2.2 accounts for the audibility impacts resulting from repository operation. Specifically, low frequency noise from the on-site switch engine is the major cause of audibility levels in the park. This condition will occur during two to four hours each day. Of the four alternative rail routes modeled, the two Colorado River Canyon routes, which follow corridors nearer the park, are predicted to result in higher noise impacts than the Spanish Valley and Kane Springs routes. The Colorado River routes would impact Canyonlands National Park, scenic overlooks, and noise sensitive wildlife habitats along the Colorado River (see Section 3.4.2.3).

Areas in Spanish Valley and Moab within approximately 25 meters (80 feet) of the Spanish Valley rail alignment will experience L_{dn} levels in excess of the EPA recommended level of 55 dBA. Areas between U.S. Highway 191 and the rail route may experience L_{dn} levels in excess of 55 dBA where the highway and the Spanish Valley routes are within 175 meters (580 feet) of each other (BNI, 1985d). No residences have been identified within these zones of impact.

In summary, local impacts from the operation of the proposed repository are mainly due to rail and road traffic and the on-site switch engine. The one daily round trip may affect areas for approximately 2 to 4 hours per day. On the basis of the audibility criteria presented in Section 4.2.1.6.1, impacts may include the following:

- Noise levels audible 2.4 kilometers (1.5 miles) into Canyonlands National Park
- Some likelihood of individual complaints at the nearest park boundary (19 dB above the threshold of audibility)
- Strong likelihood of individual complaints at Bridger Jack Mesa Wilderness Study Area (up to 31 dB above the threshold of audibility).

5.2.7.3.3 Decommissioning and Closure. Noise caused by decommissioning and closure of the site has not been modeled. It is expected that these activities can be scheduled, and sound power levels controlled, such that the sound levels would not exceed those identified for repository construction.

5.2.7.4 Impact Mitigation

Mitigation measures identified in Section 4.2.1.6.5 are reflected in the modeling results and will also be employed during the repository phase. The DOE will include noise control provisions in contracts with trucking firms and construction contractors to ensure the noise controls assumed in the modeling are implemented. It is assumed that all rail operations will be limited to daylight hours and that there will be no at-grade road crossings. State-of-the-art mitigation methods have been assumed in the analysis. Options for additional mitigation are limited. One possibility is the implementation of unproven equipment-noise controls providing 5 to 10 dB reduction for scrapers, loaders, and compaction equipment.

If the Davis Canyon site is chosen for repository development, noise mitigation requirements will be established based on identified need and consultation with appropriate agencies.

5.2.8 Cultural Resources

This section assesses the impacts that construction, operation, and decommissioning and closure may have on cultural resources. Cultural resource studies related to repository construction, operation, decommissioning and closure will be conducted in consultation with state agencies and Federal land managing agencies whose cultural resource responsibilities may be directly or indirectly affected by DOE repository program activities.

5.2.8.1 Construction

Construction of a repository at the proposed site, including the required road, rail, and utilities corridors, and associated subsurface facilities will create adverse effects on cultural resources eligible for the NRHP. These impacts will be both direct and indirect in nature. Prior to the initiation of any land-disturbing activities, all areas of direct impact (e.g., transportation corridors, utility and water corridors) will be subjected to an intensive field survey to identify cultural resource sites. Should this site be selected for development of a repository, similar intensive surveys will be performed throughout the 2,331-hectare (5,760-acre) controlled area, which will be withdrawn from Bureau of Land Management (BLM) administration and acquired from State and private sources.

An intensive archaeological survey was performed on a 160-hectare (400-acre) representative repository site; adverse impacts to significant cultural resources were not expected for that area (see Section 4.2.1.8.1). Systematic field surveys have not been conducted for the proposed railroad, access road, utility, and water corridors. However, cultural resource site file searches of the proposed transportation corridors were conducted. Within 0.8 kilometer (0.5 mile), on either side of each of the proposed routes, 237 cultural resource sites were recorded. These include 34 sites along Colorado River railroad route "A", 44 sites along Colorado River railroad route "B", 22 sites along Kane Spring Canyon railroad route, 87 sites along Spanish Valley railroad route, 33 sites along the repository access highway option, and 17 sites along the Newspaper Rock State Historical Monument bypass (BNI, 1985d). With the exception of Newspaper Rock, none of the recorded sites is currently listed on the NRHP. Once the specific railroad route, access road, utility corridor, and water route are selected, they will be surveyed prior to ground disturbing activity. Sites recorded during these surveys and the previously recorded sites will be assessed for NRHP eligibility.

Potential adverse indirect impacts to cultural resources from the construction of the repository and associated features include the following: (1) possible effects from particulate and gaseous emissions, (2) impacts from blasting and earth vibrations, and (3) increased vandalism and unintentional damage to cultural resources due to additional human intrusion into the area.

Air pollutants resulting from repository construction and subsequent operations were calculated to be below the current U.S. Environmental Protection Agency (EPA) standards. These emissions include total suspended particulates, nitrogen oxides, sulfur oxides, carbon monoxide, and other air emissions which may be produced by repository activities. Overall, current modeling (using conservative assumptions) indicates that concentrations would be lower than primary or secondary National Ambient Air Quality Standards (NAAQS). Based on these calculations, it is not expected that project activities will adversely affect nearby cultural resources through air quality degradation, and all estimates are below air quality standards designed to minimize material degradation. The significance of these features, especially rock art, however, warrants monitoring stone surfaces for chemical degradation or deposits caused by project emissions. Although the adverse effects of much greater concentrations of these emissions on monumental architecture and buildings (including deterioration of stone, alteration of pigments, and staining or darkening) have been documented in other parts of the world, it is not expected that similar effects will occur to the local rock art or stone masonry because of the lower concentration of emissions.

Potential impacts to nearby cultural resources from blasting associated with repository construction activities are not expected to be detrimental. If strong enough or near enough, blasting activities could have the potential to damage fragile prehistoric ruins or cause rock falls leading to destruction of cultural resource sites. However, the largest blasting activity during repository construction would only be approximately one-third of an established German standard used to protect "ruins, ancient and historic buildings given antiquities protection" (Siskind et al., 1980). Based on this standard, it has been concluded that project-related blastings should not affect the prehistoric ruins or rock formations in the vicinity of the proposed repository sites (DOE, 1984b). In addition to the identification, evaluation, and monitoring of cultural resources, another mitigation option for preventing potential loss of cultural resource features is archaeological ruins stabilization. Extensive ruins

stabilization efforts are currently under way in the Salt Creek Archaeological District of Canyonlands National Park. These efforts are designed to prevent future loss of prehistoric architectural elements due to natural deterioration and visitor impacts (Metzger, 1983; Metzger et al., 1985; Metzger and Chandler, 1985).

The potential for indirect impacts resulting from increased human intrusion to the area due to repository construction is substantial. Studies of vandalism to cultural resources nearby have documented increased incidences of vandalism to cultural resources due to improved access and additional numbers of people in areas where many significant archaeological sites are located (Nickens et al., 1981; Honeycutt and Fetterman, 1985). Such impacts to these resources are both intentional and unintentional. Partial mitigation of indirect impacts including vandalism and destruction of archaeological sites, illegal artifact collecting, and increased offsite land and unauthorized off-road vehicle use could be achieved through proper resource identification, evaluation, monitoring, and data recovery. In addition, possible resource protection efforts to be implemented could include: restricting offsite and off-road vehicle use; and implementing an educational program designed to develop an appreciation for the heritage value of archaeological sites; and a sensitivity for the preservation needs. Increased protection efforts could also be required of the National Park Service (NPS) and the BLM.

5.2.8.2 Operation

Operation of the proposed repository is not expected to have any direct effect on cultural resources, because no additional land will be acquired or disturbed until decommissioning and closure. Indirect impacts as discussed in Section 5.2.8.1, could continue. Mitigative procedures (developed during the construction phase) for indirect impacts will continue to be in effect during the operation phase, with monitoring of the results.

5.2.8.3 Decommissioning and Closure

Decommissioning and closure of the proposed repository are expected to produce minimal, if any, adverse direct impacts to cultural resources because little additional land will be disturbed. The potential for adverse indirect impacts would also lessen due to decreased numbers of people in the area. Direct impacts may result from placing peripheral markers around the perimeter of the controlled area, creating earthworks, and placing redundant warning symbols in the soil around the repository. Before land-altering activities are started outside the restricted area, surveys will be conducted to locate and evaluate cultural resources in the area.

5.2.9 Radiological

As with exploratory shaft development (Section 4.2.1.9), repository construction and operation would result in releases of radon and its daughter products to the environment. The rate of release and attendant level of impact would depend principally on the rate at which salt would be mined from the repository, and the content of radioactive elements in the salt. During site characterization, the radioactive content of the salt formation will be precisely measured, and an estimate of radon impact on the environment will be made.

Dose consequences of operational releases are assessed in Section 6.4.1. No repository-associated radon impacts are expected during repository closure and decommissioning, because no additional salt will be mined.

5.2.10 Impacts of Salt Management and Disposal

This section summarizes the potential environmental impacts associated with the management of salt and salt-laden rock during repository construction, operation and decommissioning, and measures for mitigating those impacts. The discussion is presented in three parts. First, the management practices are briefly described in the context of their potential for releasing salt to the environment. Secondly, measures for mitigating the impacts from these sources are discussed, and the basis for assessing the impacts is described. Finally, the options for permanently disposing of the excess salt are identified and described.

5.2.10.1 Salt Management and Control

The repository development will involve mining, handling, transport, onsite storage, reuse, and disposal of salt and salt-laden rock. The discrete elements of this salt management process are illustrated in Figure 5-27, along with each element's potential contribution to an overall salt emission and likely mitigation measures for each source point.

Repository development requires the excavation of corridors and waste emplacement rooms within the salt deposits. Salt excavated during repository construction will be brought to the surface for immediate offsite disposal, and stockpiling for backfilling during decommissioning and offsite disposal. Salt excavated during repository operation will be transferred from the development area directly to the emplacement area for use as backfill. Excess salt will be hauled to the surface for offsite disposal. The quantities of excess salt produced during construction, operation, and decommissioning are presented in Table 5-5 and discussed in Section 5.1.3.

Mined salt is brought to the surface on a skip and transferred by covered conveyors, either to the rail car loading facilities for transfer offsite or to the salt storage pile. Emissions of salt to the atmosphere occur at the outlet of the mine ventilation system and at the point of transfer of the mined salt to the surface transport vehicle. Saline water, from either the salt control devices or as storm runoff will be collected and conveyed to the evaporation and retention pond.

Although the surface transfer systems will be covered, small losses may occur along the haulage route. These will be collected as saline runoff and moved to the evaporation/retention pond.

When salt is exposed to the weather or another source of moisture, a hard surface crust forms in a few days which tends to shed rain water (Ver Planck, 1958; DOE, 1984a). According to the experience in the salt industry, stockpiled salt is not a source of windblown particles, and crusting can be accelerated by wetting the pile. Freshly deposited material will be wetted, after spreading and compacting to mitigate any wind effects (Section 5.1.2.3) (Parsons-Redpath, 1984).

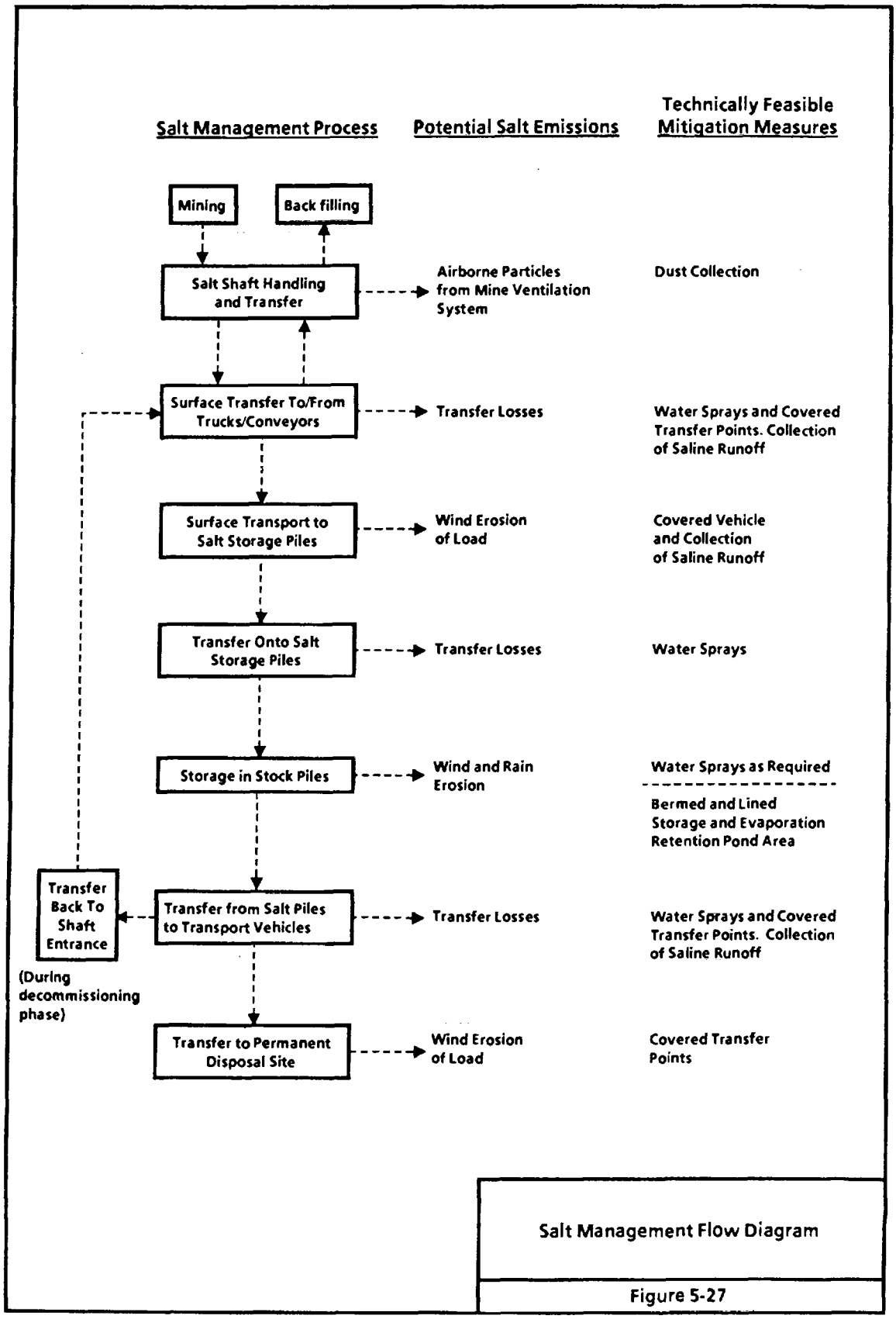
The active area of the salt storage pile will be kept moist as required to accelerate crust formation. Once the crust is established, further watering will not be necessary.

Possible leaching of brine from the evaporation and retention pond into the ground will be prevented by using double liners. These can be made of natural clays or synthetic materials (polyvinyl chloride, polyethylene, or polypropylene). A leachate collection system will be installed between the liners to monitor the integrity of the liners. The existing topsoil overburden will be stripped before emplacement of the liner and an engineered sound sub-base established. If a synthetic liner is used, an additional layer of compacted backfill material will be placed on top of the liner so that it can accommodate heavy equipment.

Three major retention ponds will collect runoff from the shaft area, haul roads and mined material stockpiles. In addition, water collected in the shaft sumps will be periodically pumped to the ditch system for collection at the evaporation and retention pond. The salt-pile runoff evaporation and retention pond will be designed for an operational volume equivalent to 100 percent of the rainfall volume from a 100-year, 24-hour storm falling on the areas which drain to the evaporation retention pond (Section 5.1.2.3).

Project GNOME and the Waste Isolation Pilot Plant (WIPP) involved salt management practices similar to those that will be employed at the repository. The knowledge gained from those two projects, therefore, provides useful insight (INTERA, 1978; DOE, 1980, DOE/EIS-0026).

Activities associated with the December 1961 Project GNOME underground nuclear test resulted in a substantial volume of sodium chloride salt being excavated and stored on the site. The storage facility for the salt is an area of approximately 3 acres enclosed by a dike and fence. The salt pile is stored inside the dike and fence but is otherwise open and



Salt Management Flow Diagram

Figure 5-27

exposed to the elements of the environment. The project GNOME test site is located approximately 30 miles southeast of Carlsbad, New Mexico. Soil samples and ecology surveys indicate that insignificant wind erosion and dispersion is occurring at the Project GNOME salt pile, and that there is little, if any, attendant adverse impact on the immediate surrounding environment due to salt dispersion by wind (INTERA, 1978).

The Waste Isolation Pilot Plant (WIPP), presently under construction approximately 40.2 kilometers (25 miles) east of Carlsbad, New Mexico, will test the feasibility of storing nuclear defense wastes in salt. Excavated salt has been stored in an uncovered, unlined pile holding about 136,080 metric tons (150,000 tons) of salt. The pile is surrounded by a bermed ditch which collects and evaporates the precipitation which falls on the pile (average rainfall: 22.9 centimeters [9 inches] per year). The salt is crusted over, and rainfall does not penetrate the pile. No problems with wind dispersion of the stored salt have been experienced (DOE, 1980, DOE/EIS-0026; 1984a).

5.2.10.2 Impacts of Salt Management

Soil productivity, water quality, ecosystems, and land use can be impacted by salt transported through air and water pathways. Assessment of the potential impacts requires identification and quantification of the various factors involved. For example, airborne salt can impact crop productivity through root uptake by the plants and foliar deposition. In these cases, not only must deposition rates be estimated, but irrigation rates, rainfall patterns, etc., must also be taken into account. The airborne particulate deposition rates for the repository are predicted to be 1.0 kilogram per hectare (0.9 pound per acre) per year at 0.8 kilometer (0.5 mile), diminishing to 0.2 kilogram per hectare (0.09 pound per acre) between 1 and 2 kilometers (0.6 and 1.2 miles) from the salt storage pile. The highest deposition rate per unit area would occur within the fenced area. The confidence level at which the deposition rate can be predicted will be improved by the monitoring of actual deposition during site characterization.

The amount of salt dispersed by a tornado would be limited by the crustation and reconsolidation of the salt storage pile and would be limited to the working face of the pile. The probability of a tornado strike to the site is addressed in Section 5.2.5.

Factors are identified in the following sections for each category of impact and numerical values provided to the degree that current information allows. Knowledge gained during characterization will be used in repository design and the planning of operating procedures.

5.2.10.2.1 Impacts on Soils. In preparation for the salt pile and associated evaporation and retention pond facilities, topsoil will be removed and stored for reuse during decommissioning. Proper lining and salt management activities should preclude contamination of soils under and adjacent to these facilities. On the basis of the deposition of windblown salt estimated for the repository operations (Section 5.2.5), the annual salt deposition rate is about 1 kilogram per hectare (0.9 pound per acre) per year. The deposition decreases with distance; most of the deposition occurs within fenced area. Deposition is estimated at 0.1 kilogram per hectare (0.09 pound per acre) 1 to 2 kilometers (0.6 to 1.2 miles) from the site (Section 5.2.5). This deposition rate will result in an incremental increase in salt concentration of the upper 0.3 meter (1 foot) of the soil strata and is estimated to be 0.2 part per million for a soil having a density of about 1,600 kilograms per cubic meter (100 pounds per cubic foot).

Accidental salt spills could adversely affect soils in a limited area by altering cation ratios that could produce sodic conditions. This would lead to dispersion of soil aggregates and loss of soil permeability. Reclamation would consist of containing the area within a berm and flooding with water to which amendments such as calcium chloride have been added (Hoffman and Meyer, 1982; Rhoades, 1982). The amendment would restore permeability as the water penetrated the soil and the leachate would be collected by drains and disposed of properly.

5.2.10.2.2 Impacts on Surface Water Quality. Runoff from the region around the salt pile and the shafts will be collected and channeled into evaporation and retention ponds. In

the Davis Canyon area, the precipitation is lower than the evaporation; therefore, there should not be excess saline water for offsite disposal.

On the basis of predicted salt deposition rates for repository operation (Section 5.2.5), the potential degradation of the water quality of the adjacent streams and water bodies by windblown salt would be small. The majority of the salt emission would be deposited within the site boundary; runoff from this area will be retained in the evaporation and retention pond. The amount of salt deposited in the adjacent watersheds was calculated to be less than 1,800 kilograms (2 tons) per year, equivalent to less than 0.5 percent of the present salt loadings carried in Indian Creek. The salt load of Indian Creek is estimated to be at least 454,000 kilograms (500 tons) per year from observed flow and water-quality data (Tables 3-14, 3-16, 3-17). The Colorado River, on the basis of water-quality data collected at the Cisco gaging station, carries a salt loading of 3.5 billion kilograms (3.8 million tons) per year. The annual salt deposition of less than 1,800 kilograms (2 tons) from repository operations in the nearby watershed would amount to less than 5×10^{-5} percent of the total salt burden of the Colorado River.

5.2.10.2.3 Impacts on Ground Water. Any area that is used for storage and handling of salt-laden material will be constructed using salt-resistant liners to minimize impacts to ground water. Salt concentrations between the liners will be monitored at various points around the site as an early warning system for possible salt contamination. Should salt be detected, appropriate measures will be taken to (1) restore the integrity of liners, (2) remove leaked effluents from between the liners, and (3) pump the leakage back to the surface.

Changes in ground-water quality due to infiltration of precipitation through soils contaminated by windblown salt will be minor. Modeling studies of repository operation show that deposition of salt for the repository will be about 1 kilogram per hectare (0.9 pound per acre) per year in the site area, diminishing to 0.1 kilogram per hectare (0.09 pound per acre) per year, 1 to 2 kilometers (0.6 to 1.2 miles) away (Section 5.2.5). If all of this salt were carried to the water table and distributed in the top 3 meters (10 feet) of the saturated zone, it would represent an annual increase in salinity of 0.01 to 0.1 part per million. However, it is unlikely that all wind-deposited salt could reach the water table, because much of it will be transported with storm runoff to the retention ponds. In addition, because the unsaturated zone at the site is very thick and the annual precipitation is low, the transport of surface salts to ground water is expected to be slow.

5.2.10.2.4 Impacts on Ecosystems. Impacts on terrestrial and aquatic biota resulting from repository development and operation were discussed in Section 5.2.4. The discussion below focuses on impacts from salt management.

The ions present in common salt, sodium and chloride, are universal components of plant materials. However, excessive amounts of these ions deposited on vegetation or present in the soil are harmful to plant growth. The major toxic effect is osmotic inhibition of water absorption; a common symptom is leaf-tip burn. Salinity levels (generally expressed as electrical conductivity) at which a definite reduction occurs in the yield of many crops have been reported (Wadleigh and Sherman, 1978; Bernstein and Howard, 1958). Since forage crops and native grasses are considered less susceptible to salt impacts than annual crops (Hart, 1983), the salt deposition impacts on native terrestrial ecosystems are also expected to be insignificant.

Based on salt deposition and accumulation (Section 5.2.10.2), no significant impacts to natural vegetation are expected to occur outside of the controlled area. As determined from air dispersion analysis, less than 0.1 kilogram per hectare (0.09 pound per acre) per year of windblown salt is expected to be deposited between 1 to 2 kilometers (0.6 to 1.2 miles) from the site. Most of the salt deposition, therefore, is expected to occur within the fenced controlled area.

Runoff from the controlled area and salt pile will be collected and directed to evaporation and retention ponds. Runoff outside the controlled area will contribute less than a 0.5 percent increase in the salt loading of Indian Creek and no measurable increase to the

Colorado River (Section 5.2.12.2.2). Hence, no impacts to aquatic biota in Indian Creek or the Colorado River will occur.

The evaporation and retention ponds will contain water only on an intermittent basis and consequently will not be a source of attraction of raptors or waterfowl.

5.2.10.2.5 Effects on Land Use. Deposition of windblown salt from the salt stockpile will not significantly affect plant growth (Sections 5.2.10.2.1, 5.2.10.2.4) and consequently, use of land for grazing activities at the Davis Canyon site. The impact will be minimal because predicted salt deposition rates are low (Section 5.2.5). In addition, deposition rate decreases with increasing distance from the site and the highest deposition rates will be confined to within the fenced controlled area. Control measures discussed in Section 5.2.10.1 will minimize the potential for soil and vegetative impacts that would affect land uses in the Davis Canyon site.

Consequently, no significant impacts to natural vegetation are expected to occur outside of the fenced controlled area. Hence, no impact or grazing productivity is expected.

5.2.10.3 Salt Disposal and Impacts

The development of a mined geologic repository in underground salt deposits will involve excavating large diameter shafts from the surface to the underground geologic formation and tunneling drifts in which the waste packages will be placed. More than half the excavated material will be used to backfill the mined areas after the placement of the wastes. The backfill material will be stored on the site and the excess 8.8 million metric tons (9.7 million tons) will be permanently disposed of.

5.2.10.3.1 Disposal Options. The excess salt and salt-laden material brought to the surface during repository construction and operation could be disposed of in the following ways (Section 5.1.3.4):

- Onsite disposal
- Commercial market
- Ocean disposal
- Great Salt Lake disposal
- Offsite (surface) disposal
- Mine disposal.

Selection of the disposal option will be based on a comparative evaluation of the advantages and disadvantages of all options suitable for a given site. A principal factor in such an evaluation will be the potential for environmental impact. The primary consideration will be assurance that the quality of the environment in the affected area during this and future generations will be adequately protected. Transportation, with its potential impacts and costs, will also be a significant factor in the evaluation, but will be given less weight than environmental impact.

The potential environmental impacts of each option have been identified and evaluated (D'Appolonia, 1976; BGI, 1983, ONWI-453; NUS, 1985; Scheriff, 1983; Langill, 1983; SCC, 1984), and the results of these works provide a basis for comparing the advantages and disadvantages among the options. While the repository program has not advanced to the point where the final selection of a disposal method can be made using data specific to the selected site, the significant impacts of the options at potential sites can be reliably anticipated at this time. The following sections summarize the salient features of each option.

Onsite Disposal. Onsite disposal would require the construction of a large surface storage area, underlain and covered by impervious materials. As discussed in Section 4.3.4.2, this option is relatively low in cost and has few immediate environmental impacts. Problems in ensuring long-term integrity of the landfill raises questions about long-term environmental impacts.

Commercial Market. Excavated salt would either be supplied through the General Services Administration to buyers or governmental agencies "as is," or following some onsite processing. Because the salt would be removed from the repository site, there would be no potential for long-term impact. Potential for short-term impacts would be limited in duration to the operating period of the repository and in magnitude to those of a commercial salt production facility.

If transportation costs exceed the market price of the salt, a subsidy might be required. Feasibility of this alternative has not been fully developed.

Ocean Disposal. The excess salt could be converted into brine and dispersed in ocean waters through outfalls. Transport of either the brine or the solid material from the site to the disposal point would be required.

As discussed in Section 4.3.4.2, such disposal techniques employed in the Gulf of Mexico have experienced negligible impacts on marine biota. There remains a concern regarding a potential for long-term irreversible changes that have not yet been observed in the short term.

Disposal in Great Salt Lake. Excess salt can be transported to the Great Salt Lake and discharged into the lake. Chemical companies are at present withdrawing lake water, extracting potassium and magnesium compounds, and returning concentrated brine to the lake. The amounts of salt disposed of commercially per year are larger than the amounts expected to be disposed of for the repository project. Negligible impacts are expected from this disposal procedure.

Offsite (Surface) Disposal. The potential for impact of this option would depend heavily on the environment chosen for disposal. Alkali flats and dried saline lake beds present the least potential for impact since the disposed salt would be blended into a natural environment composed of evaporite materials very similar in composition to the material being disposed of.

Short-term impacts would occur from transport and leveling of the salt over the lake beds; long-term impacts are not expected.

Mine Disposal. Excess salt would be transported by rail to existing evaporite mines, transferred underground on a closed conveyor system, and packed into unused sections of the mines. The principal impacts of this option would be the transport of salt from the repository site to the mine used for disposal. Those impacts would occur only during the operation of the repository and, therefore, would be short term.

There would be no expected long-term impacts associated with this option.

The supporting studies for the preceeding sections identify mine disposal as being environmentally benign and technically feasible. Numerous mine operations were contacted (Scheriff, 1983) to locate evaporite mines with the capacity to accept waste salt. These contacts have provided assurance that many mines with sufficient capacity are available.

Tentative mine sites have been identified within 2,240 kilometers (1,400 miles) of the repository site. The resulting transportation impacts, both environmental and economic, are relatively modest. This tentative choice could be modified, if warranted, on the basis of new information that will be obtained during the characterization phase.

Disposal in such a mine would eliminate the need to isolate the excess salt from the surrounding environment. Any mine selected as a candidate to receive excess salt would be subjected to detailed geotechnical, hydrological, and mine engineering evaluation to determine its suitability for that purpose.

5.2.10.3.2 Impacts of Disposal. For any selected disposal option, the excess salt will be loaded into hopper-type railroad cars and shipped to the disposal site. In the case of the reference option the excess salt will be shipped to an evaporite mine near Carlsbad, New

Mexico. Approximately 52 rail carloads of salt will be removed from the site each week. The Denver and Rio Grand Western, and the Atchison, Topeka and Santa Fe will be the likely railroads used. Distance is about 2,240 kilometers (1,400 miles). The salt will then be fed to skip loaders and transported down into the mine for backfilling. Conveyors will be covered and loadout structures enclosed as much as practicable with dust collection/suppression equipment used to reduce escape of salt dust. Thus, every effort will be made to limit additions of salt dust to the environment, although, as has been noted in the above report (NUS, 1985), the Carlsbad area is already heavily impacted by salt from natural sources and from the potash mining industry. Ecological effects from repository salt disposal are expected to be undetectable, given existing conditions. Water quality is generally poor and yield is low. Potable water is usually piped in from sources that are 30 to 45 kilometers (20 to 30 miles) away. Soil, vegetation, and wildlife have adjusted to saline conditions intensified by low rainfall (33 centimeters [13 inches] per year). Land use would not be adversely affected by using existing or abandoned mines, and air quality would be protected from further degradation by use of dust collection and suppression devices during unloading.

In the event of an accidental spillage of salt during transport, the potential impacts will depend on several factors:

- Location and quantities involved
- Proximity to water bodies
- Cleanup response time
- Weather conditions during that period.

Impacts resulting from accidental transportation spills on land will be localized and short-term. Spills occurring during precipitation could lead to infiltration of saline runoff. During dry conditions, a small plume of dust would be generated at the accident site, settling out within a short distance. Some vegetation that is not otherwise crushed or broken by either the vehicle or its load, may demonstrate symptoms of salt stress after prolonged exposure to salt drift or runoff in the event the site is not rapidly cleaned up. Procedures will be established to reload the salt into another vehicle, test soils for elevated salt concentrations, reclamate soil, and remove and replace soil or vegetation, as necessary.

There is a lower probability that accidental spillage into a body of water could occur. In that event, mitigation action would be more difficult and time dependent. If effective mitigation is not feasible, precautions are possible that will reduce the probability even lower (e.g., route selection and vehicle speed control).

5.3 EXPECTED EFFECTS OF TRANSPORTATION AND UTILITIES

This section identifies and describes the potential impacts of repository construction, operation, and decommissioning and closure on the existing transportation network and on utilities serving the study area. Nuclear transportation impacts are discussed in Section 5.3.1, environmental impacts of improvement to transportation corridors and facilities are described in Section 5.3.2, nonnuclear transportation impacts are discussed in Section 5.3.3, and the impacts of providing utilities for repository construction and operation in Section 5.3.4.

5.3.1 Nuclear Waste Transportation

This section presents information on the costs and risks of nuclear waste transportation to the Davis Canyon site to fulfill the requirements of the NWPA that the costs and impacts of waste transportation be considered in repository siting. This section addresses impacts specific to the region around the Davis Canyon site as well as nationally. Concerns that are generic to all sites are addressed in Appendix A.

There are also institutional issues related to transportation in the vicinity of the site as well as nationally along routes to the site. For discussion of these issues, the reader is referred to Appendix A and the DOE Mission Plan (DOE, 1985, DOE/RW-0005, Vol. 1, p. 98), Chapter titled: "The Institutional Development of the Transportation System."

Nuclear waste to be disposed of in a deep-mined geologic repository arises from a variety of sources across the United States. Wastes being considered for disposal include spent nuclear fuel, spent fuel consolidated at a monitored retrievable storage facility and the associated wastes generated from consolidation, defense wastes and high level waste from the cleanup of the West Valley, New York facility.

Two waste acceptance systems are presented in Appendix A. One is called the authorized system, the other is called the improved performance system. The impacts of both these systems on waste transport to the repository will be presented in this section.

The authorized system is based on the receipt of waste shipped directly from the point of generation to the Davis Canyon candidate repository site. For the authorized system, 62,000 metric tons uranium (MTU) of Spent Fuel from commercial nuclear power plants is received.

Additional waste sources considered in the authorized system include high-level waste from the cleanup of the commercial reprocessing plant at West Valley, New York, and from defense-related reprocessing activities at Savannah River, South Carolina; Idaho Falls, Idaho; and Hanford, Washington. The Mission Plan discusses the receipt of the equivalent of 8,000 MTU of defense and West Valley high-level waste (DHLW and WVHLW), making the evaluation consistent with the NWPA which states that the total capacity of the first repository shall be limited to 70,000 MTU until the second repository is in operation. Based on evaluations documented in Appendix A, waste equivalent to 11,425 MTU of defense waste and 400 MTU of West Valley HLW may be available for disposal. To be conservative, this section of the EA considers the impacts of transporting 62,000 MTU of spent fuel plus the equivalent of 11,825 MTU of HLW to the repository site.

The improved performance system considers the receipt of consolidated spent fuel from a monitored retrievable storage (MRS) facility. Generally, no spent fuel would first be moved from a reactor to the repository. Spent fuel is first shipped to the MRS for consolidation and storage if required (See Section 5.3.1.1 for a detailed description of the MRS scenarios). Then all the consolidated spent fuel along with the additional waste generated as a result of consolidation are shipped directly from the MRS facility to Davis Canyon via dedicated trains. The total quantity of consolidated spent fuel shipped from the MRS is 62,000 MTU. The improved performance system also considers the same additional waste sources as were considered in the authorized system, namely wastes from cleanup of the West Valley, New York, facility and from three defense related reprocessing activities (see Table 5-24). For the purpose of this analysis, it is assumed that these waste forms are shipped directly to the repository in both the authorized and improved performance systems.

The following subsections summarize waste transportation activities, the cost of such activities, the radiological and nonradiological risks associated with nuclear waste transport, and regional risks of nuclear waste transport.

5.3.1.1 Waste Transportation Activities

The introduction to this section briefly described the basis for the transport impact assessment. In order to describe the nuclear waste transportation activities, it is necessary to specify the geographic distribution of waste sources and the quantity of waste from each source location.

For the authorized system, the transportation analyses considers the shipment of spent fuel from each reactor to the Davis Canyon candidate site. The reactor sites considered, the quantity of waste shipped from each site, and the distance from each of the reactor sites to Davis Canyon by highway and railroad are included in the analysis. Because of the uncertainty in the combination of truck and rail transport, both 100 percent truck transport and 100 percent rail transport are considered.

For the improved performance system, truck and rail transport is considered from the reactor sites to the MRS facility but only rail transport of consolidated spent fuel is

considered from the MRS facility to the Davis Canyon site. The point of origin for the consolidated spent fuel shipments is taken as Oak Ridge, Tennessee.

In Appendix A, the transportation impacts are presented for four cases involving the MRS operations. The first case ships 62,000 MTU of spent fuel to the MRS, consolidates and overpacks the spent fuel so that it is ready to emplace upon arrival at the repository, and uses a 90.8-metric-ton (100-ton) rail cask to ship the consolidated and overpacked spent fuel to the repository. The 90.8-metric-ton (100-ton) cask is also used to transport the hardware and high activity wastes generated during the consolidated operation. The second case is similar to the first with the exceptions that a 136.2-metric-ton (150-ton) rail cask is used in place of the 90.8-metric-ton (100-ton) cask, and the consolidated spent fuel is not overpacked before shipment. The third case takes all spent fuel generated west of longitude 100 degrees and ships it directly to the repository. Longitude 100 degrees passes through the Texas panhandle and about 7.5 percent of the waste is generated west of this longitude. The remaining 92.5 percent of the spent fuel is shipped to the MRS. The fourth case is similar to the third except that a 136.2-metric-ton (150-ton) rail cask is used and consolidated spent fuel is not overpacked at the MRS. The fuel shipped from the MRS to the repository in 90.8-metric-ton (100-ton) rail casks as ready-to-emplace waste packages, making this case similar to Case 1 for these shipments.

In the EA it is desirable to give conservative impacts. A comparison of the four cases in Appendix A shows that Case 1 is the most conservative MRS case, and Case 4 is the most optimistic. In the impact sections that follow, Case 1 results will be shown in all the tables.

5.3.1.1.1 Required Shipments. The authorized and improved performance systems contain common elements. Thus, it is convenient to divide the analyses into four components which can then be combined to fully characterize the authorized and improved performance systems. These four components are as follows: Component 1: Transport of 62,000 MTU of spent fuel from the reactors directly to the repository via 100 percent truck transport or 100 percent rail transport; Component 2: Transport of 22,850 canisters of defense HLW and 800 canisters West Valley HLW from their points of origin to the repository using 100 percent truck transport or 100 percent rail transport; Component 3: Transport of 62,000 MTU of spent fuel from the reactor sites to the MRS facility via near Oak Ridge, Tennessee, either 100 percent truck or 100 percent rail; Component 4: Transport of consolidated spent fuel and secondary wastes from Oak Ridge, Tennessee, to Davis Canyon via dedicated train.

The estimated number of truck and rail shipments required for nuclear waste transport for the four components for all waste types is shown in Table 5-24. Also shown in the table are the cask capacities used for each of the packagings. These capacities are based on using current waste package data and packaging technology discussed in Appendix A.

For the spent fuel to repository component, it is estimated that approximately 71,000 shipments would be required for 100-percent-truck transport. Approximately 10,000 shipments will be required for spent fuel 100-percent-rail transport.

The defense and West Valley HLW component results in approximately 23,700 shipments for 100 percent truck transport or 4,700 shipments for the 100 percent rail transport. The breakdown of shipments among the waste sources is presented in Table 5-24.

The third component considers shipment of 62,000 MTU of spent fuel to the MRS by truck or rail. The number of shipments is approximately the same as the numbers required if the shipments had been sent directly to the repository Component 1. Approximately 10,000 rail shipments and 71,000 truck shipments are required. The numbers differ slightly because of shipping schedule differences.

The final component considers shipment from the MRS facility to the repository of 62,000 MTU of consolidated spent fuel and the resultant waste from the consolidation. The consolidated spent fuel, shipped as ready to emplace waste packages, require approximately 8,100 cask loads or approximately 1,600 dedicated train shipments over the lifetime of the

Table 5-24. Lifetime Nuclear Waste Shipment Requirements to Repository, Davis Canyon

Waste Receipt	Total Packages	100 Percent Truck		100 Percent Rail		Shipment Miles (millions)(f)	
		Payload(a)	Total Shipments	Payload(a)	Total Shipments	100% Truck	100% Rail
Component 1 - Spent Fuel Direct to Repository							
PWR(b)	--	2	43,611	14	6,190		
BWR(b)	--	5	26,942	36	3,737		
Total	--		70,553		9,927	115.1	18.8
Component 2 - Defense(c) & West Valley Wastes							
SRL	11,600	1	11,600	5	2,320		
INEL	9,000	1	9,000	5	1,800		
Hanford	2,250	1	2,250	5	450		
Total DHLW	22,850		22,850		4,570	28.0	6.5
WV-HLW	800	1	800	7	115	2.0	0.2
Total	23,650		23,650		4,685	30.0	6.7
Component 3 - Spent Fuel to MRS							
PWR	--	2	44,222	14	6,267		
BWR	--	5	26,346	36	3,667		
Total	--		70,568		9,934	48.8	8.0
Component 4 - Consolidated Fuel from MRS							
Consolidated SF	--	--	--	24 PWR/30 BWR(d)	8,074		
Hardware (HDW)	5,455	--	--	4	1,364		
High-Activity Waste (HAW)	5,084	--	--	4	1,270		
CH-TRU 36 Drums	11,400	--	--	72(e)	159		
Total					10,867	20.6(g)	20.6(g)
Authorized System Components 1 & 2							
Spent Fuel			70,553		9,927		
Defense & West Valley HLW			23,650		4,685		
Total			94,203		14,612	145.1	25.5
Improved Performance System (Components 2, 3, & 4)							
Spent Fuel to MRS			70,568		9,934		
Consolidated SF & Assoc. Wastes			(g)		10,867		
Defense & West Valley HLW			23,650		4,685		
Total			94,218		25,486	99.4	35.3

(a) Payload refers to number of fuel assemblies, canisters, waste packages, or drums per transport package.
(b) PWR = pressurized water reactor; BWR = boiling water reactor.
(c) SRP = Savannah River Plant; INEL = Idaho National Engineering Laboratory.
(d) 100-ton cask, 24 PWR assemblies in two ready-to-emplace waste packages, 30 BWR assemblies in one ready-to-emplace waste package. This is the most conservative MRS case.
(e) 2 CH-TRU packages, 36 drums per package, in each rail car.
(f) One-way loaded miles.
(g) All shipments from MRS to repository via dedicated train shipments (train miles given).

repository. It is estimated that another 2,800 casks, containing wastes produced from the consolidation operation will also be shipped in the dedicated trains over the lifetime of the repository.

From these four components, it is possible to construct the shipment requirements, costs, and risks associated with both the authorized system and the improved performance system. The authorized system includes Components 1 and 2, the improved performance system includes Components 2 through 4. The shipment data for these two transport systems is shown at the bottom of Table 5-24.

5.3.1.1.2 Waste Transportation Costs. The shipment information in Table 5-24 has been used with the source distribution data to estimate the total cost of transporting nuclear waste to the Davis Canyon site by rail and by truck. These costs were developed using data and techniques summarized in Appendix A. The total life-cycle costs for the two Mission Plan Transportation Systems are shown in Table 5-25. The costs shown are the projected total transport costs for the repository's shipping lifetime (approximately 25 years) expressed in undiscounted 1985 dollars.

The costs consider fleet capital, fleet servicing and maintenance, and shipping charges. Fleet capital costs were based on transportation system characteristics and comparison with costs of existing transportation systems. Servicing and maintenance costs were estimated by multiplying a fraction of the unit capital costs per year by the operating fleet size. It was also assumed in the capital cost estimate that the casks would be replaced once during the repository operation lifetime for any shipment schedule that exceeded 15 years. Based on the shipment schedule shown in Appendix A, the cask fleet was completely replaced for spent fuel, consolidated spent fuel, and associated waste, West Valley HLW, and defense high-level waste from the Savannah River plant. The cask fleet was not replaced for Idaho Falls, and Hanford HLW shipments.

Freight charges were based on published tariffs, where available, and estimates were based on spent-fuel shipments where no tariffs have been published. Charges for physical security in transit were based on current spent fuel escorting experience. These costs were applied to all waste forms. The cost projection is believed to be conservative in that current regulations do not include such requirements for HAW, HDW, and CH-TRU waste shipments from the MRS.

5.3.1.2 Radiological and Nonradiological Effects Associated with Nuclear Waste Transport

The measure used for estimating the radiological and nonradiological effects of nuclear waste transport to the Davis Canyon site is the risk of several categories of health effects to the general population. The categories are broadly divided into nonradiological and radiological health effects.

The radiological impacts considered health effects associated with both normal transport and very infrequent accidents severe enough to release some of the radioactive material being carried. Health effects considered both acute fatalities and latent cancer fatalities to both the present and future generations. The estimates were made by a computer code, RADTRAN-II (Appendix A). RADTRAN-II models both incident-free radiological exposure and the consequence of radiological releases following severe accidents. The results depend on such factors as population density, transport mode, distance, cask capacity, and accident rates. The results of analyses show that no acute radiation fatalities are projected as a result of any postulated accidents. Thus, only latent cancer fatalities (LCFs) have been included in the results tables shown in this section and in Appendix A.

The nonradiological health effects include injuries and fatalities associated with transport vehicular accidents as well as pollution health effects caused by truck and train emissions primarily in urban areas. Accident rate experience using transportation accident rate statistics was used for estimating the number of nonradiological injuries and fatalities and is described in Appendix A. Pollution health effect estimates were based on analysis

Table 5-25. Total Life-Cycle Nuclear Waste Transport Cost

Receipt Type	100 Percent Truck Transport	100 Percent Rail Transport
Authorized System		
Spent Fuel	1,080	917
West Valley HLW	10	11
Defense HLW	214	278
Total	1,305[a]	1,207[a]
Improved Performance System[b]		
Spent Fuel to MRS	600	593
Consolidated Spent Fuel from MRS	728[c]	728
HAW and HDW Wastes from MRS[d]	144[c]	144
CH-TRU from MRS[d]	9[c]	9
West Valley HLW	10	11
Defense HLW	214	278
Total	1,709[a]	1,767[a]

(a) Sum of component values shown may not add up to total because of round off.
(b) Ready for emplacement waste packages in 100-ton casks, the most conservative MRS case.
(c) Dedicate train cost of consolidated spent fuel and associated waste shipments included to completely describe truck transport of spent fuel to MRS and Defense & West Valley HLW to the repository.

(d) HAW = High-activity waste, HDW = Hardware; CH-TRU = Contact-handled transuranic waste.

methods and data developed by the Transportation Technology Center (TTC) at Sandia National Laboratories and are summarized in Appendix A. These analyses conclude that essentially all pollution health effects from transportation occur while vehicles are travelling through urban areas. Appendix A provides estimates of the fractions of travel through urban areas for shipments to the repository sites. These estimates are used tc estimate the pollutant health effects shown in Table 5-26.

Table 5-26 summarizes the nonradiological and radiological risk measures for transporting waste to the Davis Canyon site. As stated previously, an upperbound estimate of the risks associated with waste transport is desired. To obtain this estimate, the two Mission Plan Transportation Systems, the authorized system, and the improved performance system have been evaluated. Analyses which maximize truck and rail shipments for the two systems show that the upper-bound truck radiological risk estimates are obtained using the authorized system, and upperbound rail radiological impacts are essentially the same for both cases.

The purpose of this analysis is to bound the impacts and not compare the two transportation systems. The more important fact to recognize is that the risks, even for the bounding case, are very small compared to other risks. This perspective will be discussed in Section 5.3.1.2.3.

Based on the values in Table 5-26, the limiting impacts, over the approximately 25-year shipping lifetime are as follows: the maximum number of injuries projected to occur from traffic accidents are 230 for rail and 410 for truck; the maximum number of fatalities projected to occur from traffic accidents are 22 for rail and 35 for truck; and radiation exposure resulting from normal transport is estimated to result in less than 1 latent cancer fatality to present and future generations for rail and approximatley 10 for truck transport. The potential risk associated with accidents severe enough to release some of the radioactive material being transported to the repository is less than 1 fatality over the shipping period of approximately 25 years.

5.3.1.2.3 Risk Perspectives. The previous paragraphs have presented many data regarding the maximum risks of nuclear material transport to candidate repository sites. It is important to place these values into perspective to be meaningful. All results have been based on a minimum operating period of 25 years of repository operation. During a 25-year period, using the same models and data as in this analysis, which is based on methods developed by the Committee on the Biological Effects of Ionizing Radiation (CBEIR, 1980) of the National Academy of Sciences, 113,000 LCFs would be predicted in the nation from background radiation. Based on the accident data for 1983 (National Safety Council, 1984), 112,500 individuals would be predicted to die during a 25-year period as a result of accidents involving truck tractors and semitrailers. For transport of all freight over all rail lines, using 1983 accident data (National Safety Council, 1984) the same reference predicts that the number of fatalities would be 27,000 individuals.

The fatalities resulting from accidents, and not from the radiological nature of the cargo, are less than 0.03 percent of the fatalities attributed to the transport of commercial freight. The latent cancer fatality estimates are less than 0.01 percent of those attributable to natural background. Thus, all the national risks resulting from nuclear waste transport are extremely small relative to other comparable risks. This conclusion is valid for both the authorized and improved performance systems.

5.3.1.3 Mode of Transport and Access Routes

The most visible impact on the region around the repository will be the regular transport of waste materials into the region. The frequency of shipments will depend on the mix of truck and rail transport used.

The daily receipt rate estimates are shown in Table 5-27. The maximum receipt rates are 16 trucks per day for the 100 percent truck case and 3 rail cars per day for the 100 percent rail case. It should be pointed out that the payload of the casks and a mix of rail and truck shipments has a large effect on the daily receipt rates. The maximum truck shipment numbers shown in Table 5-24 are not expected to be exceeded.

Table 5-26. Total Risk of Nuclear Waste Transport to Davis Canyon During the Operational Period (Approximately 25 Years)[a]

Risk Measure	Waste Transport Mode	
	100 Percent Rail	100 Percent Truck
Authorized System		
Nonradiological		
Number of injuries	25	380
Number of fatalities	2.4	30
Pollutant health effects[b]	0.2	0.4
Radiological[c]		
LCFs from normal transport	0.3	9.5
LCFs from accidents	0.02	0.03
Improved Performance System[e]		
Nonradiological		(d)
Number of injuries	230	410
Number of fatalities	22	35
Pollutant health effects[b]	0.3	0.4
Radiological[c]		
LCFs from normal transport	0.3	5.4
LCFs from accidents	0.04	0.05

(a) Includes WVHLW and DHLW shipments.
(b) Calculated latent cancer fatalities (LCFs) from which emissions to present and future generations.
(c) Calculated LCFs from radiation exposure to present and future generations.
(d) Includes rail shipments from MRS.
(e) Ready for emplacement waste packages in 100-ton casks, the most conservative MRS case.

Source: Appendix A.

Table 5-27. Average Daily Waste Receipts

Scenario Receipt Form	Transport Mode	
	100 Percent Truck	100 Percent Rail
Authorized System		
Spent Fuel[a]	12	2
Defense & West Valley Waste[b]	4	1
Total	16	3
Improved Performance System		
Consolidated SF and Secondary Waste[a]	(c)	2[d]
Defense & West Valley Waste[b]	4	1
Total	4	3

(a) Total of 3,000 MT (3,307 tons) per year of spent fuel, 50 weeks per year, 6 days per week.
(b) Based on peak receipt rate of 1,190 canisters per year during 50 weeks per year, 6 days per week.
(c) Consolidated spent fuel; rail only in dedicated trains.
(d) Receipts will occur via dedicated train, approximately one train of less than 10 cars every 5 days.

The exact mode of transport to the site from the many waste generation and storage points in the United States is difficult to project for rail transport because the routes may be dependent on contractual agreements entered into by the Department of Energy (DOE) with waste carriers. For highway transport, the local routes are uncertain because the State of Utah, using the Department of Transportation (DOT) guidelines, can designate preferred alternative routings. The analyses presented here are based on routes judged reasonable by the DOE.

The region, as defined for this regional calculation, is a circle with a radius of 200 kilometers (125 miles) centered on the site. The 200-kilometer (125-mile) radius was selected based on a need to include the major rail interchange locations that may be used to bring waste to the site. A similar situation exists for highways, although the major consideration there is site access from the national interstate highway system. For the Davis Canyon Site, the interstate north of the site is intersected by the 200 kilometer radius circle but the interstate south of the site is not. Because access from the south (I-40) is a reasonable alternative, it has been included in the analyses. The major highways and rail lines in the area, along with access route alternatives to the site, are described in Sections 3.5 and 5.1.2.2. The following paragraphs consider first the regional impacts of highway transport then the regional impacts of rail transport.

5.3.1.3.1 Regional Highway Routing - Davis Canyon, Utah. Consistent with DOT regulations for hazardous material transport, it is expected that nuclear waste will enter the region using the interstate highway system. The closest interstate highway is I-70. However, I-40, located south of the site is another possible entry route. Both are major east-west truck routes and access from both routes will be considered in the following analysis. A description of the access routes from these interstate highways is discussed in Sections 3.5 and 5.1.2.2.

The DOT highway routing regulations (49 CFR 177.825) state that "Preferred Routes" are defined as any route designated by a "State routing agency" and any Interstate System highway for which an alternative highway has not been designated by the State agency (see Appendix A for further discussion). At this time in the siting process, the State routing agency has not designated any preferred routes, thus several feasible routes to the site will be evaluated not for the purpose of comparing routes but rather to insure that the impacts of nuclear waste transportation have been adequately bounded. Consistent with this approach the following three routes are considered below.

I-70 West - U.S. 191 South. Traffic from the eastern U.S. would enter the region on I-70 traveling west to the interchange with U.S. 191 at Crescent Junction, Utah. I-70 is in excellent condition and of typical interstate design east of Crescent Junction. The exit ramp from I-70 is adequate for heavy truck traffic.

Carriers would turn south onto U.S. 191 and travel for about 106 kilometers (66 miles) to the new access route. U.S. 191 is a two-lane asphalt road with 0.3-to 1-meter (1- to 3-foot) shoulders and 3- to 4-meter (10- to 12-foot) lanes. The highway is relatively flat and straight for the first 24 to 32 kilometers (15 to 20 miles) before it winds down into the Colorado River Canyon and Moab, Utah. From Moab to La Sal Junction, the highway is relatively flat except for crossing two canyons, each with steep grades and sharp turns. U.S. 191 may need to be widened and upgraded in certain spots, although it already handles a fair amount of heavy truck traffic. U.S. 191 would interchange with a newly constructed repository highway (or Utah 211, depending on which repository access route is chosen).

I-70 East - U.S. 191 South. Traffic from the western U.S. would enter the region traveling east on I-70 to Crescent Junction. Carriers would exit I-70 at Crescent Junction and follow the route described above.

I-40 East or West - U.S. 666 and 191 North. Traffic from the eastern and western U.S. could travel on I-40 to Gallup, New Mexico. At Gallup, traffic would exit I-40 and travel north on U.S. 666 through Shiprock, New Mexico, Cortez, Colorado to Monticello, Utah. From Monticello, Utah, the access route follows U.S. 191 north to the junction of Utah 211 or the repository access route. The road already carries a fair amount of heavy truck traffic. It may need to be widened and upgraded in certain spots.

A methodology for estimating cost and risk on a national basis, has been developed, and Appendix A summarizes the data and methodology. However, these analyses do not address the relative impact on the region near the potential repository site to meet the needs of this environmental assessment.

In the following paragraphs, the national risk-estimating methodology will be applied to the region in order to make a preliminary evaluation of the regional impact. It should be pointed out that many of the parameters used in a national evaluation may not apply locally because of site-specific conditions or characteristics. At this time, an evaluation thorough enough to establish the validity of using national techniques in a regional analyses cannot be completed because of insufficient data. Therefore, these analyses should be considered preliminary.

The regional risk calculation assumes that all shipments of the authorized system and the highway fraction of the improved performance system will be shipped on each route analyzed. Since the goal of this calculation is to estimate the regional risk, the above assumptions are adequate. Attempting to try to specify the fraction being shipped by rail or truck, and the fraction utilizing a specific route, cannot be done with certainty at this time.

The risk calculation requires several parameters concerning the region, the population density along the route, the fraction of travel along each route, and the total route length. In addition, the total number of shipments made along the route is needed.

Route-specific population density estimates are preliminary at this stage. They were obtained from the County and City Data Book (Bureau of the Census, 1983, pp. 60, 564, 822, 917). To characterize the population density along the route, three population density classifications have been considered. They have been termed urban, suburban, and rural for these transportation assessments. They are defined in the following paragraph. The definitions are consistent with those in the national analysis but should not be confused with somewhat different usages of the terms in the socioeconomic evaluations.

The suburban density was estimated by taking all towns and cities of between 2,500 and 100,000 population in the region and estimating the average population density. This value was used for all routes in the regional analyses. The rural density was based on a route specific evaluation. For each route a weighted rural density was calculated using the following procedure. The distance through each county was estimated. Then the rural density in the county was calculated by taking the county population and land area and subtracting from these values the population and land area of any towns and cities. The average rural density along a route was then calculated by weighting the county data by the fraction of travel through the county and summing the weighted values. The mean urban densities were assumed to be 3,861 people per square kilometer (10,000 people per square mile). This density has been used in the national analyses presented in Appendix A. For the Davis Canyon regional analysis, there were no cities of greater than 100,000 people within 200 kilometers (125 miles) of the site. Thus the urban calculation was skipped and the fraction of travel through urban zones was set to zero in all routes. The results of the population density calculation for Davis Canyon are shown in Table 5-28 in the section of the table labeled Population Density.

The next step in the regional calculation was to estimate the fraction of travel through each population zone on a route-specific basis. The route fraction estimates are shown in the second section of lines in Table 5-28 under the heading Fraction Through Population Zones. The unit risk factors for the routes were adjusted for population density using a technique described in Section A.8.3.3. of Appendix A. The unit risk factors were then multiplied by the appropriate vehicle mileages traveled in the region to get the impact results shown at the bottom of Table 5-28.

The purpose of the regional risk calculation is to estimate the risk to the people in the vicinity of the site should the site be chosen as a first repository for high level nuclear waste. The values presented in Table 5-28 are not presented for the purpose of comparing routes but rather to estimate the spectrum of risks that are projected. The size of the risk number and not the variation caused by using different routes is of interest. Based on the

Table 5-28. Regional Risk Calculation (Highway), Davis Canyon

Route Characteristic	Route No. 1	Route No. 2	Route No. 3
Interstate route	I-70 West U.S. 191 South	I-70 East U.S. 191 South	I-40 East or West U.S. 666 & 191 North
Distance (kilometers)	381	352	370
Fraction through population zone (percent)			
Urban	0	0	0
Suburban	2.5	1.8	0.4
Rural	97.5	98.2	99.6
Population density (people/km^2)			
Urban	3,861.0	3,861.0	3,861.0
Suburban	363.0	363.0	363.0
Rural	1.6	0.8	1.7
RISK PARAMETERS			
Authorized System			
Nonradiological			
Fatalities	4.8	4.4	4.7
Injuries	59	54	58
Radiological LCFs[a]			
Normal transport	1.2	1.1	1.1
Accident risk	0.0003	0.0002	0.00005
Improved Performance System[b]			
Nonradiological			
Fatalities	3.3	3.2	3.3
Injuries	37	36	37
Radiological LCFs[a]			
Normal Transport	0.3	0.3	0.3
Accident Risk	0.0002	0.0002	0.0002

(a) LCF = Latent cancer fatality.
(b) Includes risk of dedicated train shipments to the repository from the MRS.

size of the numbers, the incremental risk associated with regional transport is very small compared with other risks to the same population.

5.3.1.3.2 Railroad Routing. It is too early to be certain of the exact railroad routes which will be used to the potential site. However, the Denver and Rio Grande Western (D&RGW) is the only Class 1 rail line operating within a 200 kilometer (125 mile) radius of the site. Potential alternative access routes are shown in Section 5.1.2.2. In an attempt to bound the transportation impacts, not compare routes, the following access corridors have been analyzed.

1. Route 1: Numerous railroads could interchange with the Denver and Rio Grande Western (D&RGW) at Denver and Pueblo, Colorado. Most waste traffic from the east is expected to use these interchanges. From there, traffic would proceed along the D&RGW to Grand Junction, Colorado. Nuclear waste repository traffic would then be switched to local train service to Potash, Utah. The cars destined for the repository would be picked up by the repository railroad for delivery to the site along the Colorado River route. It is described in Section 5.1.2.2 as the Colorado River Canyon Route A.

2. Route 2: The second route is identical to the first down to the point where the waste is switched to local train service to Potash, Utah. Rather than go all the way to Potash on the spurline, the waste is interchanged with the repository access railroad about 9 miles north of Potash. This access route follows a route through Moab and Spanish Valley generally paralleling U.S. 191. It is described in Section 5.1.2.2 as the Spanish Valley Route.

3. Route 3: Nuclear waste traffic from the west, and possibly waste from the east, could be interchanged with the D&RGW at Ogden or Salt Lake. From there it would proceed east through Provo to Helper, Utah, where crews are changed. From Helper, cars carrying nuclear waste could be carried in local service for delivery to Potash. From Potash, the cars would be delivered to Davis Canyon via the repository railroad designated as Colorado River Canyon Route A.

4. Route 4: This route considers waste coming from the west similar to Route 3, and repository access on a route through Moab as was done in Route 2.

The regional risk rail shipment to the site will be evaluated by assuming each of the routes is used to ship waste materials to the repository. Table 5-29 summarizes the results of the calculation using the unit risk factors based on the actual population densities along the routes. The first seven lines provide a summary of the characteristics of the route, expressed in terms of distance traveled in the 200-kilometer (125-mile) radius, the fraction traveled through urban, suburban, and rural routes, and the population density in those regions. The same techniques used in the regional highway analyses were used in this rail analysis.

As was the case with the highway risks, of concern is the magnitude of the regional risk value and not the differences among routes. Based on the magnitude of these numbers the risk of nuclear waste transport is very small.

5.3.1.3.3 Barge Transport of Spent Fuel. Up to this point the entire discussion of the costs and risks of waste transportation to the repository have considered truck or rail transport. However, barge transport is discussed in Appendix A. Because the Davis Canyon site is hundreds of kilometers from these points of debarkation, no regional effects of barge transport are envisioned. Casks shipped by barge could be transferred on to rail cars at the ports on the Gulf or Mississippi River. It would appear to individuals in the region as a typical rail nuclear waste shipment. It may be more likely to arrive as a dedicated train, a case that has been bounded by the analyses of the Improved Performance System.

Table 5-29. Regional Risk Calculation (Rail), Davis Canyon

Route Characteristic	Route No. 1	Route No. 2	Route No. 3	Route No. 4
Point of Entry	Grand Junction, Colorado	Grand Junction, Colorado	Helper, Utah	Helper, Utah
Access Route	Colorado River Route A	Spanish Valley Route	Colorado River Route A	Spanish Valley Route
Distance (kilometers)	328	339	267	286
Fraction Through Population Zone (percent)				
Urban	0	0	0	0
Suburban	3.4	4.7	1.8	3.4
Rural	96.6	95.3	98.2	96.6
Population Density (People/km^2)				
Urban	3,861[a]	3,861	3,861	3,861
Suburban	363	363	363	363
Rural	1.8	1.8	0.8	0.8
RISK PARAMETERS				
Authorized System				
Nonradiological				
Fatalities	0.3	0.3	0.2	0.2
Injuries	2.8	2.9	2.3	2.5
Radiological LCFs[b]				
Normal Transport	0.05	0.05	0.04	0.05
Accident Risk	0.0002	0.0002	0.00007	0.0001
Improved Performance System				
Nonradiological				
Fatalities	2.3	2.3	2.2[c]	2.3[c]
Injuries	23	23	23	23
Radiological LCFs[b]				
Normal Transport	0.02	0.02	0.02	0.02
Accident Risk	0.0002	0.0003	0.0002	0.0003

(a) 10,000 people per square mile.

(b) LCF = Latent cancer fatalities.

(c) Dedicated train shipment of consolidated spent fuel and associated wastes were assumed to enter the region via Grand Junction. The risk of these shipments through Grand Junction was calculated and added to the DHLW and WVHLW shipments over this route.

5.3.1.4 Additional Regional Concerns

Concerns have been expressed about the consequences of releases from severe transport accidents, radiation exposure to individuals under normal conditions of transport, and the cumulative exposure occurring to the people in the vicinity of the site because some individuals could see several shipments. These concerns are addressed in the following paragraphs.

5.3.1.4.1 Radiation Exposures to Individuals From Normal Transport. The previous risk analyses aggregate the radiation exposure and, in turn, health effects to the national and regional population from all nuclear waste transportation activities. This section identifies several activities and routine operations in which individual workers are exposed to radiation. Also included, are exposures to individuals in the public domain under conditions which may occur during normal transportation operations. These exposures are summarized in Tables 5-30 and 5-31. Further description of these activities and assumptions made in the calculations of radiation exposure are given in the references cited in Appendix A.

It should be noted that the likelihood of repeated exposures of individuals in the public domain is low; however, such repetitive exposures could conceivably occur in the vicinity of the repository but have not yet been quantified except as noted in the next paragraph. Detailed studies of repetitive exposures will be done during site characterization activities (Section 4.1.3.1.10) in the vicinity of the repository where such repetitive exposures could conceivably occur. Repetitive exposure to services personnel or other transportation workers will also be examined and necessary procedures and equipment developed, if required, to limit occupational exposures to acceptable levels.

5.3.1.4.2 Cumulative Exposure. As the shipment nears the repository, more vehicles will carry waste along fewer routes. Thus, one concern in the region is the cumulative exposure realized by an individual. This exposure is commonly termed the Maximum Individual Dose and is given in the last entry of Table 5-30.

The range of estimates for the maximum individual dose assumes the individual is 30 meters (98 feet) from all shipments as the transport vehicle (truck or rail) moves past the individual at 24 kilometers (15 miles) per hour. Over the 25-year shipping period of the repository, the cumulative individual dose received ranges from 40 to 203 millirem.

Annually the maximum individual exposure values range from 2 to 8 millirem. Assuming the average individual dose 139 millirem per year from natural background (Section 3.4.7), the maximum exposed individual would receive an increase above background ranging from 1 to 6 percent as a result of waste transport. Additional data on traffic patterns through regional highway and rail systems are needed for more precise analyses of the maximum individual dose in the region. The values given here are believed to be very conservative, and actual exposures are expected to be significantly lower.

5.3.1.4.3 Radiation Exposure to Individuals and Population Groups Under Accident Conditions. The previous risk analyses aggregate the radiation exposure from accidents and, in turn, health effects to the national and regional population into the overall risk analyses which includes both normal and accident exposures. This section identifies several classes of severe accidents which could occur and summarizes the resulting exposures to individuals and population groups in the vicinity of the postulated accidents. Only accidents involving a rail cask are analyzed because it is assumed that the accident severity and isotopic releases in a truck accident would be bounded by the rail accident. Further detail on description of the accident scenarios, assumptions used in the calculations and resulting radiation dose distribution and pathways to humanity is given in the references cited in Appendix A.

Accident consequences in terms of dose and LCFs to individuals and population groups are given in Tables 5-32 through 5-34 for atmospheric release and land or water contamination. Isotopes considered and pathways to man assumed are discussed in Appendix A.

The accident classes listed are considered to include credible but extremely severe and unlikely rail accidents. In the extreme case, the rail cask and its air-cooled, spent fuel

Table 5-30. Estimated Radiological Exposures to an Individual in the Public Sector from a Single Shipment Under Normal Conditions of Transport[a]

Activity Transport	Mean Distance from Center of Cask (meters)	Exposure Time (minutes)	Approximate Total Dose (mrem)
TRUCK TRANSPORT			
Caravan			
Passengers in vehicles traveling in adjacent lanes in the same direction as cask vehicle	10	30	1
Traffic Obstruction			
Passengers in stopped vehicles in lanes adjacent to the cask vehicle which have stopped due to traffic obstruction	5	30	3
Residents and Pedestrians			
Slow transit (due to traffic control devices through area with pedestrians)	6	6	0.4
Truck stop for driver's rest. Exposures to residents and passers-by	40	480[b]	3
Slow transit through area with residents (homes, businesses, etc.)	15	6	0.1
Residents exposed to 100 percent of shipments	30	25 years	203
RAIL TRANSPORT			
Caravan			
Passengers in rail cars or highway vehicles traveling in same direction and vicinity as cask vehicle	20	10	0.3
Traffic Obstruction			
Exposures to persons in vicinity of stopped/slowed cask vehicle due to rail traffic obstruction	6	25	2
Residents and Pedestrians			
Slow transit (through station or due to traffic control devices) through area with pedestrians	8	10	0.7
Slow transit through area with residents (homes, businesses, etc.)	20	10	0.2
Train stop for crew's personal needs (food, crew change, first aid, etc.)	50	120	0.7
Residents exposed to 100 percent of shipments	30	25 years	40

(a) Appendix A, Authorized System. Values for the Improved Performance System will be lower.
(b) Assumes overnight stay.

Table 5-31. Estimated Radiological Exposures to an Individual Worker from a Single Shipment During Selected Activities Under Normal Conditions of Transport

Activity Transport	Mean Distance from Center of Cask (meters)	Exposure Time (minutes)	Approximate Total Dose (mrem)
Truck Servicing and Monitoring			
Refueling (100-gallon capacity-1 nozzle-1 pump)	7	40	2
Tire change or repair to cask trailer	5	50	5
Load inspection and enforcement	3	12	2
State weight scales	5	2	0.2
Train Servicing and Monitoring			
Engine refueling, car changes, train maintenance, etc.	10	120	5
Cask car coupler inspection and maintenance	9	20	1
Axle, wheel or brake inspection, lubrication, and maintenance on cask car	7	30	3
Cask inspection and enforcement by train, State or Federal officials	3	10	2

Source: Appendix A, Authorized System.

assemblies are assumed to suffer impact rupture, or both impact and burst rupture, or a combined impact and burst rupture accompanied by increased release due to spent fuel oxidation. This is assumed to result from severe mechanical disruption and intense heating from a fire fueled by petroleum or other highly flammable materials. Spent fuel assemblies which are 5 years or older (i.e., have been out of the reactor core for 5 years or more) do not produce sufficient self-heating from radioactive decay to support a rapid oxidation process. Therefore, a large external source of heat, similar to a burning rail tank car of fuel, is needed to create any substantial increase in release above that from impact and burst rupture.

The probability of accidents of the severity assumed in the analysis is very low, and the likelihood of releases from a cask in such accidents is even lower. The doses calculated and, in turn, the health effects in terms of latent cancer fatalities (LCFs) are considered to be very conservative upper bounds to the consequences of extremely severe accidents in both urban and rural settings. No attempt has been made to examine accident scenarios peculiar to a specific site. Such scenarios will be developed and analyzed during site characterization activities (Section 4.1.3.1.10).

5.3.2 Environmental Effects of Improvements to Transportation Corridors

This section discusses the environmental impacts of constructing repository transportation corridors, as presented in Sections 4.3.5 and 5.1.2.2. Impacts are presented by environmental discipline for constructing a new exclusive-use access road and, alternatively, improvements to Utah State Highway 211 (Utah 211) for repository access, and impacts for four alternative rail routes. Data obtained during site characterization will be used to plan final access road alignment (see Section 4.1.3.1.10). All routes presented in this analysis are alternatives and are used for the purpose of assessing potential environmental impacts; no final selection of routes will be made prior to site characterization.

5.3.2.1 Roadways

The alternative repository highway access routes described in Section 5.1.2 utilizes U.S. Highway 191 (U.S. 191) (which may have to be upgraded at certain points) from Interstate 70 at Crescent Junction, Utah, south through Moab, Utah, and beyond for a distance of 106 kilometers (66 miles). Alternatives for repository road access include a new exclusive-use access highway or permanent upgrading and improvements to Utah 211. The exclusive-use highway, described in Section 5.1.2.2, would originate at U.S. 191, about 4.8 kilometers (3 miles) north of Utah 211. The total distance of new highway construction is 47 kilometers (29 miles), and includes 3.8 kilometers (2.3 miles) of tunnels and 1.0 kilometers (0.6 mile) of bridges.

As an alternative to the exclusive-use highway, permanent upgrading and improvements to Utah 211 would be required for repository access. These improvements, described in Sections 4.3.5 and 5.1.2.2, include 0.3 kilometer (0.2 mile) for highway realignment, 1.4 kilometers (0.9 mile) for a bypass around Newspaper Rock State Historical Monument, road widening, three-lane design on grade, and construction of a cloverleaf at the Utah 211/U.S. 191 junction.

The impacts discussed below will ultimately depend on the final access route alternative selected. In general, the environmental impacts caused by new construction of the exclusive-use route will be greater than upgrading an existing route. Upgrading an existing route will be more disruptive to the current users of Utah 211.

5.3.2.1.1 Soils. The construction and upgrading of roadways will affect the soils along the routes. The amount of soil disturbed will vary with the topography and with the amount of cut and fill necessary to prepare the route. Compaction of soil exposed by grading, removal of vegetation, and paving will reduce the infiltration rate of precipitation, possibly causing an increase in surface water runoff and resultant local soil erosion. Soil banking, ridging, diking, and runoff diversion structures will be used to retard surface runoff and hence reduce local soil erosion and rutting. Section 5.2.1.2 discusses erosion reduction methods to be used. Impacts are local and temporary, occurring during construction.

Table 5-32. Maximum Individual Radiation Dose Estimates for a Rail Cask Accident Involving Release to the Atmosphere

Accident Class	Dose (mrem)[a]			
	Inhalation	Plume Gamma	Ground Gamma	Dust Inhalation
Impact	180	11	12	0.0001
Impact and Burst	6,100	711	91	0.004
Impact, Burst, and Oxidation	9,000	550	710	0.0006

(a) Maximum individual dose occurs 70 meters downwind of the release point.

Source: Appendix A.

Table 5-33. 50-Year Population Dose Estimates for a Rail Cask Accident Involving Land Contamination[a]

Accident Class	Urban Area (3,861 people/km^2)				Rural Area (6 people/km^2)			
	Inhalation	Plume Gamma	Ground Gamma	Total	Inhalation	Plume Gamma	Ground Gamma	Total
Impact								
Dose (man-rem)	3	0.33	940	940	0.005	0.0005	1.4	1.4
Latent Cancer Fatalities[b]				0.2				0.0003
Impact and Burst								
Dose (man-rem)	110	2.2	13,000	13,000	0.2	0.003	21	21
Latent Cancer Fatalities[b]				3				0.004
Impact, Burst, and Oxidation								
Dose (man-rem)	150	17	110,000	110,000	0.2	0.03	170	170
Latent Cancer Fatalities[b]				22				0.04

(a) The ground dose is what would be received if each member of the population stayed at the same location for 50 years. The inhalation dose is a 50-year dose committment from inhalation of the passing plume. Doses are for the population within 80 km (50 mi) of the release point. Cleanup occupational doses not included.

(b) Based on 1 man-rem = 0.0002 latent cancer fatalities (relates to early fatalities plus first- and second-generation effects).

Source: Appendix A.

Table 5-34. 50-Year Population Radiation Exposure From a Drinking-Water Reservoir Contamination From a Rail Cask Accident

Accident Class	Population Dose Effects From Water Ingestion[a, b]
Impact	180 man-rem 0.04 LCF[c]
Impact and Burst	6,900 man-rem 1.4 LCF[c]
Impact, Burst, and Oxidation	63,000 man-rem 13 LCF[c]

(a) The noble gas Kr-85 is omitted because of its negligible uptake by a surface water body.
(b) A 100-acre, one-billion-gallon urban reservoir is assumed to supply domestic, agricultural, industrial needs to the surrounding population. Radioactive decay, settling, or water filtration is not assumed.
(c) Based upon 1 man-rem = 0.0002 latent cancer fatalities (relates to early fatalities plus first- and second- generation effects).

Source: Appendix A.

5.3.2.1.2 Hydrology. Temporary soil exposure during construction of a new access road or Utah 211 improvements will result in a temporary increase in sediments in surface runoff. Potential sediment increase in surface runoff will be minimized by appropriate construction techniques and thus will not affect downstream water quality. Drainage control structures and ditches to direct runoff will be incorporated in all roadway designs. Measures to control sedimentation are discussed in Section 5.2.2.

Construction of the alternative Newspaper Rock bypass may cause increased stream siltation; however, siltation will be limited by minimizing the use of equipment in the stream and drawing material toward the bank (see Section 4.3.5).

No effects on ground-water flow patterns or water quality are expected to occur as a result of road construction and upgrading.

5.3.2.1.3 Land Use. Construction of the road corridor will disrupt grazing within the corridor rights-of-way. The loss of land, however, will be small relative to the total grazing land available. Construction of the road corridors may temporarily disturb visitors to recreational areas in proximity to the project site, primarily accessibility to Newspaper Rock and Canyonlands National Park. However, this impact will occur during construction of the road improvements or the new exclusive-use access route. Once completed, the new exclusive-use access route or the alternative Newspaper Rock bypass will divert project traffic and maintain access for park visitors. These potential impacts are discussed further in Sections 5.3.3 and 5.6.1.

5.3.2.1.4 Terrestrial and Aquatic Ecosystem. Construction and operation of the exclusive-use repository access road into Davis Canyon could potentially impact a number of wildlife species (Section 5.2.4), including the pronghorn antelope, mule deer, golden eagle, peregrine falcon and black-footed ferret. Construction impacts to all important species will be minimized, if necessary, by such measures as routing around sensitive breeding areas or avoiding construction activities during sensitive periods. Increased road kills of wildlife along the repository access road may be an operational impact. Construction and operation of the Utah 211 bypass around Newspaper Rock may impact mule deer migrating onto Harts Point each winter (Section 5.2.4). Impacts will be minimized by scheduling the 9-month construction activities to avoid nonmigrating periods.

5.3.2.1.5 Air Quality. Grading and other earthmoving activities could result in increased fugitive dust during road construction and upgrading. As described in Section 4.2.1.3, watering controls described in Section 4.2.1.3 are examples of methods that could be used, as necessary.

Diesel equipment will generate primarily NO_x emissions. Because of the short-term nature of these activities, resulting air-quality impacts are not expected to be significant.

5.3.2.1.6 Aesthetic Conditions. The visibility of the exclusive-use access road from specified viewing positions on key observation points is presented in Section 5.2.6. From Utah 211, the repository access road is primarily visible 6.4 to 8 kilometers (4 to 5 miles) from its junction with Utah 211 where it enters the side canyon on the southwestern edge of Harts Point. The access road is potentially visible from seven key observation points. Within Canyonlands National Park, the access road is theoretically visible from the road to Grand View Point in the Island-in-the-Sky District, but is likely not to be visible due to its great distance and low visual contrast.

5.3.2.1.7 Noise. Road construction activities will result in an increase in existing noise levels in the vicinity of the construction activities. The equipment used will be similar to that used during the repository clearing and grading activities. However, the activities associated with road construction and upgrading will take place at some distance from Canyonlands National Park. Noise levels from road construction will decrease when construction is completed. During operation, traffic will extend the Ldn 55 dBA level to 0.2 kilometer (0.1 mile) on either side of the access road. Intervening canyon walls will, however, decrease these distances.

5.3.2.1.8 Cultural Resources. Procedures will be followed to identify cultural resources along the roadways. All areas of direct impact will be intensively surveyed for cultural resources prior to any ground-disturbing activities. A site file search of archaeological resources in the transportation corridors revealed a moderate to high potential for their existence (see Section 5.2.8). The site file search indicated that 33 sites exist within 0.3-kilometer (0.5 mile) corridor on either side of the exclusive-use roadway centerline and 17 recorded sites in the vicinity of the alternative Newspaper Rock State Historical Monument bypass. Because public access to the area will be increased, indirect impacts to these and other sites will be mitigated as outlined in Section 4.2.1.8. Any archaeological, historical, or Native American religious sites that may be discovered will be recorded and evaluated for eligibility to the National Register of Historic Places. Significant sites will be avoided or mitigated through a data recovery plan formulated in consultation with the Bureau of Land Management (BLM), the National Park Service (NPS), The State Historic Preservation Office (SHPO), and The Advisory Council on Historic Preservation (ACHP). Impacts of road construction activities to Newspaper Rock State Historical Monument are expected to be temporary and minor, consisting primarily of blasting noise and traffic delays. This may inconvenience some visitors to the monument (see Section 4.3.5).

5.3.2.2 Railroads

Four alternative railroad access routes are described in Section 5.1.2.2. Three of the four originate at the southern terminus of the Denver and Rio Grande Western's (D&RGW) branch line in Potash. The Spanish Valley Route, originates at a connection with D&RGW's Cane Creek Branch near Moab. All alternative routes cross the Colorado River and Indian Creek. Descriptions of the alternative routes are presented in Section 5.1.2.2. Table 5-4 presents engineering data on each of the alternative routes.

Colorado River Route "A" would require a total of 6.72 kilometers (4.2 miles) of tunnels, 2,725 meters (8,940 feet) of bridges, and 60.3 kilometers (38 miles) of new track. Colorado River Canyon Route "B" requires 2.2 kilometers (1.4 miles) of tunnels, 2,039 meters (6,690 feet) of bridges, and 62.1 kilometers (39 miles) of new track.

The Kane Springs Canyon route requires a total of 16.6 kilometers (10.4 miles) of tunnels, 1,021 meters (3,350 feet) of bridges, and 74.2 kilometers (47 miles) of new track.

The Spanish Valley route requires 14.4 kilometers (9.0 miles) of tunnels, 1,320 meters (4,330 feet) of bridges, and 86.4 kilometers (54.0 miles) of new track.

The following subsections describe the environmental effects of the rail access routes. Differing impacts between the four routes are indicated as applicable.

5.3.2.2.1 Soils. The amount of soil disturbed along the railroad corridors will vary with topography and with the amount of cut and fill required to prepare the route. Between 3.62 and 8.43 million cubic meters (4.73 and 11.03 million cubic yards) of cut and 4.33 and 9.88 million cubic meters (5.66 and 12.92 million cubic yards) of fill is required, depending on the route. The Kane Springs route requires the least amount of cut and fill, the Colorado "B" route, the most. Impacts will be similar to those described for access road construction (Section 5.2.1.1), including increased temporary and local soil erosion.

5.3.2.2.2 Hydrology. Impacts associated with construction of the railroad access are discussed in Section 5.2.2 and would be similar to those described for the access road construction. These include temporary increases in sediment in surface runoff during construction. Appropriate construction techniques will minimize this impact; consequently, no adverse impact on downstream water quality is expected. Between 13 and 18 bridges would be required, depending on the route. Total water usage required for rail route construction ranges between 261 million liters (69 million gallons) (Kane Springs route) and 594 million liters (157 million gallons) (Colorado River route "B"). Colorado River Route "A" would require the most extensive bridge construction (3.4 kilometers [2.1 miles]) cumulatively, the Kane Spring Canyon Route the least (1.0 kilometer [0.6 mile]), cumulatively.

5.3.2.2.3 Land Use. The rail corridors will require between 240 hectares (592 acres) and 312 hectares (770 acres) of grazing land (Section 5.2.3), depending on the route. However, the amount lost is small relative to the total grazing land available. To mitigate the impacts of bisecting grazing land, cattle crossings will be provided for access to grazing and water areas. The Spanish Valley route will affect land uses in the town of Moab. This route, however, would parallel existing rights-of-way for pipelines, U.S. 191, and powerlines.

5.3.2.2.4 Terrestrial and Aquatic Ecosystems. A discussion of the potential ecological impacts which could result from construction and operation of one of four alternative railroad options is provided in Section 5.2.4. The two Colorado River routes would have the greatest potential for adversely affecting biological resources, including desert bighorn sheep, peregrine falcons, bald eagles, Colorado squawfish and rare plants. The Kane Springs route contains considerably fewer habitats (or proximity to such habitats) for these important species, and therefore correspondingly fewer potential impacts than along the Colorado River routes. The Spanish Valley option has the least conflict with important species habitats and populations; however, a new peregrine falcon eyrie has been discovered within 0.8 kilometer (0.5 mile) of this corridor (BNI, 1985b).

Impacts to biota can be mitigated by scheduling constructing rail access to avoid critical life history periods; proposed tunnels will also avoid impacts to some terrestrial species. Results of site-specific field studies and continued consultation with the U.S. Fish and Wildlife Service will determine the extent of any adverse impacts and appropriate mitigation measures.

5.3.2.2.5 Air Quality. Grading and other earth-moving activities would result in temporary increases in fugitive dust during construction of the rail route. Watering controls will be used as necessary to reduce dust (Section 4.2.1.3). Diesel construction equipment will generate primarily NO_x emissions. Because of the short-term nature of these activities, resulting air-quality impacts are not expected to be significant. During operations, train diesel engines will generate primarily NO_x emissions along the rail route. Since emissions will be small, and the source will be in motion, resulting air-quality impacts are not expected to be significant. Specific air quality effects on the town of Moab would be evaluated during site characterization.

5.3.2.2.6 Aesthetic Conditions. The visibility and visual contrast of the railroad alternatives from specified viewing positions or Key Observation Points (KOPs) were presented in Section 5.2.6. The viewshed analysis indicated that the Kane Springs Route Alternative is the least visible of the four alternative rail routes, followed by the Spanish Valley Route and the Colorado River Route "B". The Colorado Canyon Route "A" alternative is potentially seen from the most Key Observation Points at close distances, for long distances, and with many tunnel portals exposed.

Based on visual contrast evaluations (Section 5.2.6.2.2), the Kane Springs route has the least visual impacts of the four alternative rail routes. Visual contrast impacts can be reduced by applying red-colored ballast and, at appropriate points, blast rock cuts to create naturally appearing land forms. The application of a coloration spray on freshly made rock cuts to simulate desert varnish would further reduce contrasts.

5.3.2.2.7 Noise. Rail construction activities will be audible in Canyonlands National Park, scenic overlooks, and wilderness study areas. The Colorado River routes, which follow corridors nearer the park, have potentially greater noise impacts, to these areas than the Kane Springs and Spanish Valley routes (Section 5.2.7). Noise impacts will be local and noise levels will decrease as rail construction is completed.

Rail operation noise from the on-site switch engine and diesel locomotives are the major source of audibility impacts during repository operation. Locomotive noise will be audible approximately 8 kilometers (5 miles) from the rail line, 2 to 4 hours daily when the train passes twice each day. The Colorado River routes are the nearest routes to Canyonlands National Park and impact more areas than do the other two routes. The Kane Spring Route passes near a service overlook and critical wildlife habitats resulting in significant impacts.

Areas in Spanish Valley and Moab within approximately 25 meters (80 feet) of the Spanish Valley rail alignment will experience Ldn levels in excess of the EPA recommended level of 55 dBA. Areas between Highway U.S. 191 and the rail route may experience Ldn levels in excess of 55 dBA where the highway and the Spanish Valley routes are within 175 meters (580 feet) of each other (Nickens and Associates, Inc., 1985). No residences have been identified within these zones of impact. Rail operations will be limited to daylight hours and there will be no at-grade crossings. Use of an electrified railroad would further reduce noise levels from rail operations along the rail corridors, but would have little effect on the noise levels in Canyonlands National Park, adjacent to the site.

5.3.2.2.8 Cultural Resources. Procedures will be followed to protect cultural resources in railroad corridors. All areas where construction will occur will be intensively surveyed for cultural resources prior to any ground disturbing activities. A site file search of transportation corridors revealed a moderate to high potential for encountering cultural resources in and near the corridors. Although no systematic archaeological surveys of the railroad routes have been conducted, 187 sites (Colorado River Route "A" = 34, "B" = 44; Kane Springs Route = 22; Spanish Valley = 87) have been recorded in a 1.6 kilometer (1 mile) corridor centered upon the centerline of the proposed grades. Because access to the area will be increased through this project, indirect impacts to these and other sites are expected and will be mitigated as outlined in Section 4.2.1.8. Archaeological, historical, and Native American religious sites will be recorded and evaluated for eligibility to the NRHP. Significant sites will be avoided or mitigated through a data recovery plan formulated in consultation with the BLM, NPS, SHPO, and ACHP.

5.3.2.3 Airports

Airport improvements as a result of repository development have not been identified at this time.

5.3.2.4 Waterways

No improvements to existing waterways are expected as a result of repository development.

5.3.3 Effects on Transportation Infrastructure in the Area

This section discusses the potential impacts on transportation networks in the area during project construction, operation, and decommissioning. Activities which may impact the transportation network in the area include transport of workers to and from the site; and transport of supplies, construction materials, and excess salt, rock, and other uncontaminated wastes. Nuclear waste transportation impacts are discussed in Section 5.3.1.

Repository construction and operation will affect the use, location, condition, and maintenance and capital cost requirements of transportation facilities. The studies during site characterization (described in Section 4.1.3.1.10) will better determine the nature of impacts on transport facilities; how and to what extent these might be mitigated; and whether improvements are required to accommodate the additional traffic generated by repository construction, operation, and decommissioning.

The following discussion of potential impacts on transportation is based on information presented in Section 3.5 on the existing transportation network.

5.3.3.1 Roadways

5.3.3.1.1 Construction. Direct construction impacts on highways will result from increased automobiles transporting employees, truck traffic associated with delivery of construction materials and equipment, and upgrading of existing roads or construction of new rights-of-way associated with site development and access.

Table 5-2 shows the personnel requirements for repository construction, operation, and decommissioning. This table shows that the peak work force is 1,591. The average number of

construction workers required over the 8-year period is 1,125. At a conservatively estimated two workers per car, the average number of daily passenger vehicle round trips over the 8-year construction period is 562. During the peak construction year, the number of daily passenger-vehicle round trips will average 769. It is expected that workers will form larger car pools or van pools which would reduce these traffic estimates.

As stated in Section 5.1.2.3, the total number of truck deliveries required during the 8-year construction period is 24,000, or approximately 12 truck round trips per working day.

Using Table 5-39 (In-migration Population Location Results During Construction) as an indication of likely domiciles for the entire work force, Table 5-35 shows average and peak traffic increases on area highways.

During the first year of repository construction, while Utah 211 upgrading or the exclusive-use repository access road is under construction (Section 5.1.2.2), traffic on Utah 211 will increase by 819 vehicles per day over existing levels. Based on employing the same traffic control and safety measures employed during site characterization (Section 4.1.2.1.10), Utah 211 will adequately accommodate expected traffic volume until either the Utah 211 upgrade or new exclusive-use access road has been completed.

Traffic traveling to and from the repository will occur in basically six surges; these are traffic arriving before and traffic departing from each of the three shifts. If peak repository construction traffic is divided equally over three shifts, approximately 260 vehicles would travel to the site before each shift change, and 260 vehicles would leave the site after each shift change. Before and after each shift change, visitors traveling to and from the park may experience some traffic congestion due to repository traffic on Utah 211. This inconvenience could be reduced by van-pooling or busing. After completion of the improvements discussed in Section 5.1.2.2, Utah 211 will be able to accommodate remaining repository construction traffic. The exclusive-use access highway alternative would eliminate all traffic impacts on Utah 211.

As stated in Section 3.5, there are 5 sections of U.S. 191 where capacity, due to grades, is reduced to 310 to 680 vehicles per hour (the rest of U.S. 191 has capacities of 1,000-1,820 vehicles per hour). As discussed above for Utah 211, project traffic occurs in six surges. During peak construction activities, this represents approximately 260 vehicles before and after each shift change. Of these 260 vehicles, about 50 percent use U.S. 191 between Moab and Utah 211. Therefore, approximately 130 vehicles will travel from Moab to Utah 211 before each shift change, and 130 will travel from Utah 211 to Moab after each shift change.

The studies to be undertaken, as described in Section 4.1.3.1.10, will assess the impact of these traffic increases in relation to highway conditions and capacities. The studies will also consider traffic mitigating measures such as busing of workers, and highway improvements, in addition to measures that may have been taken for site characterization activities (Section 4.2.1.10).

During repository construction, the traffic volumes and domicile patterns previously noted would result in 314 million additional vehicle kilometers (196 million vehicle miles) over the 8-year construction period. This additional vehicle mileage will increase the number of predicted highway accidents and resulting injuries and fatalities. Using the accident rates given in Section 3.5 for U.S. 191, accidents predicted during the 8-year construction period would increase by 163 and fatal accidents would increase by 2.4. Using national rates, the corresponding increases in accidents and fatal accidents during this eight-year period would be 803 and 5.3, respectively. This may be compared to 1980-1984 experience on U.S. 191. During this time accidents varied from 55 to 94 per year and fatalities from 1 to 4 per year (Section 3.5).

5.3.3.1.2 Operation. The nature of impacts on highways during operation will be similar to those described in the previous section on construction.

Table 5-35. Traffic Increases on Area Highways During Construction

	1983[a] AADT	Peak Year Average[b]		8-Year Average[b]	
		AADT Increase	Percent Increase Over 1983	AADT Increase	Percent Increase Over 1983
Moab to Access Road[c]	2,850	735	26	540	19
Monticello to Access Road[d]	3,325	827	25	609	18
Blanding to Monticello	3,325	431	13	322	10
U.S. 191 to site via Utah 211 or new access road[e]		1,562		1,149	

(a) From Section 3.5, Figure 3-80.
(b) Calculations based on data in Table 5-2 and Table 5-38.
(c) Includes 6 truck round trips from Moab.
(d) Includes 6 truck round trips from Monticello/U.S. 666.
(e) Includes 12 truck round trips. From Section 5.1.2.3.

Table 5-36. Traffic Increases on Area Highways During Repository Operation

	1983[a] AADT	Average[b] Auto AADT	Average[b] Truck AADT[c]	Average[b] Total AADT	Percent Increase Over 1983
Moab to Utah 211	2,850	460	54	514	18
Monticello to Utah 211	3,325	540	54	594	18
Blanding to Monticello	3,325	290	--	319	9
Upgraded Utah 211		1,000	108	1,108	

(a) Based on Section 3.5, Figure 3-80.
(b) Calculations based on data in Table 5-2 and Table 5-39.
(c) Does not include nuclear waste. See Section 5.3.1 for nuclear waste transportation.

During repository operation, the work force will average 1,000 employees per day. Using the assumption of two employees per car, daily passenger vehicle round trips will average 500. Car pooling and van pooling would reduce this traffic.

While the number of employees decreases about 125 from construction activities, trucking activity increases. During repository operation, 270 truck deliveries per week (approximately 54 per day) are required for supplies.

Using Table 5-40 (In-migration Population Location Results During Operation - Davis Canyon) as an indication of likely worker domiciles and assuming that truck deliveries are split equally from the north and south (half from I-70/Moab and half from U.S. 666/Monticello), Table 5-36 shows traffic increases on area highways.

The traffic increases could be reduced by busing employees from Moab, Monticello, and Blanding. This will be investigated during site characterization and is described in Section 4.1.3.1.10.

If Utah 211 is upgraded to accommodate repository construction traffic, the improvements will be sufficient to accommodate repository operation traffic. Park visitors will experience some delays during shift changes, particularly during the afternoon shift change. These delays can be reduced by busing or car and van pools. If the exclusive use access road is constructed, traffic on Utah 211 will not be affected by repository operation traffic.

In Section 5.3.3.1.1, it was noted that there are sections of U.S. 191 that presently have reduced capacities. Any improvements that may have been required to accommodate repository construction traffic will be adequate to handle traffic for operation.

During repository operation, the traffic volumes and domicile patterns previously noted would result in 37.3 million additional vehicle kilometers (23.3 million vehicle miles) per year on area highways. This additional vehicle mileage will increase the number of predicted highway accidents and resulting injuries and fatalities over existing levels. Using the accident rates given in Section 3.5 for U.S. 191, predicted accidents would increase by 19 per year and fatal accidents by 0.3 per year. Using national rates, the yearly increases would be 96 and 0.6. As described in Section 3.5, between 1980 and 1984 accidents on U.S. 191 ranged from 55 to 94 per year and fatal accidents ranged from 1 to 4 per year.

5.3.3.1.3 Decommissioning and Closure. Traffic volumes will increase slightly during decommissioning and closure. A total of 1,040 employees will be required. Consequently, traffic congestion, road maintenance, and accidents during decommissioning and closure are expected to be similar to that experienced during operation.

5.3.3.2 Railroads

5.3.3.2.1 Construction. Early in the repository construction phase, a new rail line would be constructed to the site from the Denver and Rio Grande Western's (D&RGW) Cane Creek Branch line. Prior to its completion, increased rail traffic of construction materials and equipment (with final delivery by truck) is expected to be minor. The access railroad will be completed prior to repository operation, and can be used to deliver some equipment and materials, with a resultant reduction of truck traffic to and from the site during a portion of the construction phase.

5.3.3.2.2 Operation. The major nonnuclear uses of the rail line will be outbound salt shipments and occasional inbound shipments of materials or equipment. Approximately 8.8 million metric tons (9.7 million tons) of salt are to be disposed of during repository operations. Approximately 16 carloads of salt per day will be moved from the repository to the D&RGW line at Potash or Grand Junction, Colorado for consolidation into train load lots. An equal number of empty salt cars are expected to be delivered to the repository daily.

The disposal site for Davis Canyon salt is assumed to be Carlsbad, New Mexico (Section 5.2.10), approximately 2,240 kilometers (1,400 miles) by rail. The major impact of

offsite disposal is related to transportation. Although salt could be transported via either truck or rail, rail transportation would have much less impact in terms of number of loads transported. In addition, because of the large tonnage involved, rail transport may also be more economical. For these reasons, rail was selected as the recommended mode for salt transport. Rail shipments of salt are typically handled in covered hopper cars and hence pose virtually no threat of fugitive salt loss enroute.

At a conservatively estimated average payload per car of 82 metric tons (90 tons),* about 110,000 carloads would be required, or slightly over 4,000 per year. These cars would be handled by one train daily bringing supplies, nuclear waste, and empties in (about 15 to 20 cars per train) and returning with loaded salt cars and unloaded supply and waste cars. Salt unit trains of up to 100 cars per train would be made up by the common carrier (D&RGW) railroad for transport to Carlsbad. For this traffic volume, carrier trackage may not require improvements.

Based on the number of accidents that the D&RGW and Atchison, Topeka and Santa Fe Railway (ATSF) had per million train miles in 1984 (DOT, 1985), and the use of 100-car train loads, the following accident results could be expected:

Total Salt Transported	9.7 million tons
Approximate Length of Haul (One way to Mine Site)	1,400 miles
Number of Accidents Over Life of Repository	6.4.

Because railroad accident data are based on train miles, use of train loads smaller than the 100-car size assumed above would increase the number of train miles and correspondingly, the number of accidents. Seventy-car trains would, for instance, increase the accident predictions shown by 43 percent.

The statistically expected 6.4 accidents are based on data which classify accidents as those in which damage exceeds $4,500. The likelihood of a serious accident involving a car body rupture and spillage of salt is much less. Impacts of salt which might escape from the rail car in the event of such an accident are discussed in Section 5.2.10.

5.3.3.2.3 Decommissioning and Closure. Rail facilities will remain available and capable of handling transport associated with decommissioning and closure. Such traffic demand is expected to be small and impacts on existing railroad networks correspondingly small compared to repository construction and operation phases.

5.3.3.3 Airports

Increased air traffic into and out of the region during project construction could have an effect on local municipal airports. This may result from the increased air freight and passenger service associated with project construction. Impacts on local municipal airports will be studied further during site characterization (Section 4.1.3.1.10).

If air transportation facilities are expanded and upgraded during the construction phase, there should be no additional impact on air facilities during the operation and decommissioning phases.

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*Most covered hopper rail cars manufactured in recent years have payload capacities of between 95 and 105 tons. Older cars in the present U.S. fleet have lower capacities.

5.3.3.4 Waterways

The DOE is studying the operational safety and economics of transporting nuclear waste casks by barge from ports on the East Coast and Great Lakes to ports on the Gulf Coast and Mississippi River (Appendix A). From the Gulf Coast port, the waste would be moved to the repository by rail. Since this alternative would still involve rail shipments to the repository, no additional impacts beyond those discussed for rail operations are expected. However, this alternative will be further studied during site characterization (Section 4.1.3.1.10).

5.3.4 Utilities

Utility requirements for the repository are discussed in Section 5.1. It is expected that electrical power at the site will be supplied from an existing 138-kilovolt transmission line located in the vicinity of U.S. 191 (Figures 3-79, 5-10). A new substation would be required to tap this power line, located about 35 kilometers (22 miles) east of the Davis Canyon site and 8 kilometers (5 miles) south of La Sal Junction.

The probable source of natural gas would be from an existing 66-centimeter (26-inch) diameter pipeline near U.S. 191, approximately 32 kilometers (20 miles) east of the site.

Water would be supplied from the Colorado River by a new pipeline to the site (Figure 5-10). It may be advantageous to locate the water pipeline along the railroad access corridor and, therefore, the exact routing of the water pipeline may depend on the rail access route ultimately selected (see Figure 5-9).

Sewage would be treated on site and disposed of in a permitted disposal facility.

5.4 EXPECTED EFFECTS ON SOCIOECONOMIC CONDITIONS

This section discusses potential repository-related impacts on the demography, economy, community services, and the fiscal and social environment within study area cities and counties (Grand and San Juan Counties).

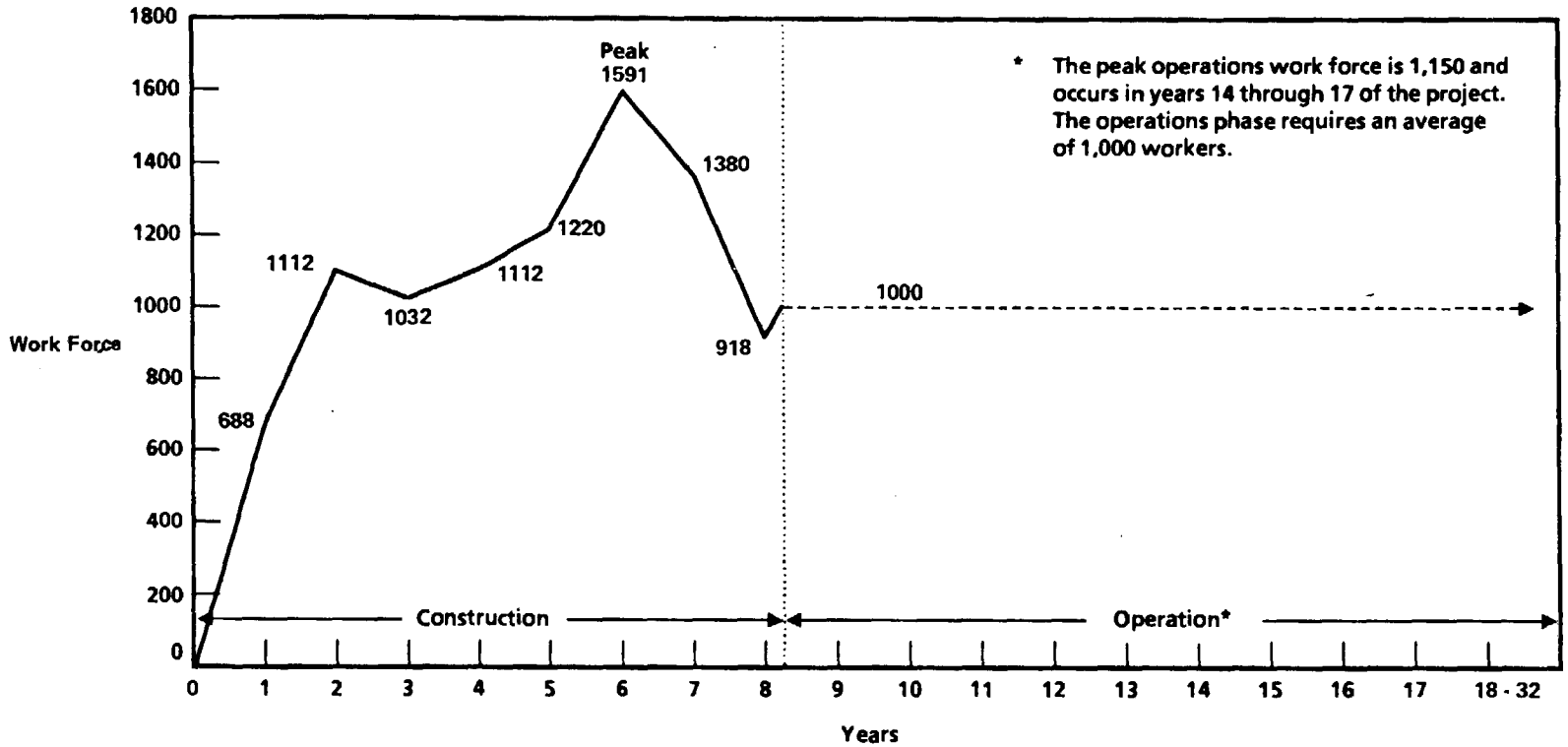
Impacts during construction will result from the influx of workers and their families who will have increased demands for housing and other community services. The cost of providing such services will affect the fiscal operation of study area communities.

Project in-migration during peak operation is expected to be less than in-migration during peak construction. Operations essentially represent a stabilization period that will last from year 8 to year 32. To the extent possible, the work force needed for operation will be drawn from the local population to minimize the number of in-migrating workers and their families.

Forecasts of potential impacts resulting from project construction, operation, and decommissioning are derived from three data sources: (1) data currently available on existing socioeconomic conditions within the study area (Section 3.6); (2) project information, labor force, and craft requirements (Section 5.1); and (3) results of the population in-migration model described here, Section 5.4.

Figure 5-28 presents total labor force requirements during project construction and operation. Construction will continue for eight years, with peak construction work force occurring in the sixth year (1,590 workers). Construction work-force estimates also reflect personnel required for offsite access development such as rail, road, and utility development (Section 5.1).

The project operations phase will continue for another 25 to 26 years after the construction phase. The peak of the operation phase is scheduled to occur between the seventh and twelfth years of that phase. During this peak about 1,150 workers will be needed.



Repository Work Force Requirements

Figure 5-28

Following the period of waste implacement will be a caretaker phase lasting about 24 years. Monitoring of the repository will occur until the repository is decommissioned. The caretaker phase is expected to require an average of 230 persons a year.

Decommissioning of the facility is expected to last about 5 years and require an average of 1,040 workers (see Table 5-2). No personnel are expected to be employed at the site after closure.

Project-related impacts were estimated using the ONWI In-migration Computer Model (Goldsmith, 1984). This model is a linear program that estimates the number of people who will relocate to an area as a result of repository construction and operation. Figure 5-29 illustrates the model operations and logic chart; the input and multipliers used in the model and the basis for each appear in Table 5-37. The definitions of terminology used in the model are shown on Table 5-38. The model calculates the following items for repository construction and operation:

- Direct and indirect in-migration
- Direct and indirect school-age children
- Direct and indirect household heads
- Single worker in-migration
- Total direct and indirect in-migrating employment.

Direct in-migrants are repository workers and their families. Indirect in-migrants are repository and consumer-related service workers and their families.

The key variables determining in-migration include the following:

- The number of repository workers needed each year
- Indirect employment multipliers
- Percent of direct and indirect workers expected to in-migrate
- Direct and indirect family size multipliers (calculates school-age children)
- Repository and indirect worker spouses employed in indirect jobs.

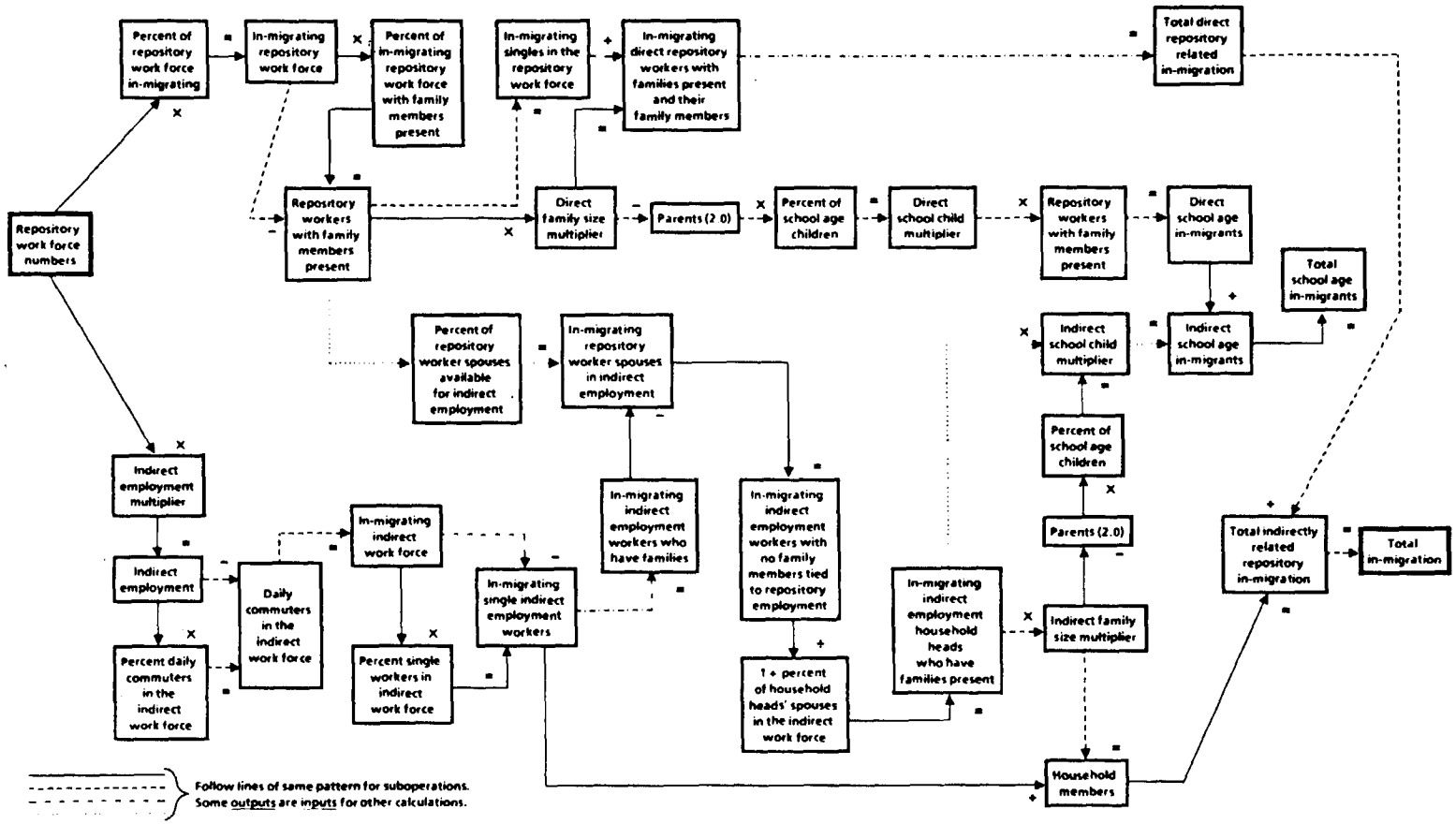
These variables were adjusted so that a range of impacts could be established for the site. The various multipliers and percentages were chosen on the basis of references listed in Table 5-37, which reflect research conducted for other large-scale developments in rural settings. The model incorporates information on local labor availability based on existing local employment in construction and mining, and total study area population and labor force.

Also, the level of economic activity in the study area was evaluated to establish realistic, conservative indirect multipliers (Section 3.6).

The changes in inputs and multiplier values for the operations phase are based on the research literature referenced. This literature indicates that during the longer operation phase of a project, (1) more workers will relocate with family members, (2) the families which relocate tend to be larger, (3) more local hires are attracted to the long-term job opportunities, and (4) indirect multipliers are higher because of an expanded economy and long-term business opportunities.

The model was designed to project a range of in-migration within which actual in-migration values would lie. The analysis presented here reflects a realistic, conservative case. It assumes no mitigation measures to limit repository-related in-migration, and referenced worker and worker family characteristics that tend to raise in-migration.

The model was validated using the documented impacts resulting from two energy projects. These projects were selected because adequate detail was provided in the project monitoring reports on model variables to perform the validation process. The validation is documented in "ONWI Population In-Migration Model" (Goldsmith, 1984). The model was validated for peak-year



Source: Goldsmith, 1984.

In-Migration Model Logic of Calculations

Figure 5-29

Table 5-37. Davis Canyon Inputs and Multipliers for the ONWI In-Migration Computer Model

	Construction	Operation
A. Direct In-Migration		
Percent of Repository Work Force In-Migrating • Available labor force within commuting distance (Section 3.6) • Skills of available labor force (Section 3.6)	95	85
Percent of In-Migrating Direct Work Force With Family Members Present • Murdock and Leistritz (1979) • TVA, Yellow Creek (1980)	75	80
Percent of Direct Worker Spouses Available for Indirect Employment • Halstead and Leistritz (1983)	20	40
Family Size Multipliers • DOE (1978, HCP/L2516-01)	3.6	3.8
Percent of School-Age Children • Bureau of the Census (1982)	65	65
B. Indirect In-Migration		
Indirect Employment Multiplier • Available labor force within commuting distance (Section 3.6) • Economic activities in the study area (Section 3.6) • Murdock and Leistritz (1979)	0.3	0.8
Percent of Local Hires for Indirect Work Force • Assumed to be 10 percent higher than the direct work force	15	25
Percent Single Workers in the Indirect, In-Migrating Work Force • Bureau of Labor Statistics (1980)	35	35
Percent of Indirect Worker Spouses in the Direct Work Force • Bureau of the Census (1982)	40	40
Family Size Multipliers • Bureau of the Census (1982)	3.3	3.3
Percent of School-Age Children • Same as direct work force	65	65

Source: Goldsmith, 1984.

Table 5-38. Definitions, Population In-Migration Model, Davis Canyon

Direct work force	The work force hired for jobs at the repository facilities.
Indirect work force	The work force hired for jobs that are available because of the repository location, but are not at the facilities (e.g., jobs with repository suppliers, town services, or retail business). Note: to avoid double counting, spouses of repository workers who are in the indirect work force are counted only as direct in-migrants.
Daily commuters	The local workers who are hired for direct or indirect jobs; these workers currently reside in surrounding communities.
In-migrants	These workers and their families will relocate on a permanent or temporary basis to communities adjacent to the site. These workers and families are considered to be in-migrants during the construction and operation phase for as long as they are present. It will be necessary to plan for the housing and service needs of these relocating workers.
In-migrating household heads	The in-migrating workers who will be seeking housing for themselves and their families, if present.
Baseline projections	Future estimates of the population, employment, etc., of a community or larger jurisdiction based on conditions without the planned project.

projection; projections for years other than the peak are not as accurate. Variable sensitivity analysis, scenario hypotheses testing, and testing with historical data from actual facility monitoring reports (as described above) were completed as part of the model's validation and verification.

The repository-related populations were allocated to communities on the basis of a population location (gravity) model. The new in-migrants projected by the model were allocated to communities on the basis of a population allocation model. This model assumes that relocation decisions will be made in direct proportion to community population and in inverse proportion to the distance to work. Four percent of the total expected in-migrants were allocated to smaller communities and rural areas. Approximately 4,690 repository-related in-migrants are expected to be present during the peak of construction, and 3,730 during the pack of operations. On a general level, population size and distance also reflect other factors which can influence individual location decisions. These factors, which cannot be easily modeled, include types of schools, taxes, housing, shopping, amenities, work place of spouse, and many others correlated with size of population. The model results for Davis Canyon are shown in Tables 5-39 and 5-40. Baseline population projections (Section 3.6) were added to project-related in-migration to determine total population and service demands.

Community service requirements and fiscal impacts on communities were determined based on data presented on existing service capacity in Section 3.6. Potential changes in service capacities (e.g., water, sewer, etc.) and service standards (e.g., police to population ratios) resulting from projected baseline project-related growth were assessed. Impacts on local revenues and expenditures are addressed similarly. Additional sources of revenue and mitigation measures are discussed.

5.4.1 Population Distribution and Displacement

This section discusses potential changes in baseline population trends resulting from the influx of workers and their families during construction, operation, and decommissioning.

Changes in regional and local population during project construction, operation, and decommissioning will result from changes in baseline population (growth without repository construction) and from in-migration of direct and indirect project workers. Both of these factors are discussed below.

The estimated baseline population growth in the area (Grand and San Juan Counties) for 1984-2006 was discussed in Section 3.6 and shown in Table 3-39. By 1997, during peak construction, the baseline population in Grand and San Juan Counties is projected to increase to 24,030. The baseline population of Moab, including Spanish Valley, is projected to increase to 7,464 by 1997. The baseline population of Monticello and Blanding are projected to increase to 2,433 and 3,933, respectively by the same year.

By the year 2006, the peak year of project operation, the baseline population of Grand and San Juan Counties is projected to increase to 26,400. The population of Moab and Spanish Valley is expected to increase to 8,290 by the year 2006, while the baseline populations of Monticello and Blanding are projected to increase to 2,660 and to 4,300, respectively, by the same year.

5.4.1.1 Construction

Expected in-migration during repository construction and operation will change the demography of San Juan and Grand Counties. Estimates of repository related in-migration (Tables 5-41 and 5-42) show a cumulative population increase of about 4,690 persons over the first six years of project construction. This growth represents a 20 percent increase over the 1997 baseline population projection for Grand and San Juan Counties.

Table 5-39. In-Migration Population Location Results During Construction, Davis Canyon

City	Population In-Migration Percentage[a]	Peak In-Migrant Population (1997)	Percent Change in the 1997 Baseline Population
Moab	50	2,350	31.4
Monticello	26	1,220	50.1
Blanding	20	940	23.8

Note: Percentage of in-migrating population distributed using a gravity model which relates the size and distance of communities from a work site based on the following formula:

$$I_i = \frac{\dfrac{P_i}{D_{ij}^{b_j}}}{\displaystyle\sum_{i=1}^{N} \dfrac{P_i}{D_{ij}^{b_j}}}$$

I_i = in-migration percentage residing in community i

P_i = population of community i

D_{ij} = distance in highway miles between the work site j and the community i

b_j = distance elasticity with respect to job location; $b_j = 2$ (Krueckeberg and Silver, 1974)

N = number of communities being considered.

(a) 4 percent of the in-migrants were distributed to the rural unincorporated areas.

Table 5-40. In-Migration Population Location Results During Operation, Davis Canyon

City	Population In-Migration Percentage[a]	Peak In-Migrant Population (2006)	Percent Change in the 2006 Baseline Population
Moab	50	1,860	22.4
Monticello	26	970	36.5
Blanding	20	750	17.4

Note: Percentage of in-migrating population distributed using a gravity model which relates the size and distance of communities from a work site based on the following formula:

$$I_i = \frac{\dfrac{P_i}{D_{ij}^{b_j}}}{\sum_{i=1}^{N} \dfrac{P_i}{D_{ij}^{b_j}}}$$

I_i = in-migration percentage residing in community i

P_i = population of community i

D_{ij} = distance in highway miles between the work site j and the community i

b_j = distance elasticity with respect to job location; $b_j = 2$ (Krueckeberg and Silver, 1974)

N = number of communities being considered.

(a) 4 percent of the in-migrants were distributed to the rural unincorporated areas.

5.4.1.2 Operation

The peak number of in-migrants present during repository operation (3,730) is expected to be 20 percent less than that for project construction (Table 5-41). The peak number of in-migrants during project operation represents a 14 percent increase over the baseline population in the year 2006.

5.4.1.3 Decommissioning and Closure

The size of the repository work force will decrease during the caretaker period. Some job displacement may occur at this stage, creating unemployment and out-migration. The transition between the operation activities and the caretaker activities may be phased so the communities can adjust to the new economic conditions. At the end of the caretaker period decommissioning and closure will occur. Decommissioning will probably require the in-migration of skilled craftspersons. When the facility is closed area unemployment and out-migration should increase.

5.4.1.4 Population Displacement

It is not expected that any households will be displaced because of land requirements for repository construction or operation. Furthermore, construction of the transportation and utility corridors is not expected to result in the displacement of any households.

The DOE is required under the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970" (42 USC 4601 et seq.) to compensate individuals, partnerships, corporations, and associations who are to be displaced because the Federal government has acquired their property. Under this Act, the acquiring agency must offer fair market value for the property. This Act encourages Federal departments to make every reasonable effort to acquire real property expeditiously by negotiation, or by offering just compensation that must be at least as much as the DOE's approved appraisal of the fair market value of the property.

5.4.2 Economic Conditions

The local and regional economy will benefit during project construction and operation. Local employment opportunities will increase, as will purchase of local materials and services, and local wages. These factors and the potential for displaced economic activities are discussed below.

5.4.2.1 Employment

It is expected that some jobs will be filled by residents of Moab, Monticello, and Blanding. New employment opportunities will be especially beneficial in Grand and San Juan Counties since unemployment in both countries has increased significantly. Workers from adjacent counties and other parts of Utah who in-migrate to work on the project may return home on weekends, thus minimizing some impacts (e.g., permanent housing) while increasing others (e.g., need for temporary housing).

5.4.2.1.1 Construction. Repository construction will stimulate employment as new jobs are provided for direct and indirect workers (see Table 5-43). The Population In-Migration Model Report (Goldsmith, 1984) estimates that 5 percent of the peak direct construction work force will be filled by local residents, while 15 percent of the additional indirect jobs at the peak will be held by local workers.

5.4.2.1.2 Operation. Operation of the repository will continue to stimulate employment opportunities and contribute to the growth of the economic base of the project-area cities and region. The Population In-Migration Model Report (Goldsmith, 1984) estimates that of the peak direct operation work force, 15 percent of the workers will be local, and of the peak secondary workers, 25 percent will be local residents (Table 5-44).

Table 5-41. Estimated Yearly Increment of Direct, Indirect, and Total In-Migration During Repository Construction

Year	Direct			Indirect			Total Annual Increment	Cumulative In-Migration[a]
	Single Workers	Married Workers	Family Members	Single Workers	Married Workers	Family Members		
1	160	490	1,280	60	10	30	2,030	2,030
2	100	300	780	40	10	20	1,250	3,280
3	(20)[b]	(60)	(150)	(10)	0	0	(240)	3,040
4	20	60	150	10	0	0	240	3,280
5	30	80	200	10	0	0	320	3,600
6	90	270	690	30	0	10	1,090	4,690
7	(50)	(150)	(390)	(20)	0	(10)	(620)	4,070
8	(110)	(330)	(850)	(40)	(10)	(20)	(1,360)	2,710

Note: All numbers are rounded to the nearest 10.

(a) Cumulative in-migration indicates the total number of in-migrants present from the start of construction.
(b) Numbers in parentheses indicate decrease in work force resulting in out-migration.

Source: Hines, 1986.

Table 5-42. Estimated Peak of Direct, Indirect, and Total In-Migration During Repository Operation

Direct			Indirect			Cumulative In-Migration[a]
Single Workers	Married Workers	Family Members	Single Workers	Married Workers	Family Members	
200	780	2,190	240	100	220	3,730

Note: All numbers are rounded to the nearest 10.

(a) Cumulative in-migration indicates the total number of in-migrants present from the start of construction.

Source: Hines, 1986.

Table 5-43. Estimated Yearly Increment of Employment Generated by Repository Construction, Davis Canyon

Year	Direct Employment				Indirect Employment				Total Cumulative[a] Employment
	In-Migrating	Local	Total Yearly Increment	Cumulative[a]	In-Migrating	Local	Total Yearly Increment	Cumulative[a]	
1	640	40	680	680	180	30	210	210	890
2	410	30	440	1,120	100	20	120	330	1,450
3	(80)[b]	(10)	(90)	1,030	(20)	0	(20)	310	1,340
4	80	10	90	1,120	20	0	20	330	1,450
5	90	10	100	1,220	30	10	40	370	1,590
6	350	20	370	1,590	90	20	110	480	2,070
7	(200)	(10)	(210)	1,380	(60)	(10)	(70)	410	1,790
8	(440)	(20)	(460)	920	(110)	(20)	(130)	280	1,200

Note: Numbers rounded to nearest 10.

(a) Cumulative indicates the total number of workers present in the category from the start of construction.
(b) Parentheses indicate decrease in work force resulting in out-migration.

Source: Hines, 1986.

5.4.2.1.3 Decommissioning and Closure. As described in Section 5.4.1.3, a decline in employment related to the repository will occur in the phase down period between operations and decommissioning. This phase down will also result in an decline in the indirect work force. There will be an increase in area employment when decommissioning begins, followed by a decline.

5.4.2.2 Economic Activity

Changes in economic activity in the study area cities and region will be caused by purchases of local materials and services, purchases of personal goods and services by new residents, and higher wage rates.

Construction and operation materials will be obtained from local, regional, and national suppliers. The economic base of the area will expand through the use of local materials and services. The degree of expansion within local economies will depend on the availability of necessary suppliers.

Employee wages during project construction and operation for local and in-migrant workers will result in higher incomes within the region. Circulation of employee expenditures through Grand and San Juan Counties would generate a substantial increase in wages and salaries of other workers as the demand for goods and services increases.

Increased employment may also reduce labor supplies for other sectors of the local economy and could increase the cost of living in the area. A potential increase in the cost of living would most affect those people whose incomes are not positively affected by the repository project, particularly if rents and food prices increase in affected communities. New large-volume stores that may be attracted to the area could compete with smaller local businesses.

5.4.2.2.1 Construction. The estimated cost of materials purchased locally for the repository is $43 million (1984 dollars) during the 8-year construction period. Local project purchases for materials would average about $5.4 million per year. The estimated portion of wages and salaries available to be spent locally would be $141 million (1984 dollars) during the construction phase and average about $18 million per year (SCC, 1984b; 1985b).

5.4.2.2.2 Operation. The estimated cost of materials purchased locally for the repository operations phase is $93 million (1984 dollars) during the operation period. Project purchases during the operations phase would average about $3.6 million per year. The estimated portion of wages and salaries available to be spent locally would be $530 million (1984 dollars) during the operations phase, and average about $20 million per year.

5.4.2.2.3 Decommissioning and Closure. During the caretaker period and at the end of decommissioning, an increase in area unemployment and decrease in personal income would result from reduced employment at the repository. Some communities may experience more severe economic dislocations, to the degree that their economies may have become dependent on the operation of the repository. In addition, this decline will precipitate secondary impacts such as a decrease in consumer spending. As consumer spending decreases, demand for secondary goods and services and the subsequent revenues will decline.

Several factors could mitigate the social and economic dislocation which could occur at the end of the operation phase and at the beginning and end of the decommissioning phase. For example, the repository will probably generate some additional economic growth and diversification in the area. The long period of project operation would also give communities time to develop and implement programs to mitigate social and economic impacts, in association with State and Federal governments.

Table 5-44. Peak Employment Generated by Repository Operation, Davis Canyon

Direct Employment			Indirect Employment			Total Direct and Indirect Employment
In-Migrating	Local	Total at Peak	In-Migrating	Local	Total at Peak	
980	170	1,150	690	230	920	2,070

Note: Numbers rounded to nearest 10.

Source: Hines, 1986.

5.4.2.3 Displacement of Economic Activity

Federal land will be required in Davis Canyon for repository construction. This will result in the loss of land in Davis Canyon suitable for cattle grazing. No additional land will be required during project operation and decommissioning, so no additional economic activity will be displaced during these phases.

The potential for significant mineral resources in the study area is low (Section 3.2.8). Therefore, loss of income from displacement of mineral production is expected to be insignificant. The potential impact to tourism is analyzed in Section 5.6.1.

5.4.3 Community Services

Workers and their families who in-migrate during project construction and operation will require housing and other community services. Potential requirements and the potential effects on the local and regional infrastructure are described below and are summarized in Table 5-45. In general, less housing and other community services will be required during project operation. The excess service capacity identified in Chapter 3 is not considered in the new service demand estimates for baseline and project-related growth. Table 5-45 presents data on service requirements for Moab, Monticello, and Blanding. Although the gravity model projected that La Sal and other unincorporated areas of the two Counties (excluding Spanish Valley) would attract about 200 in-migrants at the peak of in-migration, the addition of these persons is not expected to affect the general provision of services. This is due to the fact that the Counties and not the communities are the primary providers of services delivered in the rural areas.

Even though national service standards or averages were used in all calculations except housing needs, it must be recognized that such levels (ratio of service per capita) may or may not be suitable for an individual community. National service levels are used in this analysis so that a comparison from site to site can be made. Local service levels vary as shown in Section 3.6.3, and a local level of service may be preferred by a specific community. The use of a particular service level affects the amount of excess capability that would be absorbed by baseline growth.

During the caretaker phase, a decline in employment and subsequently in population as the unemployed move out the region, would create an excess supply of housing and municipal services. The rental values of property, housing prices, and income derived from services may decline for a few years. The demands for services such as housing would increase during the initial years of decommissioning when workers would be temporarily locating in the area. This phase is several decades in the future and it is difficult to predict whether the excess capacity present at the end at the operation phase will be present and capable of handling the additional public service demands created by the decommissioning phase. If it is not, additional mitigation may be required to assist affected communities in providing necessary services.

5.4.3.1 Housing

Total housing units needed to accommodate future populations will depend on the housing needs of the projected baseline population and the housing needs of new households in-migrating into the project vicinity during construction.

Baseline projections for the peak year of construction appear in Table 5-45. These projections indicate a need for 290 units at Moab, 130 units at Monticello, and 180 units at Blanding. Forecasted baseline housing needs in Moab, Monticello, and Blanding are shown in Table 5-45.

Table 5-45. Projected Baseline and Project-Related Service Requirements - Peak Project Construction and Operation, Davis Canyon

Service	Moab				Monticello				Blanding			
	Baseline		Project-Related		Baseline		Project-Related		Baseline		Project-Related	
	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006
Housing												
Added population since 1984[a]	840	1,670	2,340	1,860	450	680	1,220	970	720	1,090	940	750
Additional housing required since 1984[b]	290	580	840	800	130	200	440	420	180	280	340	320
Education												
Added students[c]	110	220	600	490	100	160	310	250	170	260	240	200
Added teachers[d]	6	11	32	26	5	8	16	13	9	14	13	10
Protective services												
Added police[e]	2	3	5	4	1	1	2	2	1	2	2	2
Added firefighters[f]	1	1	2	2	0	0	1	1	0	1	1	1
Health												
Added doctors[g]	1	2	2	2	0	1	1	1	1	1	1	1
Added beds[h]	4	8	12	9	2	3	6	5	4	5	5	4
Water supply												
MGPD required[i]	.13	.25	.35	.28	.07	.10	.18	.15	.11	.16	.14	.11
Sewage treatment												
MGPD required[j]	.08	.17	.23	.19	.04	.07	.12	.10	.07	.11	.09	.08
Solid waste												
Lbs/capital/day[k]	5,250	10,440	14,630	11,630	2,810	4,250	7,630	6,060	4,500	6,810	5,880	4,690
Recreation												
Playgrounds (acres)[l]	0	1	2	1	0	0	1	1	0	1	1	1
Neighborhood parks (acres)[m]	1	2	2	2	0	1	1	1	1	1	1	1

(a) Baseline population is from Section 3.6.1.3. Project-related population is from Tables 5-41 and 5-42.

(b) Baseline housing required assumes the 1980 household sizes: Moab - 2.89, Monticello - 3.44, Blanding - 3.96 (BGI, 1984, ONWI-471). Project-related housing requirements are from Goldsmith, 1984.

(c) Baseline students assumes the same proportion of students to population as in 1981: Moab - 13 percent, Monticello - 23 percent, Blanding -24 percent (Table 3-47).

(d) Baseline and project-related teacher requirements assume 1 teacher per 19 students (National Center for Education Statistics, 1984).

(e) Based on 2 police officers per 1,000 population (Federal Bureau of Investigation, 1984).

(f) Based on 2 paid firefighters per 1,000 units (Stenehjem and Metzger, 1976).

(g) Based on 1.0 physicians per 1,000 population (National Center for Health Statistics, 1983).

(h) Based on 5 beds per 1,000 population.

(i) Based on 150 GPCD (International City Management Association, 1979).

(j) Based on 100 GPCD (International City Management Association, 1979).

(k) Based on 6.25 lbs per capita per day (International City Management Association, 1979).

(l) Based on 1 acre per 600 children (International City Management Association, 1979).

(m) Based on 1 acre per 1,000 population (International City Management Association, 1979).

Projections of housing units needed by the in-migration population during project construction are based on estimates of in-migrant households. During the peak of construction, 1,660 repository-related in-migrant households are expected to be present in the project area. During the peak of operation, 1,320 repository-related in-migrant households would be present.

In addition to the baseline and project demand for housing, there is usually some additional supply needed to provide flexibility in the housing market. The expected residence of in-migrating households are shown in Table 5-45. During project construction, 840 units will be needed in Moab, 440 units in Monticello, and 340 units in Blanding. The types of housing available to meet the increased demand would be expected to include single-family dwellings, multiple-family housing units, and temporary housing. Accommodations for families or individuals may include houses, mobile homes, apartments, and motel rooms. The development of new housing will also require streets, sewers, water, and other utilities.

During project operation, 800 units will be needed in Moab, 420 units in Monticello, and 320 units in Blanding. Assuming that sufficient housing is constructed during project construction, no additional housing will be needed during project operation.

5.4.3.2 Education

Estimates of school age in-migrants during peak repository construction and operation are presented in Table 5-45, the expected place of residence of these in-migrants is presented in the same table.

Baseline student growth since 1984 is expected to range from 110 in Moab to 170 in Blanding during the construction peak. The growth in the student population since 1984 is expected to range from 220 at Moab, to 160 at Monticello, and 260 in Blanding during the operation peak. These estimates are based on current student to population ratios within the study area.

The projected peak number of school in-migrants in Moab will reach 600 during project construction and 490 students during project operation. Assuming 19 students per teacher, 32 teachers would be needed during project construction and 26 during project operation to accommodate in-migrating school children in Moab.

During peak project construction, 310 students are expected to in-migrate into Monticello and 240 to Blanding; 250 in-migrating students would be expected during project operation in Monticello, and 200 in Blanding. About 13 teachers may be needed to accommodate students in Blanding, while 16 would be needed in Monticello during project construction. Blanding would need 10 additional teachers for the in-migrating students and Monticello would need 13 during the project operation phase. Moab, Blanding, and Monticello all appear to require new schools to accommodate the baseline and project-related growth in their local school systems.

5.4.3.3 Protective Services

The 1980 national average for police service was two officers per 1,000 population. The current police to population ratios in Moab, Monticello, and Blanding are below the national average (Table 3-48). Additional police officers will be needed in each city to meet the national average for the 1997 baseline population growth.

The projected peak repository construction population in Moab would require an additional five police officers and two police officers in Monticello and Blanding to maintain adequate service. During project operation, no community should require additional officers.

Each community would require the equivalent of one full-time firefighter to meet its baseline needs. Assuming two full-time firefighters per 1,000 units (Stenehjem and Metzger, 1976), Table 5-45 presents an estimate of paid firefighters needed to meet project-related needs. The combined service needs for baseline and project growth for firefighters would be three full-time firefighters for Moab, two for Blanding, and one for Monticello. Additional police and fire protection services may be identified as the emergency preparedness plan is developed.

5.4.3.4 Health Services

Assuming a physician to population ratio of one per 1,000 population is adequate coverage for a rural area (National Center for Health Statistics, 1983), the baseline growth by 1997 would require one doctor each for Moab and Blanding. By the peak of operations, Moab would need two doctors and Monticello and Blanding would each need one for the baseline growth. An adequate number of hospital beds would be available in the study area to meet the baseline needs, due to excess capacity (Section 3.6).

Physicians needs for the project-related in-migrants would require about two additional doctors for Moab, and one each for Blanding and Monticello. The need for the construction and operation period would be about the same. The in-migrant requirements for hospital beds at the peak of construction and operation appears in Table 5-45. Moab in-migrants would need 12 hospital beds during construction and nine during the operation phase. Monticello in-migrants would need six hospital beds by 1997 and five beds by 2006. Blanding in-migrants would require five hospital beds by 1997 and four beds by 2006.

5.4.3.5 Water Supply

Table 5-45 presents estimates of water supply requirements for the increase in the projected baseline, and in-migrant population expected during peak construction and operation in Moab, Monticello, and Blanding. If current plans to upgrade the water system in Moab and Monticello are completed (Section 3.1.6), there should be sufficient water available to accommodate the baseline population in 1997 and 2006. There will be an excess capacity available in all cities after baseline needs are met.

5.4.3.6 Sewage and Solid Waste Disposal

Existing sewage treatment facilities are adequate to meet baseline growth in Moab, Monticello, and Blanding. Excess capacity will remain in Moab and Monticello by 2006. Sewage treatment capacity in Blanding will be just adequate to meet baseline needs.

Moab is planning to expand its wastewater treatment plant to serve 10,800 people in Moab and Spanish Valley. Assuming a baseline population of 7,464 persons in 1997 and 8,290 in 2006, there would be additional capacity for growth available. The sewage treatment demands for project-related in-migrants to Moab are shown in Table 5-45. By 1997, 0.87 million liters per day (0.23 million gallons per day) of additional sewage will be created. This will drop to 0.71 million liters per day (0.19 million gallons per day) by the year 2006.

Monticello has completed work on a new sewage treatment system, which has the capacity to process waste for 5,000 people. The baseline population for Monticello was projected to reach 2,433 by 1997 and 2,660 by 2006. Project-related sewage treatment requirements will range from 0.45 million liters per day (0.12 million gallons per day) in 1997 to 0.37 million liters per day (0.10 million gallons per day) in 2006.

Blanding's new treatment lagoon system is expected to have a capacity for 4,720 persons. Blanding's baseline growth should reach near this capacity by 2006. Sewage treatment requirements for project-related in-migrants will range from 0.34 million liters per day (0.09 million gallons per day) by 1997 to 0.30 million liters per day (0.08 million gallons per day) by 2006.

Solid-waste disposal facilities will be needed to meet baseline, as well as project-related needs. As discussed in Section 3.1.6, Moab's two solid-waste disposal sites have only a 5-year life. Hence, additional facilities will be needed to accommodate expected baseline growth. These projections are shown on Table 5-45.

Monticello's landfill site is expected to have a 20-year life, which should be adequate to meet projected baseline growth through 2006. However, additional facilities will be needed to meet solid-waste requirements for project-related in-migrants.

Blanding presently has no landfill site, so it is assumed that solid-waste disposal facilities will be needed to accommodate any baseline growth, as well as project-related in-migration. These estimates, assuming 2.8 kilograms (6.25 pounds) per capita per day (International City Management Association, 1979), are shown in Table 5-45.

5.4.3.7 Recreation Facilities

The additional recreational needs of the baseline population would appear to be met by the existing community facilities. Estimates of the recreational demands of the project-related in-migrants are presented in Table 5-45. Additional recreational needs could be met by the use of various State and National Parks in the region. Section 5.5.1 discusses repository impacts on tourism and recreation in Canyonlands National Park.

5.4.4 Social Conditions

It has been documented in case studies conducted on rural, rapid growth communities in North Dakota, Wyoming, and Colorado that social conditions and social services are affected by the influx of large number of project workers. Not only are there more people needed to staff social service, medical, and mental health care facilities, but the types of problems are different from those usually handled by rural and small town social agencies. These problems are often compounded because the experienced personnel needed to handle these problems are not readily available.

In the case studies that have been completed, community populations had increased by 100 percent or more within a 5-year period (Gilmore and Duff, 1975; Kohrs, 1974; Little, 1977; Davenport and Davenport, 1979; Finsterbusch, 1980). It is estimated that Moab will experience about a 30-percent increase in population during the first 6 years of the repository project. Monticello is expected to increase by 50-percent during that period and Blanding a 25-percent increase.

Even though the increase would be less than 100 percent, it would still be very dramatic for Monticello and other communities. The information supplied by the case studies indicate a potentially significant increase in the reported cases of alcoholism, child abuse, mental illness, drug abuse, crime, suicide attempts, and divorce. These increases are expected to be greater than the proportional increase in the population.

It must also be noted that there can be social problems linked to the stresses that sudden growth places upon existing residents and from the characteristics of the new residents. For example, new residents tend to be under 25, to have moved often in the past 5 years, to have no sense of belonging, and to be living in unsatisfactory housing (Davenport and Davenport, 1979, p. 39). Additional services, programs, and recruitment of staff will be necessary in both San Juan and Grand Counties to help these residents cope with their problems.

In the case studies that were reviewed, churches increased in number and size, with greater diversity in the denominations established. Church organizations also made changes in their orientation and provided more social services. In addition to the changes to religious institutions, other local institutions and organizations will be affected by the influx of new people. Formality, change in leadership, and conflicts between new and long-time residents may result.

One way of addressing potential social conflicts between long-time residents and new comers over leadership positions in a community is to look at the projected change in the native population base. The native population base is defined as the persons residing in the community who were born in the State of Utah (place of their mother's residence when they were born, not the place of their birth such as a hospital).

By 1997, Moab's native population base could be reduced from 41 percent to 31 percent, while Monticello could drop from 62 percent to 41 percent and Blanding's could drop from 76 percent to 62 percent. Monticello would appear to be the most likely to experience

political conflict between the established order and the newcomers because the native population will potentially change from a majority to a minority.

This kind of analysis does not consider the values and beliefs of the current residents versus the values and beliefs of the newcomers. It has been noted that the traditions and religious values of the current residents may be different from the values of newcomers. Some of the current energy boom-towns are occurring in predominantly rural or Mormon areas. The construction worker's need for recreation is likely to find outlets which are not appreciated by the current residents. Another group with values that may conflict with those of some project workers is the Native Americans (Finsterbusch, 1980, p. 143).

The quality of life of existing residents in Monticello, Blanding, and Moab will also be affected. Quality of life impact issues generally revolve around the way in which local residents' lifestyles are going to be disturbed or enhanced by change. An assessment of these issues using quantitative methodologies is, according to Wilcox (1981, p. 15), currently "in a primitive stage of development." Certainly it is difficult to measure an individual's perception of what may happen to his or her quality of life in the future (Campbell et al., 1976).

Nevertheless, while it may not be possible to assess the degree to which an individual's quality of life may be beneficially or adversely affected by future changes, it is possible to generalize in a qualitative manner about which social groups stand to benefit or incur the costs of these changes (Napier and Maurer, 1978). Social scientists (Fitzsimmons et al., 1975) stress that factors such as age, economic security, and geographic location in relation to a project should be considered. Using such a social cost and benefit approach can be helpful in suggesting how the development of a repository will affect different resident groups.

Long-time residents who may have been satisfied with their communities and services prior to the building of a repository may view the development as making their communities less friendly, less familiar, and significantly different from before. Individuals who hold Canyonlands National Park in high esteem may view the project as an intrusion upon their wilderness experience. The differences in lifestyle between the long-time residents and temporary construction workers could create social conflicts that may be disruptive to the quality of life for both groups when the behavior of one group is different from the expected norms of behavior for the other (Section 3.6.4).

Low income and elderly residents on fixed incomes who could not take advantage of the new economic opportunities might be negatively affected by inflation caused by increased demands for locally supplied goods and services. In addition, the advent of increased demands for many services could result in overloading local social services. This could cause a decline in the standard of living for those groups dependent upon these services (i.e., the unemployed, marginally employed, and female household heads, and their dependent children).

On the other hand, underemployed residents, youths, and others seeking more job opportunities, might view a repository as providing a boost to the local economy and as enhancing their quality of life. Local business persons may have the same perception. Residents who wanted to see an expanded community service base might also see the development as enhancing the quality of life.

Some form of mitigation or compensation may be necessary to ensure that the quality of life of local individuals will not be significantly altered by the construction, operation, and closure of a repository. For example, social programs can be developed to promote positive interaction between new and long-term residents and to help reduce the initial conflicts. A primary goal of the NWPA negotiated local mitigation measures could be to provide better access to social services and aid for the disadvantaged such as housing for the elderly, or low-income housing.

5.4.5 Fiscal Conditions and Government Structure

Project construction will result in added revenues to study area cities and the region as well as added costs. Expected costs and revenues are discussed below.

5.4.5.1 Fiscal Conditions

5.4.5.1.1 Construction. Revenues anticipated during project construction include impact funds, property taxes, sales taxes, user fees, and other governmental payments.

The Nuclear Waste Policy Act of 1982 requires the DOE to provide grants-equal-to-tax payments to the State and general units of local governments in which a candidate characterization site is approved by the President. As described in Section 4.2.2, payments will be made during the site characterization phase, the repository construction phase, and the repository operation phase. These payments will continue until activities at the site are terminated. These funds are not earmarked for specific community projects. Grant-equal-to-tax payments will be made to San Juan County; Grand County, Moab, Blanding, and Monticello may not be eligible to receive such payments because the site is not located within their taxing jurisdictions.

Technical and financial assistance will be provided to any host State requesting such assistance within 6 months, following issuance of a construction authorization from the NRC, and following initiation of construction activities at such site. Such assistance shall be provided to mitigate the impact on the State of the development of the repository. The DOE must seek to enter into an agreement with the State on the amount of financial and technical impact assistance to be provided, and the procedures to be followed in providing such assistance. To receive these payments, the State must submit an analysis of the probable social, economic, public health and safety, and environmental impacts to the Secretary of the DOE. These funds will be distributed by the State to the communities in accordance with agreements then in existence.

The expected additional service demands are likely to be high (Section 5.4.3) for the affected communities in Grand and San Juan Counties. Such demands will also result in increased public expenditures. There will be some revenues generated by property, sales, and user taxes paid by the new in-migrants.

Additional revenues from these sources and the NWPA would finance service improvements, such as new schools, and water and sewer systems. However, new service demands would arise immediately during project construction, and revenues from sources other than the NWPA may not be available to adequately meet those costs until project operations. Problems may arise in the timing of revenue collection in relation to public service costs and in the distribution of costs and revenues between Utah jurisdictions and, therefore, temporary reductions in the extent or quality of public services provided may occur.

The DOE has identified the need for preproject impact planning and front-end financing in the Mission Plan (DOE, 1985, DOE/RW-0005). The Mission Plan (1985, DOE/RW-0005, Vol. 1, p. 139) suggests that the DOE will encourage the State to allocate a portion of its NWPA grant issued during site characterization to potentially affected communities. This would allow these communities to participate in assessment of repository impacts and engage in planning.

The Mission Plan (1985, DOE/RW-0005, Vol. 1, p. 262) further notes the following:

1. The DOE will work closely with States, affected Indian tribes, and local governments to ensure that impact-mitigation needs are met in a timely fashion. This may be achieved, in part, by creating work groups composed of representatives from the DOE, State, affected Indian tribes, and local governments; these groups would work together to develop impact avoidance and mitigation strategic that would reduce requirements for financing before construction begins.

2. The DOE may want to establish a task force that would coordinate requests for impact-mitigation assistance from the States and affected Indian tribes. It may be possible to make preconstruction assistance available from other Federal agencies through interagency agreements with the DOE.

5.4.5.1.2 Operations. Governmental revenue sources would be influenced by the same factors that influenced them during repository construction, although the magnitude of the changes may be different. Property tax revenues would increase due to the projected increase in home ownership. These revenues would fluctuate in the transition from construction to operations because of work force size and characteristic changes. Other factors discussed under construction impacts would probably remain the same. The DOE grants-equal-to-taxes would continue and may increase revenues depending on how the repository is assessed.

User fees are related to specific services and would fluctuate as the population fluctuates. The same factors discussed under construction impacts would influence user fees during repository operations.

Bonding requirements would probably drop, since most of the demand for new facilities would have been met during the construction period. There will be replacement requirements as the useful life of the various facilities is exhausted. These requirements would be part of the communities' service planning and budgeting process.

Changes in expenditures are subject to the same factors discussed for repository construction. Service requirements will fluctuate with changes in total population and in the demographic characteristics. This may result in periods of over- or under-utilized capability. The differences between construction and operational work-force family characteristics such as the number of dependents may require expansion of some services, such as water and sewer lines, and schools.

5.4.5.1.3 Decommissioning and Closure. Revenues to State and local governments will decrease as operations phase down and when the repository is permanently closed. The DOE grants-equal-to-taxes will continue but may be at a reduced level due to reassessments of value. Out-migration of unemployed repository workers in the short-term may create a greater than normal housing vacancy rate, resulting in a reduction of new home construction. Thus, residential property tax income could stabilize or decline if home values also decline. The extent of this effect will depend on levels of other economic activity in the region.

City sales tax revenue may decline if unemployed repository workers cannot find other job opportunities in the area.

User fees are related to specific services. Per capita costs may increase if repository workers leave, because fixed costs will have to be paid by fewer users.

Bonding requirements could drop if excess facility capacity resulted from out-migration.

Changes in expenditures are subject to the same factors discussed for repository construction. Service requirements will decline if unemployed repository workers leave the area. This may result in excess capacity and reductions in expenditures to reduce capacity. The maintenance of public facilities which must operate at reduced capacities, because of out-migrating project-related workers, will require mitigation planning.

It is anticipated that additional local purchases would create revenues for local governments during decommissioning.

5.4.5.2 Government Structure

Population in-migration during repository construction may result in a more formal organization in social and political institutions due to the extensive population growth expected. To some extent, the increase in population will require a scale change in government. Where local government in the past had limited contact with many large State and Federal agencies, it will now have to work closely with these agencies, if needed services are to be provided. This will require additional technical expertise and additional staff in the local government.

Increased population may also require new administrative and technical personnel within local and county governments. As new housing developments are needed, new planning and community development personnel, in particular, may be needed.

There have been difficulties in attracting medical, human-service, and other personnel in boom-town communities (Finsterbusch, 1980). If this situation occurs in the region, it may be necessary to recruit qualified individuals.

The increased use of area parks by project-related in-migrants may require additional staff. The proximity of the repository to Canyonlands National Park will probably require additional resource-protection staff for the Needles District at the park.

5.5 SUMMARY OF REPOSITORY IMPACTS AT DAVIS CANYON SITE

This section provides a discussion of the cumulative impacts of the project on Canyonlands National Park and summarizes impacts in the vicinity and area of the Davis Canyon site.

5.5.1 Cumulative Repository Impacts on Canyonlands National Park, Including Tourism and Recreation

The section contains a summary of the physical environmental impacts addressed in Sections 5.2 through 5.2.11. It also summarizes park use, economic and cumulative impacts to the Canyonlands National Park from the construction and operation of a repository and repository isolation. Impacts to the Canyonlands National Park are highlighted because of its superlative scenic, scientific, and archaeological features, and nearness to the site. This section concludes with a discussion on in-park use activities.

5.5.1.1 Approach

Impacts were identified, evaluated and finally the impacts were considered cumulatively over time. These impacts were segregated and evaluated by phases: construction, operation, decomissioning, and isolation.

5.5.1.2 Physical Environmental Impacts

The physical environmental impact areas on the Canyonlands National Park are summarized in Table 5-46. The consequences of repository activities for the construction and operation phases are given for each of the identified impact areas. The decomissioning impacts are discussed in the text. Significance of the impact consequences are indicated by impact categories in far right column of the table.

The Impact Categories were divided into three ranges:

- Insignificant (I) as no impact to insignificant
- Detectable (D) as minimal or similar to existing perturbations
- Significant (S) as minimal to perceptible change in existing conditions and visitor experience.

Those impacts judged as none or insignificant would be immeasurable and imperceptible, and would have no environmental consequence. The detectable impacts are those that may be measurable by instrumentation but may or may not be perceptible by the park visitor, and with no or little consequences.

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
Land Use and Mineral Resources (Sections 5.2.3 and 5.1)	Construction	BLM, State, and private property would be acquired for repository site and access to it	Approximately 2,331 hectares (5,760 acres) would be changed from current uses for the site and access corridors. Average per-day round trips for repository would be 769 for passenger vehicles and 12 for trucks.	No part of the controlled area would be within the park boundary. There would be a sense of adjacent industrial development to some park visitors. Ease of access to the park will be temporarily inconvenienced.	D
		Sand and gravel will be required for facilities construction	Approximately 153,000 cubic meters (200,000 yards) would be mined for concrete.	The sand and gravel would not be mined in the park.	I
	Operation	Property acquisition, sand and gravel	No additional property acquired. Small amounts of sand and gravel would be required to seal shafts.	None	I
	Isolation	Property acquisition	Surface uses may be restored except for monitoring activities and exploratory drilling.	None	I
Terrestrial and Aquatic Ecosystems (Sections 5.2.4 and 5.2.10)	Construction	Emissions, ground shaking, runoff, and noise impacts on pristine systems and sensitive plant, animal, and fish species	Salt fugitive emissions occur late in construction. Blasting ground shaking is about one-third of that which might affect geologic structures and blasting noises consist of 3 impulses per day for up to 12 days for each of 5 shafts and ends of railroad tunnels.	No detectable effects on ecosystems or sensitive plant species are projected. Bighorn sheep and birds of prey will be alerted by blasts but no effects on reproduction are expected. Water-quality impacts on tributaries and the Colorado River may not be detectable. No sensitive fish species are expected to be affected.	I
	Operation	Air and salt emissions, and runoff over 26-year emplacement	Maximum annual average of 1 and 3 micrograms per cubic meter of TSP and NO_x respectively, and 0.1 kilogram (0.09 pound per acre) salt at the park boundary. SO_2 emissions would be minimal.	No long-term atmospheric effects expected. Total deposition of 2.34 pounds per acre of salt dust may result in addition of 5 parts per million in the top foot of soil. No impacts to biota expected. Additional salt and sediments in runoff are not expected to have impacts on sensitive fish in tributaries of Colorado River.	I
	Isolation	None	None	None	I

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository
(Page 2 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
Air Quality (Section 5.2.4)	Construction	Air quality	Maximum annual increments of TSP and NO_2 are estimated to be 3 and 12 micrograms per cubic meter, respectively, at the park boundary during peak construction. SO_2 and CO emissions are too low to be of concern.	TSP/NO_2 levels in the park will be increased particularly during site clearing.	D
		Impacts on park AQRVs	Visibility impairment	For the construction period, there will be periodic occurrences where site activities will be visible from the park boundary from up Davis Canyon.	D
			Odors from diesel engines	No odors are expected to be detectable anywhere within the park.	I
			Night sky glow	Night sky glow would be increased during periods of greatest site activity and site lighting. Night sky viewing should not be significantly impaired.	D
			Soils and vegetation	No long-term impacts are projected.	I
			Geological resources; archaeological, historical and cultural resources; and water quality resources	No long-term impacts will be detectable primarily because total atmospheric releases are below NAAQS.	I
	Operation	TSP and NO_x from operating equipment, minor land grading, salt pile and shaft releases, and NO_x from steam plant buoyant plume Maximum annual increments of TSP and NO_x are 1 and 3 micrograms per cubic meter respectively for the 26-year operating period	Visibility impairment	Visibility impairment is below the threshold value of 0.1 and no impacts are expected within the park.	I
			Odor	None	I
			Night sky glow	Night sky glow is projected to be approximately equal to that from existing sources such as Moab.	D

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park for a Nuclear Waste Repository
(Page 3 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
			Soils and vegetation	None.	I
			Geological resources; archaeological, historical and cultural resources; and water quality resources	No long-term impact on these resources is projected. The releases are below NAAQS at the park boundary.	I
	Isolation	Atmospheric emissions	Visibility impairment	None	I
		No significant sources will remain on site in perpetuity	Odor	None	I
			Night skyglow	None	I
			Soils and vegetation	None	I
			Geological resources; archaeological, historical and cultural resources; and soil and water quality resources	No long-term impacts	I
Water Resources (Sections 5.2.2.1 and 5.2.2.2)	Construction	Water removal from the Colorado River or existing allotments for site and corridor construction uses	1,570,000 cubic meters (416 million gallons) of water would be used over the construction period.	This use is approximately 0.01 percent of the average Colorado River flow. The annual water use during construction is larger than for operations although not significant. Existing allotments are available to supply the needs.	D
		Surface water siltation and salt loads	Earth moving for site preparation and corridor construction will result in unstable materials available for flood water transport. Release from the salt pile will be controlled and minimal.	No detectable impacts on the Colorado River within the park are projected over existing heavy loads of silts and salt.	I
		Ground-water contamination	All significant contaminants will be controlled in lined ponds and shaft sinking is designed to minimize degradation on aquifer water quality.	No long-term impacts are projected in the park.	I
	Operation	Water removal from the Colorado River or existing allotments	Approximately 0.36 million cubic meters (94 million gallons) will be used annually. The cumulative total is 9.36 million cubic meters (2,444 million gallons) for the 26-year operating life.	This usage rate is a very minor part of the Colorado River flow (0.006 percent) and no impacts on park uses are projected. No new allotments are expected.	I

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository
(Page 4 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
		Surface water siltation and salt load	Only minor siltation and salt addition are projected because runoff from the site will be controlled.	No long-term impacts on the park are projected.	I
		Ground-water contamination	Ground-water quality impacts due to infiltration are expected to be minor because of the low precipitation rate and the deep water table in the region.	No impacts on the park are projected.	I
	Isolation	Water removal from the Colorado River or existing allotments	Minimal. The allotment would be available for other uses after the 26-year operating period and 24-year caretaker period.	No impact on the park	I
		Surface water siltation and salt load	None	None	I
		Ground-water contamination	Potential migration of radionuclides	No long-term impact to deep non-potable waters for hundreds of thousands of years and then at levels approximately equal to uranium deposits at the surface in the region.	
Soils, Geology and Paleontology (Section 5.2.1.1 and 5.2.10)	Construction	Air quality, salt deposition, ground shaking, earth moving, and flooding	SO_2, NO_x and CO are not significant enough to be considered. Ground shaking is about one-third that required to cause geologic damage, and no paleontological resources within the park will be flooded or disturbed by earth moving activities outside the park.	No long-term impacts on park resources are projected.	I
	Operation	Air quality, salt deposition, ground shaking, earth moving and flooding	Similar to construction	A total deposition of 2.34 pounds per acre of salt dust may result in an imperceptible addition of 5 parts per million in the top foot of soil of the park boundary. No other impacts are projected.	I
	Isolation	Air quality, salt deposition, ground shaking, earth moving, and flooding	There are no impacts during this phase.	None	I

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository
(Page 5 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
Noise (Section 5.2.7)	Construction	Site equipment and blasting noise affecting visitor perception within the park	Five shafts would be sunk and railroad tunnels would be opened using explosives resulting in up to 3 blasts per day for up to 12 days for each event. Equipment noises arise from land preparation, building and corridor construction.	Blasting noise, with mitigation (wind blowing away from the park) would be audible in the park, but only to 24 km (15 mi) from the repository shaft construction sites.	S
				Equipment noises will be audible along Davis Canyon at the park boundary, 2.4 km (1.5 miles) into the park.	S
	Operation	Equipment noise affecting visitor perception within the park	Operating equipment noises occur and road and railroad noise predominate. Few impulse noises would occur.	Operating noises would be audible along Davis Canyon at the park boundary.	S
	Isolation	Equipment and impulse noise affecting visitor perception within the park	Noise sources include vehicles traveling paved roads to monitoring stations	There should be no audible impacts into the park anytime during this phase.	I
Aesthetic Resources (Section 5.2.6)	Construction	Impairment of scenic qualities in the park and from vistas to the exterior of the park	Viewsheds and vistas including visual contrast	Viewshed analyses indicate that there is no significant visibility from designated vistas within the park although road and rail construction will be visible from some areas. Significant contrast occurs from the canyonlands boundary to the site. This is not a designated vista and is not easily accessible.	S
				The site would have significant visibility from a 3-kilometer (1.9-mile) segment along Utah 211 and there is a significant contrast along this segment of road.	S
	Operation	Impairment of scenic qualities in the park and from vistas to the exterior of the park	Viewsheds and vistas including visual contrast	Same as for construction over a 26-year operating period but not for the 24-year caretaker period. The train would be visible daily indicating industrial presence from portions of the park and Utah 211.	S
	Isolation	Impairment of scenic qualities in the park and from vistas to the exterior of the park	Viewsheds and vistas including visual contrast	The elevated facilities will no longer be visible from the park boundary. The disposition of the road and railroad is uncertain.	I

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository (Page 6 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
Archaeological, Cultural, and Historic Resources (Section 5.2.8)	Construction	Chemical or physical damage	Air quality, water quality, ground shaking, or earth moving	No impacts are projected on any of these park resources during the construction period. Atmospheric releases are below NAAQS at the park boundary.	I
	Operation	Chemical or physical damage	Air quality, water quality, or ground shaking	No impacts are projected on any of these park resources during any of the 50-year period of operation and caretaking.	I
	Isolation	Chemical or physical damage	Air quality, water quality, or ground shaking	None	I
Radiological Conditions (Sections 5.2.7 and 6.4.1)	Construction	Radiation exposure to the park or its visitors	Radon emissions from salt	The maximum individual dose from salt releases is 1.3 millirem which is 5 percent of the strict EPA limit.	I
	Operation	Radiation exposure to the park or its visitors	Direct radiation from transportation casks, indirect radon emissions from salt, and operational and accidental releases from the operating facilities	The combined dose from salt and operational releases is 1.8 millirem per year which is 7.2 percent of the EPA limit and is approximately 1.5 percent of background.	I
				The maximum individual 50-year dose from a worst case accident, if it occurred, is 46.8 millirem, which is also about one-third of background for 1 year. The cumulative dose to park visitors and park employees due to repository releases is insignificant.	I
	Isolation	Radiation exposure to the park or its visitors	No emission sources on site	None	I
Transportation and Utilities (Section 5.3.2)	Construction	Visibility, traffic, industrial presence, and threatened and endangered species	Construction of railroad and water supply lines causing short term turbidity in the Colorado River	Structures adjacent to or crossing the Colorado River would be constructed to minimize or avoid impacts to threatened and endangered species in the rivers.	D
			Existing Utah 211 would be upgraded, bypassing Newspaper Rock, or a new road would be constructed.	Portions of the road and railroad would be visible from park key observation points and a campground. Short-term interruption of visitor access will occur.	D

Table 5-46. Summary of Cumulative Environmental Impacts to Canyonlands National Park from a Nuclear Waste Repository
(Page 7 of 7)

Physical Impact Area	Phase	Impact Consideration	Impact Measure	Consequence	Impact Category
	Operation	Visibility, traffic, and industrial presence	The Colorado River alternative rail routes would be visible from as many as 4 key observation points within the park.	Although visible from key observation points within the park, the transportation routes do not provide an unacceptable contrast.	D
				The railroad and a new road would not have at-grade crossings with Utah 211 nor interrupt traffic, but would add to industrial presence.	D
	Isolation	Visibility, traffic, and industrial presence	Difficult to determine at this time	Minimal impact on the park unless transportation corridors are used for park benefit or other uses.	I

(a) I = Insignificant
D = Detectable
S = Significant

The category judged as significant contains the range of impacts that would be measurable and perceptible and may have possible consequences.

The insignificant impacts, Impact Category I, are not discussed further.

There are no detectable or significant consequences identified during the repository isolation phase.

The impact areas judged to have detectable impacts are summarized in Table 5-47. Five of these occur during construction and three are defined for the 26-year operating period. Detectable construction impacts include land use, transportation and utilities, air quality, water resources, and aesthetic resources. Detectable impacts during operation include air quality, aesthetic resources, and transportation and utilities.

Three areas were judged to have significant impacts and possible consequences including construction blasting and during construction and operation machine noises. Also included as significant are the short-term effects of industrial presence due to traffic delays during construction and the long-term visibility of the site throughout the period of the project (Table 5-48).

These construction explosive noises will be audible during the first few days of shaft sinking and the opening of railroad tunnels. The number of tunnels to be constructed depends on the route selected with blasting conducted when the wind blows from the park; blasting noises on those routes further from the park will be less perceptible to park visitors. Blasting noise will be well below the levels determined by the EPA (see Section 5.2.7) to affect health and are of relatively short duration.

Construction equipment noises are evaluated as significant but limited along the park boundary at Davis Canyon. This noise is expected to be somewhat reduced at night with daily cessation of activities. No audible noise is projected to occur past this point at any of the proposed wilderness areas or the Salt Creek Archaeological District. Thus, solitude and the park purposes would not be impacted past this point (see Section 5.2.7.3.1).

Operating equipment noises are similarly judged to be significant along Davis Canyon at the park boundary. The primary sources of these noises are attributable to transportation sources. Truck noise will originate from the new access highway and contributes to the noise from the southeast impacting the park edge. Railroad noise sources would impact a similar area but would emanate more from the north. The total area of impact within the park is similar to that for construction except that it would be less when the train is not moving or is moving away from the area (see Section 5.2.7.3.2).

The construction of rail and road crossings at Utah 211 and the presence of heavy equipment trucks using this route may inconvenience some park visitors entering or leaving the park. While this impact could be significant to these visitors, it must be noted that the delays will be eliminated when Utah 211 is upgraded the exclusive-use access road is completed. The development of the exclusive-use access road will remove all repository-related traffic from Utah 211 (see Section 5.3.2).

Visitors to the Needles District will see portions of the completed facility as they approach the park. The facility is visible for 3.0 kilometers (1.9 miles) of Utah 211. Visitors to Davis Canyon within the eastern boundary of the park would be able to view the facility. This visual impact will be reduced after the facility is decommissioned and the buildings are removed.

Decommissioning. Following the 50-year repository operation period, including 24 years of site caretaking, the site and repository will be decommissioned and closed. The period of this activity is projected at 5 years. Major surface facilities, including the headframes, will likely be dismantled and removed from the site. The salt pile will be disposed of or stabilized onsite to eliminate a source of fugitive dust.

Table 5-47. Detectable Physical Environmental Impacts to Canyonlands National Park

Impact Area and Phase	Summary of Impact
Construction	
Land Use	Sense of industrial presence to some park visitors.
Transportation and Utilities	Structures crossing or adjacent to the Colorado River will result in increased turbidity possibly affecting threatened and endangered species.
	The rail route and new road will be visible from portions of the park.
Air Quality	Temporary increases in TSP/NO_2 will be detectable in the park.
	There will be a detectable increase in night skyglow over the site. Night sky viewing should not be significantly impaired.
Water Resources	Removal of water through existing allotments will have an insignificant impact on water uses within the park.
Aesthetic Resources	Road and railroad construction will be visible from some key observation points in the park and from Utah 211. The site will be visible from the park boundary up Davis Canyon.
Operation	
Air Quality	The night lighting is expected to produce a slight night skyglow over the site similar to that visible from Moab. Night sky watching should not be significantly impaired.
Aesthetic Resources	The site would be visible from the eastern park boundary at the head of Davis Canyon. Visual contrast views of the access routes are not judged to be significant visual intrusions.
Transportation and Utilities	The access routes will be visible from portions of the park and at the Utah 211 crossing, possibly affecting industrial presence.
	Transportation and utilities construction impacts are taken out of order as presented in Table 5-46 to illustrate the interconnection between transportation and land use on the perception of industrial presence.

Table 5-48. Significant Environmental Impacts to Canyonlands National Park

Impact Area and Phase	Summary of Impact
Noise; Construction and Operation	Blasting noises with mitigation would be audible in the park up to 24 kilometers (15 miles) from the repository shaft construction sites. Site equipment noises will be audible to a limited area along Davis Canyon at the park boundary during construction. Site noises dominated by transportation noise will be audible to a limited area along Davis Canyon at the park boundary during operation.
Delays in Gaining Access; Construction	Park visitors will experience temporary delays in gaining access to the park during access route construction.
Facility Visibility; Construction, Operation, and Decommissioning	Park visitors will be able to see portions of the completed facility from 3.0 kilometers (1.9 miles) of Utah 211.

The air quality and visual impacts from decommissioning to the Canyonlands National Park have not been evaluated. However, potential impacts are expected to be similar to but less than those for construction, and a minimum amount of blasting expected.

During this period, there should be no impacts to resources in the park described in Sections 5.2 through 5.11.

During the isolation phase, no significant or irreconcilable impacts and no conflicts with the park's physical environmental qualities will occur.

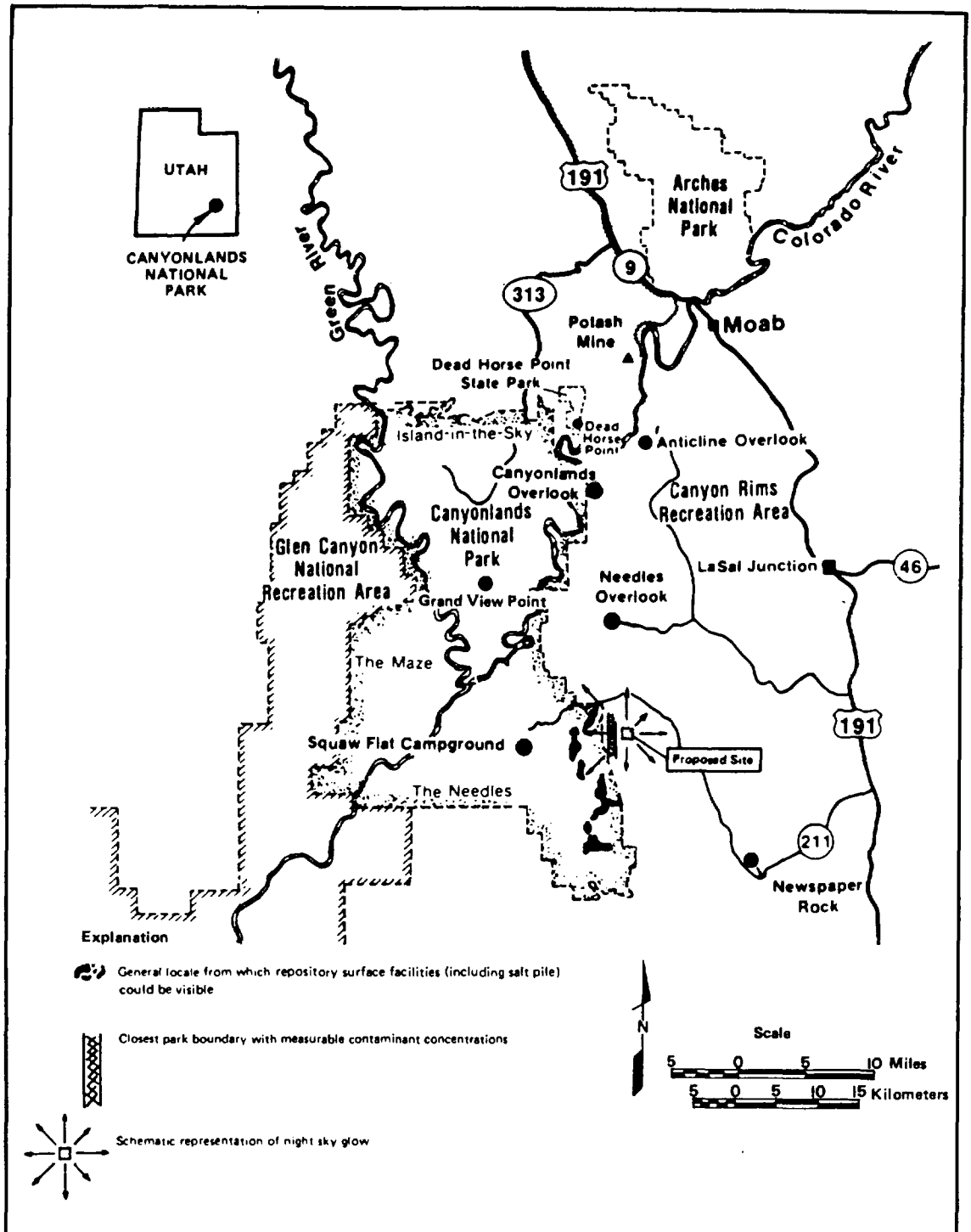
5.5.1.2.1 Repository Construction Impacts On Users Of Canyonlands National Park. The legislation that established Canyonlands National Park (16 USC Section 271) stated that it was formed "to preserve an area in the State of Utah possessing superlative scenic, scientific and archaeological features for the inspiration, benefit and use of the public ..." An area of particular interest to wilderness users and archaeologists is the Salt Creek Archaeological District in the eastern half of the Needles District. Lavender, Davis, Horse, Salt, Squaw, Lost, Elephant, and Big Spring Canyons are included in the archaeological district. Educational groups, researchers and recreationists can access the area by hiking or driving off-road vehicles. Visitors there experience deep, winding canyons, where narrow corridors lead to outstanding erosional and archaeological features such as ruins and rock art (Parry, 1985). Researchers have used these canyons to study various natural processes in an outdoor setting. Archaeological researchers have identified numerous cultural resources and have participated in the stabilization of ruins in the canyons. This area of the park is also occasionally used as an educational setting by wilderness experience groups which stress self awareness, environmental concern, interpretation of park resources, and discovery of heritage (NPS, 1984).

The following analyses address how repository construction activities may affect recreational, scientific, and educational opportunities in the park.

Repository Construction Effects on Recreationists. Because some of the alternative rail lines would be near the Island-in-the-Sky District of Canyonlands National Park, the area of potential physical impact would be greater than the area analyzed for site characterization impacts. The construction of the rail line bridge across the Colorado River could also impact some river-runners launching upstream. Therefore, the whole park must be considered in an analysis of the effects on tourists. To address how the construction of a repository will affect the attractiveness of Canyonlands National Park to tourists, the magnitude of the environmental impacts must be distinguished from their importance to the recreationist. The magnitude of a physical environmental impact on tourists can be measured objectively in terms of frequency, extent, and other quantitative dimensions of the impact (the magnitudes of the physical environmental impacts associated with site characterization are presented in Section 5.6.1.2.1). Importance is measured subjectively. It reflects the value a person assigns to a phenomenon such as visual aesthetics; this value varies among individuals.

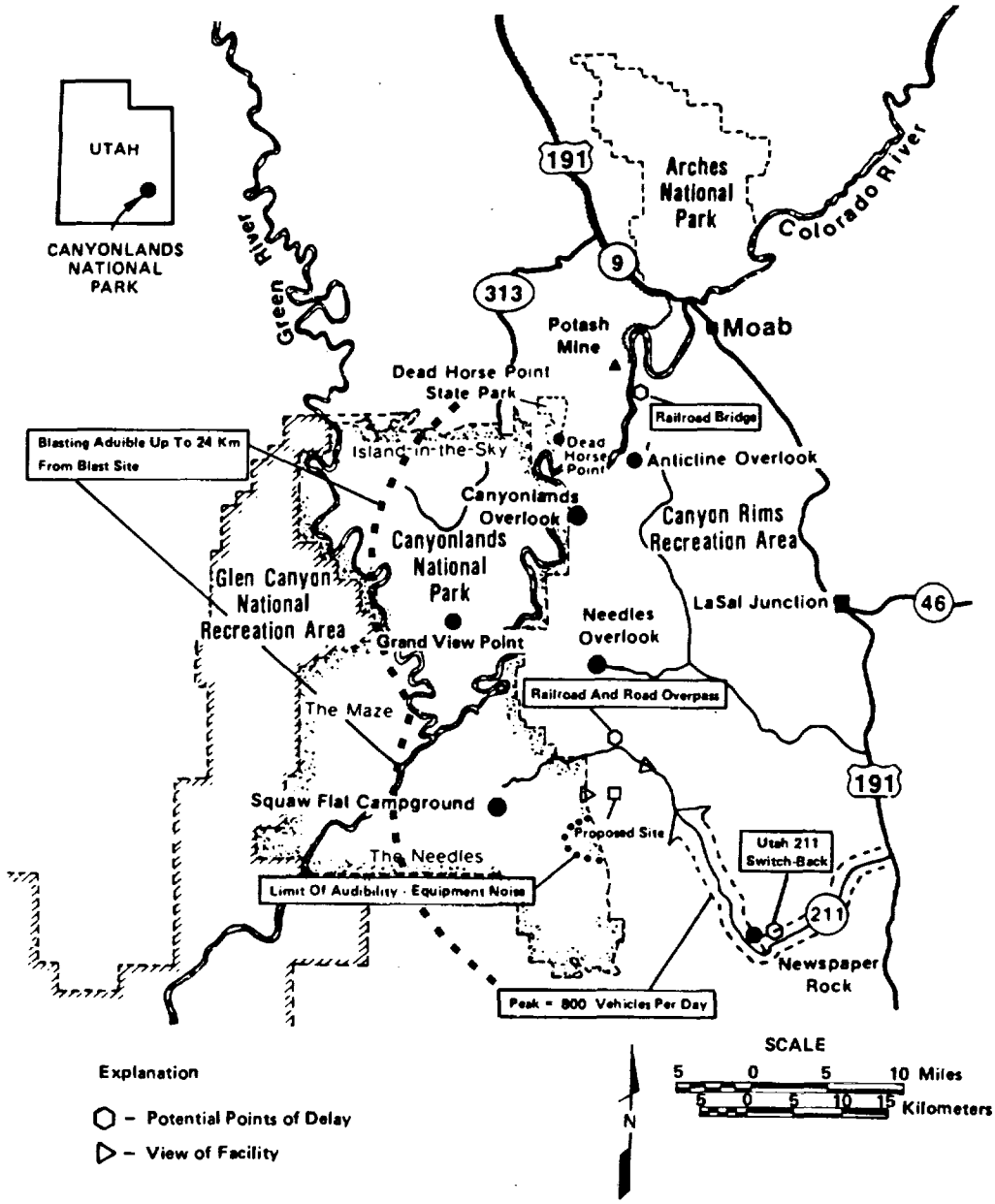
Figure 5-30 shows the approximate locations where detectable environmental impacts will occur. Figure 5-31 shows where significant environmental impacts will occur. This figure graphically represents the information supplied in Table 5-48. An analysis of the magnitude of the cumulative physical environmental impacts to the park would suggest that the physical experience of wilderness would not be significantly affected in most areas of the park. However, visitors to Davis Canyon in the Needles District seeking a wilderness experience would find that occasional impacts resulting from repository construction activities might detract from their enjoyment. This canyon was formerly used as a missile test overflight area for the U.S. Army (NPS, 1977) and has not been highly visited. Visitors to Davis Canyon account for about one percent of the annual visitation to Canyonlands National Park (see Section 3.6.2.4).

An analysis of importance suggests that the values and expectations of park users play a central role in describing their perceptions of their recreational experience (Harrison et al., 1980, p.3).



Construction Phase Detectable Physical Environmental Impacts to Canyonlands National Park

Figure 5-30



Construction Phase Significant Physical Environmental Impacts to Canyonlands National Park

Figure 5-31

A wide range of tastes and preferences for recreational opportunities exists among the public. Those who seek a chance to meet and visit with friends in convenient and comfortable surroundings prefer modern vehicle-oriented campgrounds. Those seeking solitude and minimal contact with others prefer more primitive environments. Machine sounds, visual intrusions and other impacts are less acceptable to visitors who prefer primitive or semiprimitive environments than to those who prefer vehicle-oriented campgrounds. Visitors to the Needles District of Canyonlands National Park can find vehicle-oriented camping at the Squaw Flat Campground, while primitive and semiprimitive camping can be found in the rest of the park.

According to Davidson-Peterson Associates, Inc. and PBQD (1978), the ability to get away from people (to find solitude) is a highly valued expectation of the visitors to the Canyonlands National Park. This is assumed to be especially true for visitors who go to isolated areas in the Salt Creek Archaeological District to experience its primitive environment. Whether people perceive they can find places far removed from civilization in the Needles District is central to determining the importance of the impacts to the visitors.

The project's associated impacts would be most pronounced on the eastern boundary of the park. Some visitors to the Island-in-the-Sky District would see the rail line. River-runners launching at Moab would travel under the bridge before they enter the park. Similarly, persons traveling down Highway Utah 211 would cross the repository rail and exclusive access road before they enter the park. They would also be able to see some of the repository facility. Visitors to the park who are present during the few weeks when tunnel blasting and shaft blasting could hear the noise. Visitors to Davis Canyon could experience aesthetic, and other impacts from the project (see Figures 5-30 and 5-31). Park user activities in Davis Canyon, which may be affected by the repository, can be found in many other areas of the park (see Table 5-49).

Even though mitigation measures may eliminate physical environmental impacts to areas of the district where people have sought wilderness experiences, it is possible that some of the potential visitors would view the project's activities as conflicting with their expectations of a primitive experience. For them, intensive mining activities near the park may symbolize those aspects of civilization they are seeking to avoid. Visitors to the park may occasionally hear blasting during the initial construction phase.

Many of the visitors to Canyonlands National Park have other national parks and monuments in the travel region as their primary destination. However, about 30 percent of the visitors have Canyonlands National Park as their primary destination. Some of these visitors who are drawn to the travel region specifically to experience this park go there to get away from people. While it can be stated that the projected environmental impacts of repository construction should not affect the visitor's physical experience of wilderness and solitude, it is not possible to know how many will perceive construction activities as interfering with their expected wilderness experience. Those who believe it will disturb their experience may avoid the areas of the park near the facility. Some of these persons may make decisions to avoid the park altogether.

Effects on Scientific and Educational Users. Scientific resources contained in the Salt Creek Archaeological District could be slightly disturbed by the increased access to and interest in the area. This should not inhibit scientific inquiry and discovery in the area. However, Davis Canyon would be of questionable value to wilderness experience groups. Because wilderness experience groups are seeking to promote the tangible and intangible aspects of this wilderness experience, some of the groups may believe the construction activities would be an intrusion to the wilderness experience - even if the physical experience remains unaffected. In this case some groups may seek out other areas of the park further away from the site while other groups may avoid Canyonlands altogether.

5.5.1.2.2 Potential Repository Construction Impacts on the Tourist Sectors of the Economy. Section 5.5.1.2.2 suggests that the cumulative environmental impacts and perceptions of those impacts may influence some potential visitors not to come to Canyonlands National Park. In addition to the analysis of visitors affected by the changes at Canyonlands National Park, it is necessary to address whether the repository would negatively affect the image of

Table 5-49. Construction Phase - Significance of Physical Environmental Impacts on In-Park Activities

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]: Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island in the Sky District	Maze District	River	Environmental Factors Associated with the Activity	Repository Construction Phase Impacts: Audible Blasting Noise	Audible Mechanical Noise	Delay in Gaining Access	Construction Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	Areas of the Park Where the Activity may be Affected and its Significance to Park Users
Viewing Rock and Desert Formations[d]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Visual Contrast			S	D			I	• Some visitors may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • The repository, road, and railroad will be visible from within the park, but significant contrasts occur looking from the Canyonlands National Park boundary to the site within Davis Canyon. • There should be no perceptible visibility impacts in the park due to repository air pollution.
Viewing Wild Animals[d]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Low Noise Habitat, Human Presence	S	S	S				I	• Perceptible impacts may result if noise from blasting causes animals to alert and run. Blasting noise may be heard throughout the park during shaft and tunnel blasting. • The equipment noise will be audible at the park boundary in Davis Canyon. • Some visitors may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • There should be no visibility impacts in the park due to repository air pollution.
Viewing Indian Ruins[d]	●	●	●	●	●	●	●	●	●	●	●	●	Access, Quality of Ruin			S		I		I	• Some visitors may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Increased visitation is expected to have minimal impacts on resources within the Salt Creek Archaeological District. • Indian ruins would not be affected because air pollutants are below NAAQS secondary standards designed to protect such resources.
Viewing from Scenic Overlooks[d]	●									●			High Visibility[e], Visual Contrast			S	D		D	I	• Some visitors may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Rail line construction activities may be visible from Grand View Point. • Night sky brightness would be increased during periods of greatest site activity. • Visitors to Davis Canyon may experience occasional visibility impairment from site activity.
Viewing the Colorado River[d]	●									●	●	●	High Visibility[e], Low Noise	S		S	D				• Blasting noise may be heard by visitors viewing the river from overlooks during the initial construction period. • Some visitors may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Although not in the park, river-runners launching at Moab would pass under the bridge construction.
Getting Away from People[d]	●	●	●	●	●	●	●	●	●	●	●	●	No Audible Equipment Noise, Low Human Contact[e], Access, Solitude, Undeveloped	S	S	S	S		D	I	• Blasting noise may be disturbing to visitors seeking solitude. Blasting would occur during the initial construction period and would be audible throughout much of the park. • Equipment noise will be audible in Davis Canyon near the park boundary in an area that is not highly visited. • Delays in gaining access to the park may be disturbing to Needles District visitors seeking solitude. • Visible facilities may be disturbing to visitors to Davis Canyon, and the elevated areas around it, who are seeking solitude. • Night sky brightness would be increased during periods of greatest site activity and may disturb those on high ground looking toward the site. • No visibility impairment in the park.

Table 5-49. Construction Phase - Significance of Physical Environmental Impacts on In-Park Activities (Page 2 of 3)

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]: Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River	Environmental Factors Associated with the Activity	Repository Construction Phase Impacts: Audible Blasting Noise	Audible Mechanical Noise	Delay in Gaining Access	Construction Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	Areas of the Park Where the Activity may be Affected and its Significance to Park Users
Hiking Off the Trail[a]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise[e], Low Human Contact[e]	S	D	S	I				• Blasting noise may disturb hikers. Blasting would occur during the initial construction period and would be audible throughout much of the park. • Hikers in Davis Canyon passing by the site would hear equipment noise. • Hikers in Davis Canyon passing by the site would see the facility. • Some hikers may be disturbed by delays in getting to the Needles District until the exclusive access road is built.
Hiking on Marked Trail[a]	●	●								●	●		Moderate Noise, Human Contact[e]	S		S					• Blasting noise may disburb hikers. Blasting would occur during the initial construction period and would be audible throughout much of the park.
Rock Climbing[a]	●	●	●	●				●		●	●	●	Low Noise, Human Contact[e]	S	D	S					• Blasting noise may disturb rock climbers seeking solitude. Blasting would occur during the initial construction period and would be audible throughout the park. • Equipment noise should not be audible beyond the park boundary except in Davis Canyon. • Rock climbers may be disturbed by delays in getting to the Needles District until the exclusive access road is built.
Viewing the Stars[e]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Low Noise, Low Night Sky Glow		D			D	I		• Equipment noise should not be audible to persons viewing the stars in the park except at the park boundary in Davis Canyon. • Night sky brightness at the horizon should not inhibit overhead viewing in the park • Visibility impairment would be imperceptible in the park.
Developed Camping Areas[b]	●												High Noise Level, Human Contact[b], Access		I	S			D		• Equipment noise from the repository will not be audible at Squaw Flat Campground. • Campers may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Night sky brightness would be increased at the horizon during periods of increased site activity, but should not inhibit star viewing overhead.
Semi-Developed Camping Areas[b]	●	●								●	●		Moderate Noise Level, Human Contact[b]		I	S			D		• Equipment noise from the repository will not be audible at any semi-developed campgrounds. • Campers may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Night sky brightness would be increased at the horizon during periods of increased site activity, but should not inhibit star viewing overhead.
Primitive Camping Areas[b]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise Level, Human Contact[b], Solitude		D	S			D	I	• Equipment noise from the repository would be audible in Davis Canyon within the park but not beyond. It has not been documented that visitors camp in this area. • Primitive campers may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Night sky brightness would be increased at the horizon during periods of increased site activity but should not inhibit star viewing overhead. • Visibility impairment would be imperceptible in the park.

Table 5-49. Construction Phase - Significance of Physical Environmental Impacts on In-Park Activities (Page 3 of 3)

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]													Environmental Factors Associated with the Activity	Repository Construction Phase Impacts							Areas of the Park Where the Activity may be Affected and its Significance to Park Users
	Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River			Audible Blasting Noise	Audible Mechanical Noise	Delay in Gaining Access	Construction Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	
River-Running[b]												●		High Noise Level, Low Human Contact[e]			S	D				• River-runners launching at Moab would experience some delays associated with the railroad bridge construction. • The construction activities associated with the rail line bridge construction would be visible to river-runners who pass beneath it. Most of the river-runners using the Colorado launch at Potash and this alternative shoud remain unaffected.
Four-Wheel Vehicle Driving on Designated Trails[b]	●	●	●	●	●	●	●			●	●			Moderate to High Noise Level, All Levels of Human Contact[b]	D	D	S	D				• Equipment and blasting noise would be audible to four-wheel vehicle users only when they stop their vehicles. • Four-wheel drive users may be disturbed by delays in getting to the Needles District until the exclusive access road is built. • Four-wheel drive users in Davis Canyon would see the repository.
Scientific Study[b]	●	●	●	●	●	●	●	●	●	●	●	●		Ecosystems, Geologic Formations, Archaeological Resources				D			I	• Possible increased park visitation may result in increased damage to archaeological resources. • Indian ruins would not be affected because air pollutants are below NAAQS secondary standards designed to protect such resources
Wilderness Experience[b]	●	●			●	●		●	●	●	●	●		Solitude, Low Noise, Low Human Contact, Undeveloped	S	S	S	S		D	I	• Blasting noise may be disturbing to visitors seeking solitude. Blasting would occur during the initial construction period and would be audible throughout much of the park. • Equipment noise will be audible in Davis Canyon near the park boundary in an area that is not highly visited. • Delays in gaining access to the park may be disturbing to Needles District visitors seeking solitude. • Visible facilities may be disturbing to visitors to Davis Canyon, and the elevated areas around it, who are seeking solitude. • Night sky brightness would be increased during periods of greatest site activity and may disturb those on high ground looking toward the site. • No visibility impairment in the park.

Sources:
(a) Davidson-Peterson Associates, Inc., and PBQD, 1978.
(b) NPS, 1984.
(c) Mintzmyer, 1981.
(d) NPS, 1978.
(e) Assumption.

Explanation
A blank in the Site Characterization Impacts column indicates factor is not important to the in-park activity.
● Indicates potential for a particular in-park activity being performed within selected areas of the park based on references a, b, c, and d.

I - Insignificant (immeasurable, with no consequence).
D - Detectable (measurable, with little or no consequence).
S - Significant (measurable, with possible consequence).

the State or other major national attractions in the vicinity of the repository. To date, the evidence has not shown that the presence of a Utah facility perceived as hazardous has lessened the attractiveness of the State, or the Wasatch region of the State, as a tourist destination. Tooele Army Depot is less than 64 kilometers (40 miles) from Utah's major ski areas and 32 kilometers (20 miles) from Salt Lake City. In 1981, it received considerable national press coverage as the storage site of the largest cache of chemical weapons in the free world. At the time the Department of Defense and the State of Utah were embroiled in a controversy concerning the shipment of "Weteye" nerve gas bombs from Denver to Tooele (The New York Times, 1981 a,b). Despite the controversy and media attention, recreational visits to national parks in Utah were not adversely affected (NPS, 1983). In addition, Timpanogos Cave National Monument, (about the same distance from Tooele Army Depot as Arches National Park is from Davis Canyon), had 107,000 visitors in 1980, 104,500 visitors in 1981, and 104,600 in 1982 (NPS, 1983; Bureau of Business and Economic Research, 1983).

Based on the "Weteye" experience, it is not expected that the other major parks such as Natural Bridges, Lake Powell, Monument Valley, and Arches National Park of the Canyonlands travel region will be less attractive as primary destinations. Canyonlands National Park, however, may be less attractive as a primary destination for some tourists because of the environmental impacts and other impacts associated with the facility's proximity to the park. If this occurs, there could be associated economic impacts.

The analysis of potential economic impacts resulting from repository construction activities compares losses to the retail and service sectors from tourists who might not stay in the area to gain in these sectors from construction worker expenditures. It assumes several conservative case scenarios concerning park avoidance, tourist displacement, economic displacement, project purchases outside the region and project worker wages spent outside the two-County study area. These assumptions were used whenever empirical data were not available concerning probable human behavior. For example, Baker et al., (1980) have presented empirical evidence that the construction of nuclear power plants adjacent to state beaches did not contribute to a significant reduction in beach use. This does not mean that there was no drop in visitation from the types of users who formerly were attracted to these parks. It is possible that park visits by project-related users hoping to see the plant construction counterbalanced this loss.

It can be expected that there will be project visitors who will also visit Canyonlands. Whether they will counterbalance any losses in park visitation by the types of visitors currently drawn to the park cannot be reliably predicted at present. Such insights will not be available until monitored data from site characterization activities are evaluated. This means that when projecting the impacts of Canyonlands National Park visitors on the local economy, the conservative approach would be to look at the potential losses attributed to current visitors without considering any added expenditures by project visitor.

Section 3.5.2.4.1 suggests that in the future 5.4 percent of retail and service sector sales would be directly attributed to river-runners and visitors who have Canyonlands National Park as their primary destination. If the repository construction activities make the park less attractive to these visitors, some of them may avoid the area and a portion of this amount would be lost.

Another area of potential economic loss is hotel and motel accommodations for tourists. These individuals would not be able to spend additional money in the local retail and service sectors if they were displaced from hotels and motels. If project workers are renting motel rooms that would normally be used by tourists, then these tourists might also avoid the region. This would affect the level of tourist expenditures for food, lodging, entertainment, and other retail services and transportation which are provided locally. Using the Intermountain Power Plant (IPP) experience as a guide, eight percent of the total in-migrating work force might stay in motel rooms. IPP, which is in Millard County, Utah, had a peak work force of 434 individuals in 1982. At that time eight percent of its in-migrating work force stayed in motel rooms (Paul Nelson Associates, Inc., 1982). If eight percent of the park repository construction work force (1590) is used, and it is assumed that workers are not sharing rooms, then about 200 rooms would not be available for tourists during the tourist season. A loss of

200 rooms for tourists would result in a loss of 4 percent of the two-County retail and service sector sales to tourists (see Section 3.5.2.4). This assumes that there are 2.6 persons per tourist party, 2 nights accommodation per party, a tourist season of 275 days, and expenditures of $33.95 per tourist (Hunt and Cadez, 1981).

During the time when these negative impacts could be the greatest there would also be positive economic impacts resulting from expenditures made in the local economy by repository construction workers. This means that there would be worker purchases at the local restaurants, motels, hotels, food stores, gas stations, and other retail and service establishments considered to be part of the tourist economy. The tourist-oriented businesses that would benefit least from project worker purchases would be those which deal in specialty items and services for sale or rent to tourists.

The following limiting assumptions were made to calculate worker expenditures in the local retail and service sector:

1. The average wage would be $28,000 (1981 dollars).

2. No local purchases for durable goods such as furniture, automobiles, etc. would be made in Grand or San Juan Counties.

3. The rate of local expenditures for nondurable goods and services would equal the United States average of 36 percent of wages (Bureau of the Census, 1983, PHC80-52-46).

4. The expenditures by single workers would not be included because a substantial portion of wages earned by weekly commuters would be sent to the region of their permanent residence.

5. Twenty-five percent of the construction phase workers would be single workers (see Table 5-37).

6. The average work force size would be 1,130 workers (see Figure 5-8).

With these conservative assumptions, workers would account for about 15 percent of the retail and service sector sales. A 15 percent gain should offset the potential losses presented in the above analysis. Section 5.4.2 provides a further analysis of economic impacts to the local economy.

Therefore, even if no assumptions are made about the amount spent in the local economy by weekly commuters and singles or project visitors drawn to the area, and no assumptions are made about the purchases by the project for oil, gas, and other nondurable goods and services, the local economy should still experience a net gain in the retail and service sectors. However, losses to specialized tourist businesses could occur if tourists avoid the Canyonlands National Park or if tourists cannot find hotel or motel accommodations in the area.

5.5.1.2.3 Repository Operation Impacts on Users of Canyonlands National Park. Section 5.5.1.2.1 describes the recreational and scientific resources available in the vicinity of the repository facility. The following analyses address how the repository operations phase may affect recreational, scientific, and educational opportunities in the park.

Repository Operation Effects on Recreationists. The physical environmental impacts during the operation phase are somewhat lessened because there would be no more blasting. Otherwise the magnitude of the physical impacts will be similar to those listed in Section 5.5.1.2.1. Park users activities which may be affected by repository operations can be found in other unaffected areas of the park (see Table 5-50).

The importance of repository operations impact on the perceived experience of the park visitor may be slightly different. The reason is that during the operations phase nuclear waste will be at the site. Some potential visitors may question whether the park is safe

Table 5-50. Operations Phase - Significance of Physical Environmental Impacts on In-Park Activities

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]												Environmental Factors Associated with the Activity	Repository Operation Phase Impacts					Areas of the Park Where the Activities may be Affected and its Significance to Park Users
	Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River		Audible Mechanical Noise	Operation Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	
Viewing Rock and Desert Formations[d]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Visual Contrast		D			I	• The repository rail line would be visible although it would not constitute a significant contrast. The facility would be visible from Davis Canyon in the park and this would constitute a significant contrast. Visitors driving to the park on Utah 211 would see the facility for a short period. • No visibility impairment in the park.
Viewing Wild Animals[d]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[e], Low Noise Habitat, Human Presence	D				I	• Equipment noise may be audible to birds and land animals in a portion of Davis Canyon in the park. • No visibility impairment in the park.
Viewing Indian Ruins[d]	●	●	●	●	●	●	●	●	●	●	●	●	Access, Quality of Ruin					I	• No delays in gaining access. • No visibility impairment in the park, and air pollution emissions will have an insignificant impact on these resources because the maximum levels are below the NAAQS for the protection of such resources.
Viewing from Scenic Overlooks[d]	●									●			High Visibility[e], Visual Contrast	I	D			I	• Equipment noise will not be audible from scenic overlooks in the park. • The rail line will be visible from some scenic overlooks in the park. • No visibility impairment in the park.
Viewing the Colorado River[d]	●									●	●	●	High Visibility[e], Low Noise	I				I	• Equipment noise will not be audible at Colorado River Overlooks. • No visibility impairment in the park.
Getting Away from People[e]	●	●	●	●	●	●	●	●	●	●	●	●	No Audible Equipment Noise, Low Human Contact[e], Access, Solitude, Undeveloped	S	S		D	I	• Equipment noise would be audible in a small portion of Davis Canyon in the park. This could interfere with solitude. • Visible facilities may be disturbing to visitors to Davis Canyon, and the elevated areas aroud it, in the park and to persons seeking to get away from civilization who drive to the Needles District. • Night sky glow is expected to be no greater from viewpoints in the park than would be present at the horizon in the park from Moab. • No visibility impairment in the park.
Hiking Off the Trail[d]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise, Low Human Contact[e]	D	I				• Equipment noise might be disturbing to the few hikers that may want to use the small portion of Davis Canyon where the noise would be audible. • Hikers on the Davis Canyon could see the facility.
Hiking on Marked Trail[d]	●	●								●	●		Moderate Noise, Human Contact[e]	I	I				• Equipment noise will not be audible at marked trails. • The facility will not be visible from marked trails.

Table 5-50. Operations Phase - Significance of Physical Environmental Impacts on In-Park Activities (Page 2 of 2)

In-Park Activities	Areas of the Park Where Activities are Available[a,b,c,d]												Environmental Factors Associated with the Activity	Repository Operation Phase Impacts					Areas of the Park Where the Activities may be Affected and its Significance to Park Users
	Needles District (Except Salt Creek Archaeological District)	Salt Creek Archaeological District	Upper Davis Canyon	Upper Lavender Canyon	East Fork Salt Creek Canyon	West Fork Salt Creek Canyon	Horse Canyon	Squaw Canyon	Lost Canyon	Island-in-the-Sky District	Maze District	River		Audible Mechanical Noise	Operation Activities Visible	Disturbance of Archaeological Resources	Night Sky Glow Visible	Air Quality Effects on Visibility	
Rock Climbing[d]	●	●	●	●				●		●	●	●	Low Noise, Human Contact[b]	D	D				▪ Rock climbers in Davis Canyon near the facility might hear audible equipment noise. ▪ Rock climbers going to elevated areas around Davis Canyon could see the facility.
Viewing the Stars[d]	●	●	●	●	●	●	●	●	●	●	●	●	High Visibility[d], Low Noise, Low Night Sky Glow	D			D	I	▪ Equipment noise would be audible in a small portion of Davis Canyon in the park. ▪ Night sky glow is expected to be no greater from viewpoints in the park than would be present from sky glow at Moab. ▪ No visibility impairment in the park for overhead star viewing.
Developed Camping Areas[b]	●												High Noise Level, Human Contact[b], Access	I			D		▪ Equipment noise would not be audible at Squaw Flat Campground. ▪ Night sky glow is expected to be no greater from viewpoints in the park than would be present from sky glow at Moab.
Semi-Developed Camping Areas[b]	●	●								●	●		Moderate Noise Level, Human Contact[b]	I			D		▪ Equipment noise would not be audible at semi-developed campgrounds such as Peekaboo Spring. ▪ Night sky glow is expected to be no greater from viewpoints in the park than would be present from sky glow at Moab.
Primitive Camping Areas[b]	●	●	●	●	●	●	●	●	●	●	●	●	Low Noise Level, Human Contact[b], Solitude	D	D		D		▪ Equipment noise would be audible in a small portion of Davis Canyon in the park. It has not been documented that people camp in this area. ▪ Night sky glow at the horizon is not expected to be greater than the glow from Moab. ▪ Users of Davis Canyon would see the facility.
River-Running[c]												●	High Noise Level, Low Human Contact[c]		D				▪ River-runners launching at Moab would pass under the railroad bridge.
Four-Wheel Vehicle Driving on Designated Trails[b]	●	●	●	●						●	●		Moderate to High Noise Level, All Levels of Human Contact[b]						▪ Four-wheel drive users would hear equipment noise in the park in a small portion of Davis Canyon when they stop.
Scientific Study[b]	●	●	●	●	●	●	●	●	●	●	●	●	Ecosystems, Geologic Formations, Archaeological Resources			D			▪ Possible increased park visitation may result in increased damage to archaeological resources.
Wilderness Experience[b]	●	●			●	●		●	●	●	●	●	Solitude, Low Noise, Low Human Contact, Undeveloped	S	S		D	I	▪ Equipment noise would be audible from a small portion of Davis Canyon in the park. This could interfere with solitude. ▪ Visible facilities may be disturbing to visitors to Davis Canyon, and the elevated areas around it, and to persons seeking to get away from civilization who drive to the Needles District. ▪ Night sky glow is expected to be no greater from viewpoints in the park than would be present at the horizon in the park from Moab. ▪ No visibility impairment in the park.

Sources:
(a) Davidson-Peterson Associates, Inc., and PBQD, 1978.
(b) NPS, 1984.
(c) Mintzmyer, 1981.
(d) NPS, 1978.
(e) Assumption.

Explanation
A blank in the Repository Operation Phase Impacts column indicates factor is not important to the in-park activity.
● - Indicates potential for a particular in-park activity being performed within selected areas of the park based on references a, b, c, and d.

I - Insignificant (immeasurable, with no consequence).
D - Detectable (measurable, with little or no consequence).
S - Significant (measurable, with possible consequence).

because of a perceived risk of radioactive contamination. Those who believe it will disturb their experience may continue to avoid the areas of the park near the facility. Some of these persons may make decisions to avoid the park altogether.

Repository Operation Effects on Scientific and Educational Users. Operation phase impacts should not inhibit continued scientific inquiry and discovery in the park. Wilderness education groups may not want to go to Davis Canyon. Because these groups promote the tangible and intangible aspects of a wilderness experience, some of the groups may believe the operation activities would be an unacceptable intrusion - even if the physical experience remains unaffected. Some groups may continue to seek areas of the park further away from the site, while others may continue to avoid the park as long as potentially disruptive activities are present.

5.5.1.2.4 Potential Repository Operation Impacts on Tourist Sectors of the Economy. Unlike the repository construction phase where temporary workers were expected to displace some of the tourists from hotel and motel accommodations, the operation phase will require a less transitory work force. This should reduce the economic losses from displaced tourists. The sales attributed to river-runners and visitors who have Canyonlands National Park as their primary destination are estimated to be about 5.4 percent of future retail and service sales (see Section 3.5.2.4.1).

The only difference between the construction phase and the operation phase analysis of worker expenditures is that 20 percent of the workers were estimated to be singles during the operation phase and the average size of the work force would be 1,000 (see Section 5.5.1.2.2). This would result in operation phase purchases equal to 14 percent of the sales in the local retail and service sectors. The gains from worker expenditures would be larger than the potential losses analyzed above. However, tourist-oriented businesses which deal in speciality items and services for sale or rent to tourists would probably benefit the least from these expenditures.

5.5.1.2.5 Repository Isolation Effects on Users of Canyonlands National Park. Section 5.5.1.2.1 describes the recreational and scientific resources available in the vicinity of the repository facility. The following sections address the effect of repository isolation on recreational, scientific and educational opportunities in the park.

Repository Isolation Effects on Recreationists. The decommissioning phase effects will be similar to the construction phase effects on park users. Some recreational users may feel less inhibited about visiting the park during the caretaker phase and after closure because repository activities will have been terminated and the nuclear material will have been isolated. Other potential visitors may continue to question whether the park is safe because of a perceived risk of radioactive contamination.

Repository Isolation Effects on Scientific and Educational Users. Scientific inquiry and discovery in the park will not be inhibited. If the repository site remains an attraction, then wilderness education groups may avoid using Davis Canyon for a wilderness experience. The rest of the park will remain available to provide a primitive experience.

5.5.1.2.6 Potential Repository Isolation Impacts on Tourist Sectors of the Economy. The decommissioning workers will have an economic impact on the local economy similar to the impact provided by the construction phase workers. The caretaker phase and closure of the facility will result in a reduction in the repository-related workers in the area. This would reduce the retail and service sector purchases by the facility and its workers. However earlier losses attributed to potential park visitors avoiding Canyonlands National Park are expected to be eliminated as the site is restored and safety concerns are reduced.

5.5.1.3 Summary of the Cumulative Impacts on Canyonlands National Park and Its Users

The significant sources of physical environmental impact during the repository construction phase on park users were identified as:

- Audible blasting noise
- Audible equipment noise
- Delays in gaining access to the park
- Visibility of the facility.

Each of these impacts has areal and temporal dimensions, and each can be addressed in terms of the activities it would most likely disturb.

Audible blasting noise will be heard periodically for several miles into the park. It could potentially diminish the enjoyment derived from several park activities, including viewing wild animals, viewing the Colorado River, hiking, rock climbing, and getting away from people for a wilderness experience (see Table 5-49). This temporary disturbance would be eliminated early in the construction phase when the shafts and tunnels have reached a sufficient depth.

Audible equipment noise in the park would be confined to a small portion of Davis Canyon on the eastern boundary to the park near the repository site. It is not documented that people seek out this portion of the park for a wilderness experience. However, there may be a few individuals who go there and they could find it disturbing.

Construction activities might create delays in gaining access to Davis Canyon and to the Needles District of the park. This could disturb visitors to the Needles District regardless of the activity they wished to engage in. This disturbance would be eliminated early in the construction phase with the development of the exclusive repository access road.

Finally the facility could be seen throughout the construction phase from the eastern boundary of the park near Davis Canyon and for a short stretch along Utah 211. Wilderness seekers who might view the facility from Davis Canyon or the mesa tops surrounding Davis Canyon could be disturbed by this visual intrusion.

Blasting noise and delays would be short-term impacts. Audible equipment noise and aesthetic impacts would last throughout the repository construction and operation phase, but would be limited to a small portion of the park in Davis Canyon where relatively few park visitors go. These physical environmental impacts would be reduced during the caretaker phase. After decommissioning, noise impacts would be eliminated and the visual impacts would be reduced. Site repository markers would remain to denote the presence of a nuclear waste repository a few thousand feet underground.

Throughout these phases, wilderness seeking and getting away from people would be the in-park activities most affected by the cumulative environmental changes related to the repository. Davis Canyon and the Mesa tops in the park surrounding the canyon are the areas where these changes will be evident. Despite these changes it is useful to note that visitors would continue to find unaffected wilderness areas in the park for all park activities. Figure 5-30 illustrates those areas of the park potentially affected by project activities and alternative area which can be used by park visitors. Tables 5-49 and 5-50 also indicate each area of the park where all recreation activities and experiences can take place undisturbed by project construction or operation.

While the tangible aspects of a primitive experience would not be affected, it cannot be predicted how education groups and wilderness seekers will respond to the presence of a facility. Some of them may think that the park or that area of the park near the facility can no longer provide the perceived intangible aspects of a primitive experience. It cannot be predicted how many of these park users will continue to come to this area of the park for a wilderness experience, how many will seek out the other numerous isolated areas in the park where a wilderness experience would be possible, or how many will avoid Canyonlands National Park as long as repository activities are taking place.

Even though this cannot be established, it was shown that based on the analysis of worker expenditures during construction and operation periods there should be a net gain for the retail and service sectors of the local economy. It was also noted that there could be losses

incurred by businesses which specialized in tourist-oriented items and services for sale or rent. During the repository isolation phase the reduction in the repository work force is expected to reduce the positive effect of their local expenditures, but losses attributed to park avoidance are assumed to be eliminated as the site is restored.

Overall it is judged by the DOE that cumulative physical environmental impacts for construction, operation, decommissioning, and isolation of a nuclear waste repository at the Davis Canyon site are acceptable and are not irreconcilable with respect to the park's physical features or its use.

5.5.2 Summary of Repository Impacts on the Davis Canyon Site

Repository development activities, including repository construction, operation, and decommissioning and closure, have the potential to cause various levels of repository-development impacts. The information in Table 5-51 is a summary of such impacts drawn from the text of Chapter 5.

The summary table identifies impacts that are projected or expected to occur and those not expected to occur during each phase of repository development. Impacts are discussed in terms of their duration, and intensity or significance. The use of mitigation measures is noted in determining intensity of the impact. As applicable, location of the impact is also identified.

Table 5-51. Summary of Repository Impacts

A. Repository Construction

Primary activities are as follows:

Development of offsite utility and transportation access corridors, development of onsite transportation and utility infrastructure, establishment of a water supply, site preparation and grading, construction and erection of repository surface facilities, development of shafts and subsurface facilities, storage of mined materials, transport of personnel, surface and subsurface use restrictions, and population in-migration.

1. Soils (Section 5.2.1.1)

   - About 189 hectares (467 acres) of soil to be modified and covered by surface facilities and onsite roads.

   - No significant impacts from salt contamination of soils expected. Use of engineered control measures, leak detection systems, and any necessary remedial action prevent significant soil impacts.

   - Some water and wind erosion of soils because restabilization of disturbed soils through revegetation and reestablishment of cryptogamic communities may be difficult.

2. Mineral Resources (Section 5.2.1.2)

   - Mineral and hydrocarbon resource development will be excluded from the 2,331-hectare (5,760-acre) controlled area, but is not expected to have a significant impact on resource development in the region because the resource potential of the site is low.

3. Surface-Water Quality (Section 5.2.2.1)

   - No significant impacts to surface-water quality; impact limited to local and temporary increases in sediment loads prior to completion of sediment ponds.

   - Project water requirements (about 0.01 percent of the average annual flow of the Colorado River) are likely to be met by San Juan County Water Conservancy District current allotments. The impact of repository demand in sparse water resources would be displacement of some other type of future development.

   - Impacts to flood levels and flows from encroachment of facilities on the 100-year floodplain to be offset by increased retention of runoff in sedimentation ponds; impacts are expected to be minor.

   - No significant degradation of water quality from windblown salt is expected, because expected salt deposition rates of less than 2 tons per year represent less than 0.5 percent of the Indian Creek drainage.

Table 5-51. Summary of Repository Impacts
(Page 2 of 14)

4. Ground-Water Quality (Section 5.2.2.2)

   - No significant drawdown interferences will occur in existing offsite wells because ground water will not be used for construction water supply.

   - No significant impacts to ground-water quality because repository design and monitoring measures (e.g., water seals, liners) will prevent hydraulic connection of aquifers.

   - Ground-water quality impacts from infiltration of precipitation through soils contaminated by windblown salt are expected to be minor due to low deposition of salt outside the construction area, low precipitation rate, and deep water table.

5. Land Use (Section 5.2.3.1)

   - Land required for the repository (2,333 hectares [5,760 acres]) withdrawn from the public domain and multiple uses restricted or prohibited.

   - Minor impacts to grazing; loss of grazing land represents only a small portion (2.5 percent) of the BLM Indian Creek grazing allotment. Access and utility corridors may traverse grazing lands. Cattle crossings near construction of rail and roadways to minimize impacts on use of grazing lands.

   - Insignificant salt-related impacts because the salt pile will be managed on site, and the majority of windblown salt particulates will be retained within the construction area.

   - No direct repository activities within dedicated lands; temporary impacts on access to nearby recreational areas (e.g., increased traffic and congestion) occurring during construction of repository access routes. Access through Davis Canyon will be maintained for hikers and four-wheel drive vehicles, if such access is acceptable to the Nuclear Regulatory Commission.

6. Terrestrial Biota (Section 5.2.4.1)

   - Minimal loss of plant community and small sedentary wildlife due to land clearing for repository and access routes. Temporary increase in competition for food and cover and subsequent mortality as bird and mammalian species move into adjoining habitat. Amount of loss not significant relative to existing sources.

   - Minor impacts to biota in proximity to construction areas from vehicle movements, increased noise, and human presence.

7. Aquatic Biota (Section 5.2.4.2)

   - Minor impacts on aquatic biota due to absence of aquatic communities in the site area and control of site runoff and discharges.

- Potential impacts to aquatic communities where either repository access road crosses Indian Creek.

8. Threatened and Endangered Species (Section 5.2.4.3)

   - Repository construction not expected to impact threatened or endangered species due to apparent absence of such species and their habitat at the site.

   - Construction of repository access and utility routes could potentially affect threatened or endangered species in the area including the peregrine falcon, bald eagle, black-footed ferret, Colorado squawfish, and two species of plants; surveys to be performed prior to construction and if necessary, mitigation measures taken, such as access rerouting, and scheduling of activities to avoid critical periods, to reduce impacts. The Spanish Valley Railroad route would have the lowest potential for impacts on threatened and endangered species of the routes assessed.

   - Potential impacts to Colorado squawfish minimized by drainage and erosion controls, railroad construction scheduling, and careful construction and selection of railroad crossings over the Colorado River.

9. Air Quality (Section 5.2.5.1)

   - Concentrations of air pollutants from facility construction projected to be less than NAAQS.

   - Significant but temporary increases in TSP/NO_2 will be detectable in the park.

   - Negligible wind erosion of salt pile due to natural crusting or covering of the pile.

   - Insignificant impact on visibility in Canyonlands National Park because visual range and visual contrast changes due to construction emissions are not perceptible.

10. Aesthetic Resources (Section 5.2.6.1)

   - Significant visual impacts during facility siting and construction as viewed from the Davis Canyon jeep trail and Utah 211. Impacts viewed from Bridger Jack Mesa Wilderness Study area and from Canyonlands National Park will be insignificant. Not one analyzed key observation point in either protected area will be affected, because the activities will not be visible from these points.

   - Visible portions of the alternative rail and road access routes cause significant visual impacts on key observation points due to their projected visual contrast with the surrounding landscape.

Table 5-51. Summary of Repository Impacts
(Page 4 of 14)

11. Noise (Section 5.2.7)

- Significant noise impacts at Newspaper Rock State Historical Monument, up to 24 kilometers (15 miles) into Canyonlands National Park; under prevailing wind conditions, and at Bridger Jack Mesa WSA during blasting or the peak noise periods of repository construction.

- Temporary noise impacts from surface blasting at the site occurring over a period of 6 to 12 days.

12. Cultural Resources (Section 5.2.8.1)

- No significant impacts expected at the site because no cultural sites eligible for National Historic Register listing were found on site; potential indirect impacts on unrecorded sites will be mitigated in accordance with agreements being developed through continuing consultations between the DOE and the Advisory Council on Historic Preservation.

- Significant direct impacts may occur to the numerous recorded cultural sites within 0.8 kilometer (0.5 mile) of either side of the alternative corridors during construction of the railroad, road, and utility lines. Noise from construction of a Utah 211 bypass around Newspaper Rock State Historical Monument may significantly affect this National Historic Register property for up to 9 months.

- Potential for indirect impacts from increased use and vandalism is great, but can be mitigated by a combination of worker education and increased enforcement efforts developed in consultation with the Utah SHPO, BLM, and the Advisory Council on Historic Preservation.

13. Transportation (Section 5.3.3)

- Significant, but temporary, increases in traffic on Utah 211. Increased project-related traffic on Utah 211, only during the first year of repository construction, during completion of Utah 211 upgrading or construction of the new exclusive-use repository access route.

- Temporary increase in predicted highway accidents and resulting injuries prior to completion of Utah 211 upgrading or construction of the exclusive-use repository access route.

- Minor increases will occur in rail traffic to Potash area for delivery of construction materials and equipment; upon completion of rail line, access rail lines will deliver some equipment and materials prior to operation, thus reducing peak truck traffic to the site.

Table 5-51. Summary of Repository Impacts
(Page 5 of 14)

14. Utilities (Section 5.3.4)

- No adverse impacts on utility systems expected because existing utilities will be sufficient to handle construction needs.
- No impacts on existing waste treatment facilities expected, because waste treatment will be handled on site.

15. Salt Management and Disposal (Section 5.2.10)

- Minimal impact from windblown salt deposition, expected to be 1.0 kilogram per hectare (0.9 pound per acre) per year at 0.8 kilometer (0.5 mile) producing minimal impacts because most of it will remain in the controlled area.
- Potential degradation of soils or water quality of Salt Creek and Indian Creek by windblown salt, small impact because offsite deposition is insignificant and runoff to Indian Creek will contain less than 0.5 percent of its existing salt load.
- Minor changes in ground-water quality due to infiltration of precipitation through soils contaminated by spilled or windblown salt due to controls placed on surface handling of salt and resulting small amounts of salt available for infiltration.
- Windborne salt deposition impacts on native terrestrial ecosystems expected to be insignificant because the majority of salt deposition will be within the controlled area.
- Impacts resulting firm accidental transportation spills on land will be localized and short-term due to implementation of emergency cleanup procedures.

16. Population (Section 5.4.1)

- Approximately 4,690 in-migrating workers and families are expected to be present during peak construction.
- No relocation of residents expected.
- Expected increases in population due to in-migration: Moab, 30 percent; Monticello, 50 percent; and Blanding, 20 percent.

17. Employment (Section 5.4.2.1.1)

- At the peak of construction, the repository will generate a total of 1,590 direct and 480 indirect employment opportunities; about 150 of these jobs are expected to be filled by local residents.
- Possible reduction in labor supplies for other sectors of the local economy.

18. Economic Activities (Section 5.4.2.2.1)

    - Increase in area business activity; local purchases related to construction of the repository estimated to be about 23 million dollars per year.

    - Potential losses to tourist oriented businesses which specialize in souvenirs.

19. Community Services (Section 5.4.3)

    - Possible need for over 1,660 additional housing units for project-related workers and families.

    - Requirement of additional personnel and equipment for fire protection, police protection, health services, water treatment, sewage treatment, social services, and solid waste disposal at Moab, Blanding, and Monticello.

    - Need for new landfills for all communities.

    - Need for additional classroom space in Moab, Blanding, and Monticello.

    - Need for new streets, and sewer and water lines for new housing developments in Moab, Blanding, and Monticello.

20. Social Conditions (Section 5.4.4)

    - Some stress-related social problems such as alcoholism, drug dependence, mental illness, and suicide normally associated with boomtown growth.

21. Fiscal Conditions (Section 5.4.5.1)

    - Both revenues and expenditures will increase; however, there may be a problem with front-end financing of new community infrastructure and services.

22. Government Structure (Section 5.4.5.2)

    - Need for additional staff and technical expertise by local government units.

B. Repository Operation

Primary activities are as follows:

Transport and handling of nuclear wastes, other surface facilities operations, salt storage and transportation, water and energy use, transport of personnel and nonwaste materials to and from the site, surface and subsurface use restrictions, and population in-migration.

Table 5-51. Summary of Repository Impacts
(Page 7 of 14)

1. Soils (Section 5.2.1.1.2)

   - Control measures designed to stabilize soils reduce erosion rates to near predisturbance levels.

   - Use of engineered control measures and leak detection systems under the lined storage sites to prevent significant impacts from soil contamination due to leaching or runoff.

   - Deposition of windborne salt expected to be insignificant beyond the site boundary.

2. Mineral Resources (Section 5.2.1.2)

   - No significant impact of continued exclusion of resources within the controlled area from development.

3. Surface-Water Quality (Section 5.2.2.1.2)

   - No degradation of water quality in Indian Creek due to control measures implemented as part of operating procedures.

   - Because the projected windblown salt emissions are low, no significant increase in salinity to Indian Creek or Salt Creek expected.

4. Ground-Water Quality (Section 5.2.2.2.2)

   - No significant disruption of ground-water flow patterns because no ground water will be used.

   - Insignificant impacts on ground-water quality due to low levels of wind-deposited salt on site.

5. Land Use (Section 5.2.3.2)

   - Land required for repository (2,333 hectares [5,760 acres]) to remain withdrawn from public domain.

   - Loss of grazing area for the repository represents only 2 percent of the BLM Indian Creek grazing allotment, about 7 percent of the AUMs estimated in Davis Canyon.

   - Direct impacts on access and visitation to recreation and dedicated lands would be minor from the potential exclusive-use access route to the repository; the potential Utah 211 upgrade alternative would cause delays and inconvenience at peak time of construction.

Table 5-51. Summary of Repository Impacts
(Page 8 of 14)

6. Terrestrial Biota (Section 5.2.4.1.2)

   - Minor disturbance to wildlife from vehicular activities, noise, lights, and increased human presence in areas adjacent to the surface facilities.

   - The influx of repository workers increasing the hunting of wildlife.

   - Vegetation impacts from windblown salt immediately adjacent to the salt pile. During operations some wildlife habitat regained on reclaimed areas of rights-of-way and on landscaped portions of the repository.

7. Aquatic Biota (Section 5.2.4.2.2)

   - No significant impacts on aquatic biota expected Davis Canyon contains no aquatic habitat. Measures to reduce water contamination to protect water quality of Salt Creek and Indian Creek.

   - No expected impacts to aquatic biota in Indian Creek or the Colorado River from salt deposition; negligible deposition rates 1.6 kilometers (1 mile) from the site.

8. Threatened and Endangered Species (Section 5.2.4.3.2)

   - No impacts to threatened or endangered species from repository operations due to apparent absence of such species and their habitat at the site.

   - Possible withdrawal of water from the Colorado River and the presence of endangered species in the river would require consultation with the Fish and Wildlife Service regarding potential impacts. No significant changes in river flow, sediment level, or salinity that would affect threatened or endangered species in the Colorado River will result from operational activities.

9. Air Quality (Section 5.2.5.2)

   - Wind erosion of the salt pile will be negligible due to natural crusting or covering of the pile and small working face.

   - Particulate and gaseous NO_x emissions meet NAAQS requirements; no significant effect to air-quality-related values.

   - No significant effect to visibility in Canyonlands National Park from repository operations because visual range reduction and visual contrast changes from air pollutants will be below limits of perceptibility.

Table 5-51. Summary of Repository Impacts
(Page 9 of 14)

10. Aesthetic Resources (Section 5.2.6.2)

- A significant visual impact from repository operations activities from limited areas at the eastern boundary of Canyonlands National Park, the Davis Canyon Jeep Trail, and Utah 211. Onsite activities are not visible from other key observation points.

- The Kane Springs rail access routes, representing the least visual impact, have two significant long-term impacts.

11. Noise (Section 5.2.7.3)

- Significant noise impacts (greater than 20 dB) from repository traffic at Newspaper Rock State Historical Monument if this access route option is chosen.

- Significant localized noise impacts at Bridger Jack Mesa WSA and at the Canyonlands National Park boundary nearest the site during two daily train passes (one round trip) for 2 to 4 hours per day. The noise increase of the park boundary may be comparable to the 20 to 25 dBA disturbance from existing commercial airline overflights that occur every 1 to 3 hours daily.

12. Cultural Resources (Section 5.2.8.2)

- No direct impacts to sites listed in the National Register unless road access is along an upgraded Utah 211, one of two repository access options.

- Indirect impacts to archaeological sites proportional to increased visitor and worker use of the area.

13. Nuclear Waste Transport (Section 5.3.1)

- Estimated radiological health effects from nuclear waste transport are expected to result in less than one (assumes 100 percent rail transport) to 9.5 (assumes 100 percent truck transport) latent cancer fatalities to present and future generations.

- Estimated nonradiological fatalities resulting from traffic accidents range from 2.2 (100 percent rail) to 35 (100 percent truck).

- The regional maximum individual exposure values range from 1 to 4 millirem per year, or about 0.6 to 3 percent of background.

14. Transportation (Section 5.3.3)

- Traffic impacts during operation will include increased traffic on Utah 211 and U.S. 191, with increased congestion at their intersection during peak hours. Although truck traffic is expected to be significant, driving speeds on local routes will not be substantially diminished after upgrading of Utah 211 or constructing the exclusive-use access road.

- Up to 19 additional highway accidents and less than one fatality per year are estimated to result from the traffic increase over the routes considered.

15. Utilities (Section 5.3.4)

- No significant impacts to utility systems because existing utility capacities are expected to be sufficient to handle operational needs.

- No impacts on waste treatment facilities because waste treatment will be handled on site.

16. Salt Management and Disposal (Section 5.2.10)

- Windblown salt deposition, expected to be 1.0 kilogram per hectare (0.9 pound per acre) per year at 0.8 kilometer (0.5 mile) producing minimal impacts because most of it will remain in the controlled area.

- Potential degradation of soils or water quality of Salt Creek and Indian Creek by windblown salt, small impact because offsite deposition is insignificant and runoff to Indian Creek will contain less than 0.5 percent of its existing salt load.

- Minor changes in ground-water quality due to infiltration of precipitation through soils contaminated by spills or windblown salt due to controls placed on surface handling of salt and resulting small amount of salt available for infiltration. Windblown salt deposition impacts on native terrestrial ecosystems expected to be insignificant because the majority of salt deposition will be within the controlled area.

- Impacts resulting from accidental transportation spills on land will be localized and short-term due to implementation of emergency cleanup procedures.

17. Population (Section 5.4.1)

- During the peak of operations a total of 3,730 in-migrants will be present.

18. Employment (Section 5.4.2.1.2)

- During operations, a peak of 2,070 direct and indirect jobs to be generated by the repository; estimated total of 400 local direct and indirect jobs at this time.

19. Economic Activity (Section 5.4.2.2.2)

- Continuance of local economic activity from purchases by the work force for personal goods and services.

20. Community Services (Section 5.4.3)

    - Most of the additional community infrastructure needed will have been built during the operation phase.

21. Social Conditions (Section 5.4.4)

    - Operation work force will become a long-term part of the community and, therefore, is likely to be better able to assimilate into existing lifestyles.

22. Fiscal Conditions (Section 5.4.5.1)

    - Increase in property tax revenues due to projected increase in home ownership.

    - Continuance of grants-equal-to-tax payments.

23. Government Structure (Section 5.4.5.2)

    - Need for additional staff and technical assistance continues.

C. Repository Decommissioning and Closure

Primary activities are as follows:

Dismantling of surface facilities, shaft backfilling, site regrading and revegetation, transport of personnel and materials to, from, and at the site, and population out-migration.

1. Soils (Section 5.2.1.1.3)

    - Temporary increase in soil erosion rates as a result of regrading and restoration of site to original contours. Site restoration to BLM specification ultimately reducing erosion rates to preconstruction levels.

    - Reduction in erosion rates to preconstruction levels by reclamation efforts.

2. Mineral Resources (Section 5.2.1.2)

    - No significant impact from continued exclusion of mineral and hydrocarbon resource development in the controlled area.

3. Surface-Water (Section 5.2.2.1.3)

    - Temporary increase in suspended sediments in Indian Creek as a result of regrading; however, no significant impacts on surface-water resources are expected because sediment runoff will be retained on site and soil stabilization procedures will be implemented.

Table 5-51. Summary of Repository Impacts
(Page 12 of 14)

4. Ground Water (Section 5.2.2.2.3)

   - Minimal impacts to ground-water systems because surface sources of contamination will be removed from the site.

5. Land Use (Section 5.2.3.3)

   - Permanently restriction of land in Davis Canyon for single-purpose use.

6. Terrestrial Biota (Section 5.2.4.1.3)

   - Continued human activities in the area will be disturbing to some wildlife until the end of decommissioning.

   - Reclamation and revegetation to restore wildlife habitats and wildlife repopulation of area; a gradual return of extirpated wildlife to the site will begin.

7. Aquatic Biota (Section 5.2.4.2.3)

   - Temporary increases in turbidity and sediment loads until revegetation is complete. Reclamation and revegetation to ultimately stabilize soils of disturbed areas to decrease erosion potential.

8. Threatened and Endangered Species (Section 5.2.4.3.3)

   - No expected adverse impacts to threatened and endangered species during decommissioning.

9. Air Quality (Section 5.2.5.3)

   - No impacts expected to exceed those modeled for repository construction.

10. Aesthetic Resources (Section 5.2.6.3)

    - No additional impacts; dismantling of repository structures and grading and revegetating the landscape to blend with surrounding topography.

    - Aesthetic impacts of postclosure monuments or markers depending on design and type of passive prevention barrier selected.

11. Noise (Section 5.2.7.3)

    - No noise impacts expected to exceed those identified for repository construction.

12. Cultural Resources (Section 5.2.8.3)

    - No direct impacts because no additional land will be disturbed.

Table 5-51. Summary of Repository Impacts
(Page 13 of 14)

13. Transportation (Section 5.3.3)

- Traffic congestion, road maintenance, and accident rates will be similar to operation since work force requirements are about the same.

- Minor rail traffic requirements and associated impacts significantly less than during operation.

14. Utilities (Section 5.3.4)

- No additional impacts on utility systems.

15. Population (Section 5.4.2)

- Out-migration of singles and families would occur if alternative employment opportunities are not developed at the end of the operation phase and at the end of decommissioning.

16. Employment (Section 5.4.2.1.3)

- Decline in area employment at the end of the operation phase and at the end of decommissioning.

17. Economic Activities (Section 5.4.2.2.3)

- Decline in demand for secondary goods and services as repository employment declines during the caretaker phase, followed by increased employment and purchases during the decommissioning phase.

- Some housing vacancies and an associated decrease in local residential property values due to decline in employment during the caretaker phase. Decommissioning may create added demands on the available local housing.

18. Community Services (Section 5.4.3)

- Possible excess supply or capacity of housing and community services due to out-migration caused by decline in repository employment at the end of the operation phase and at the end of decommissioning.

- Population growth associated with decommissioning may create additional demands for services.

19. Social Conditions (Section 5.4.4)

- Possible social problems associated with unemployment unless alternative measures to decrease unemployment associated with the caretaker period and closure are implemented.

- Decommissioning may bring about boom town social impacts.

Table 5-51. Summary of Repository Impacts
(Page 14 of 14)

20. Fiscal Conditions (Section 5.4.5.1)

- Decrease in both revenues and expenditures during the caretaker period and after closure of the facility.
- Increase in both revenues and expenditures during the decommissioning phase.

21. Government Structure (Section 5.4.5.2)

- Additional staff and technical expertise may be required by local government units during and after decommissioning.

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5.6.2 Federal Regulations and Statutes and Executive Orders

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30 CFR Part 57, Safety and Health Standards - Metal and Non-metal Underground Mines, revised July 1, 1984.

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Mine Safety and Health Act of 1977, 30 USC Secs. 801 et seq.

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5.6.3 State of Utah Laws

Utah Air Regulations, Section 1.1.75, Major Sources, State Air Laws.

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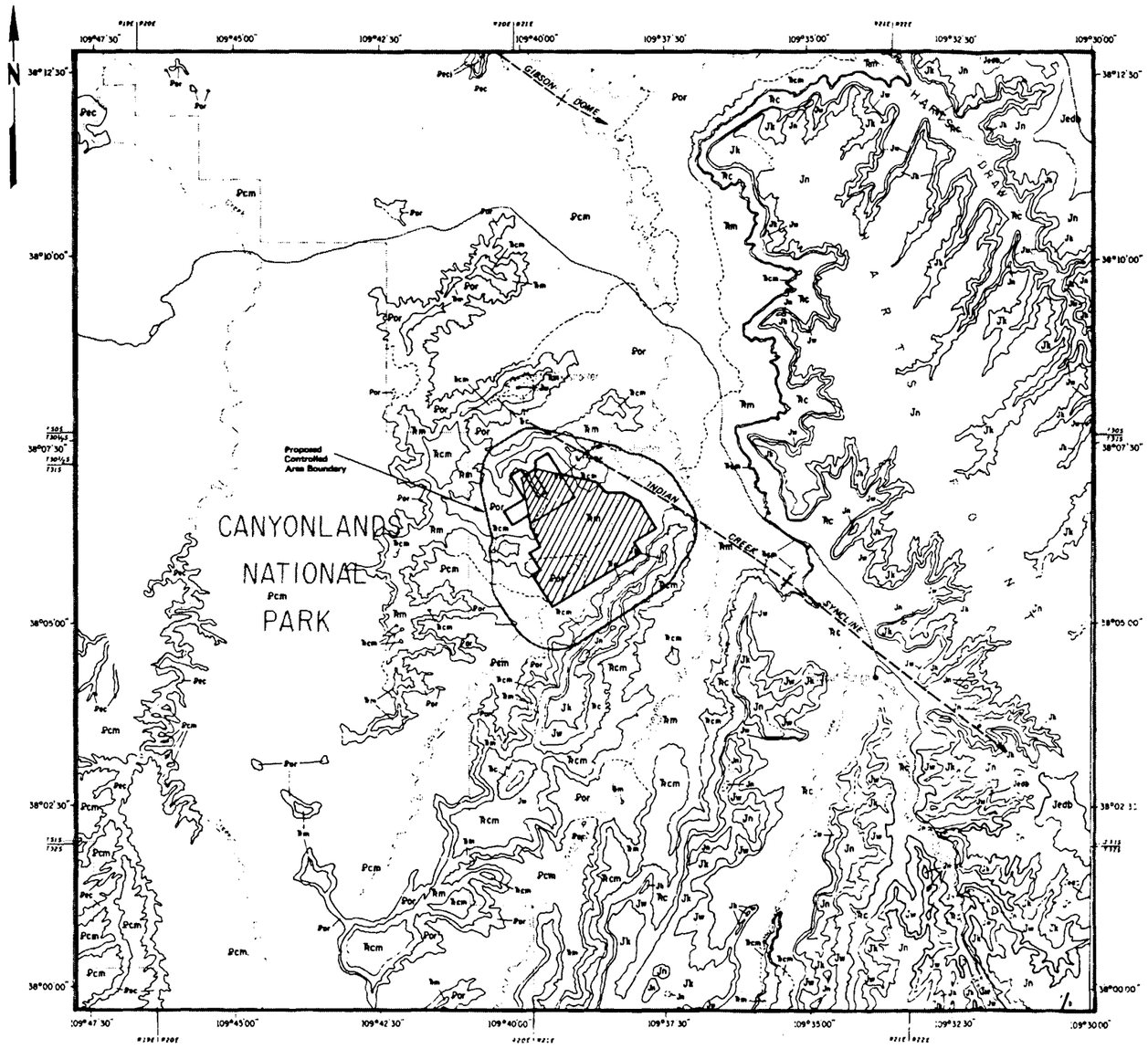


Explanation

CENOZOIC — Quaternary

Quaternary deposits in the Davis Canyon Site include alluvial deposits along drainages, colluvium, talus, dunes, and landslides deposits. These deposits are generally thin and the underlying bedrock crops out through the surficial deposits at numerous locations. Quaternary deposits were therefore, not considered in the preparation of this map.

MESOZOIC — Jurassic — Glen Canyon Group

Jedb ENTRADA SANDSTONE: Dewey Bridge Member— medium red to reddish—brown, sandy siltstone, characterized by undulatory bedding.

Jn NAVAJO SANDSTONE: Tan, cross—bedded, fine—grained, eolian sandstone with intermittent, thin horizontal limestone beds. Weathering to near vertical cliffs at mesa edges and rolling knob and dome topography in open areas.

Jk KAYENTA FORMATION: Dark reddish— to purplish—brown, fluvially deposited sandstone and siltstone characterized by thick slabby bedding

Jw WINGATE SANDSTONE: Tan to reddish—brown, massive, cross—bedded, eolian sandstone. Generally forms vertical cliffs and is noted for its columnar jointing and dark—stained exposures

MESOZOIC — Triassic

Ꞧc CHINLE FORMATION: Ꞧc (Upper Chinle Formation) — variegated mudstone, siltstone, sandstone and claystone with minor limestones; forms steep, generally talus—covered slopes. Ꞧcm (Moss Back Member)— grayish—green to tan fluvial sandstone and conglomeratic sandstone, cross—bedded, resistant bench former.

Ꞧcm

Ꞧm MOENKOPI FORMATION: Silty sandstone, sandstone and siltstone, red, noted for ripple marks and mud cracks

PALEOZOIC — Permian — Cutler Group

Por ORGAN ROCK FORMATION: Reddish—brown to purplish—red siltstone, sandstone, conglomeritic sandstone, and conglomerate. Coarser materials are generally arkosic. Locally contains thin chert and limestone lenses.

Pcm CEDER MESA SANDSTONE: White to pale red, cross—bedded sandstone interbedded with red siltstone and fine silty sandstone. Intertongues with the Organ Rock Formation in the vicinity of Indian Creek

Peci ELEPHANT CANYON FORMATION: Peci (Indian Limestone)—resistant, bench—forming limestone that marks the top of the Elephant Canyon Formation along Indian Creek. Pec (Elephant Canyon Formation)— siltstone, sandstone and limestone. Red to buff with some purplish and light green beds. Highly variable in color and lithology.

Pec

CONTACT: Dashed where approximately located, dotted where transitional.

FAULT: U, upthrown side; D, downthrown side

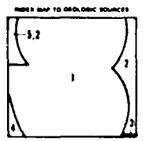
ANTICLINE: Showing trace of axial plane and direction of plunge. Dashed where approximately located.

SYNCLINE: Showing trace of axial plane and direction of plunge. Dashed where approximately located.

Geological Repository Operations Area

GEOLOGIC SOURCES:

INDEX MAP TO GEOLOGIC SOURCES



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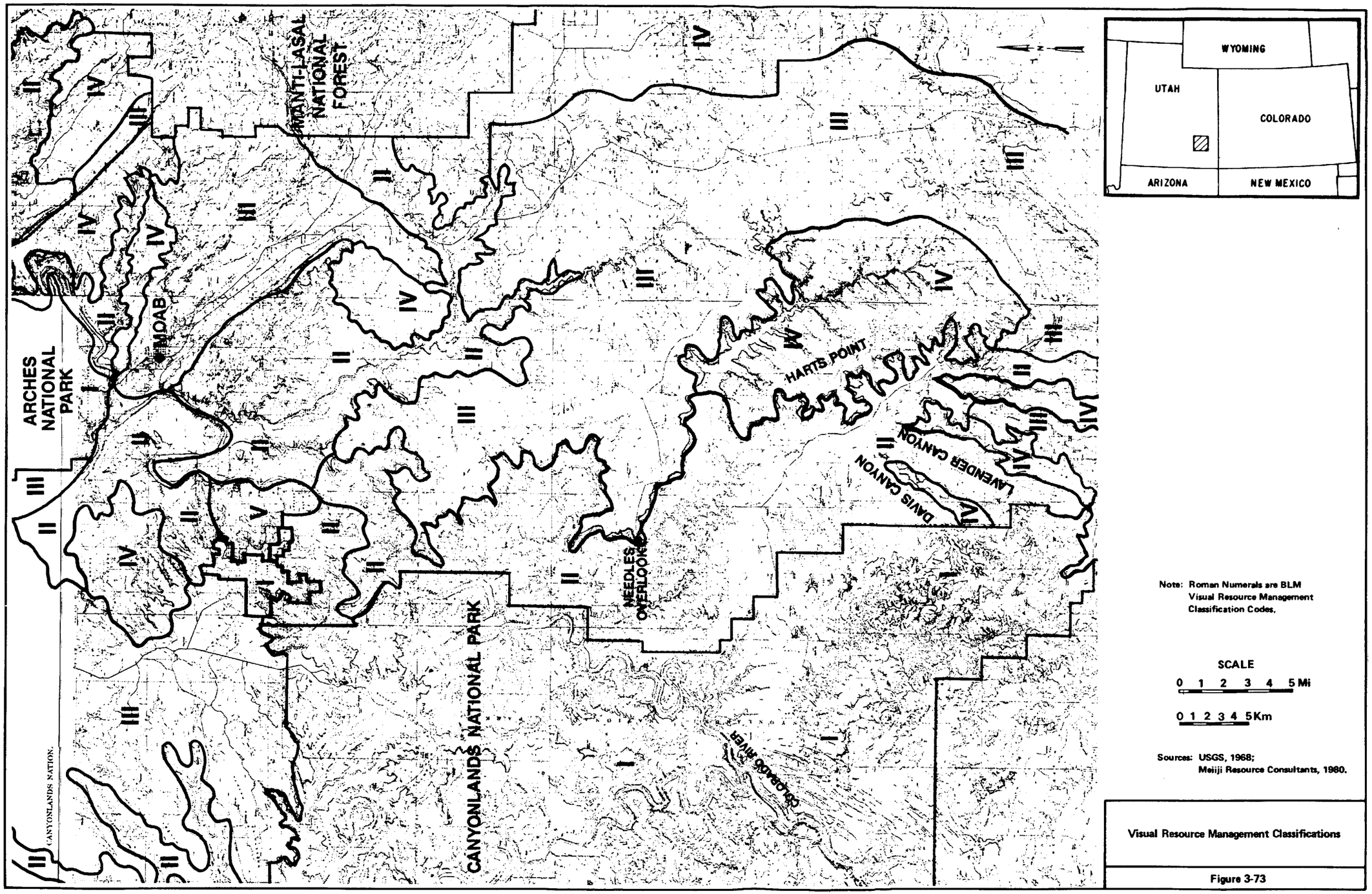
0 1 2 3 4 Miles

0 1 2 3 4 5 Kilometers

Davis Canyon

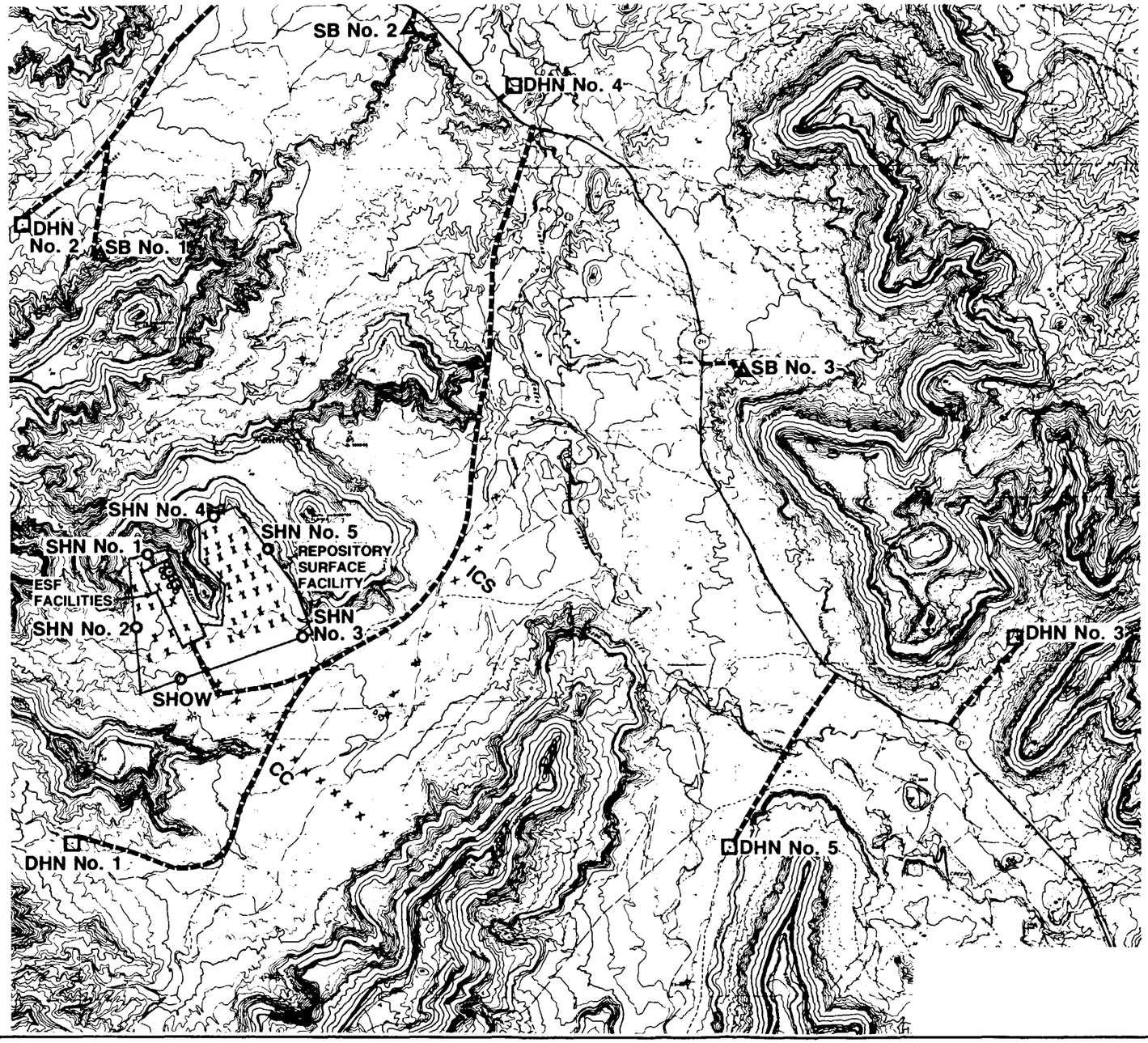
Site and Vicinity Geologic Map

Figure 3-10



Visual Resource Management Classifications

Figure 3-73



Explanation

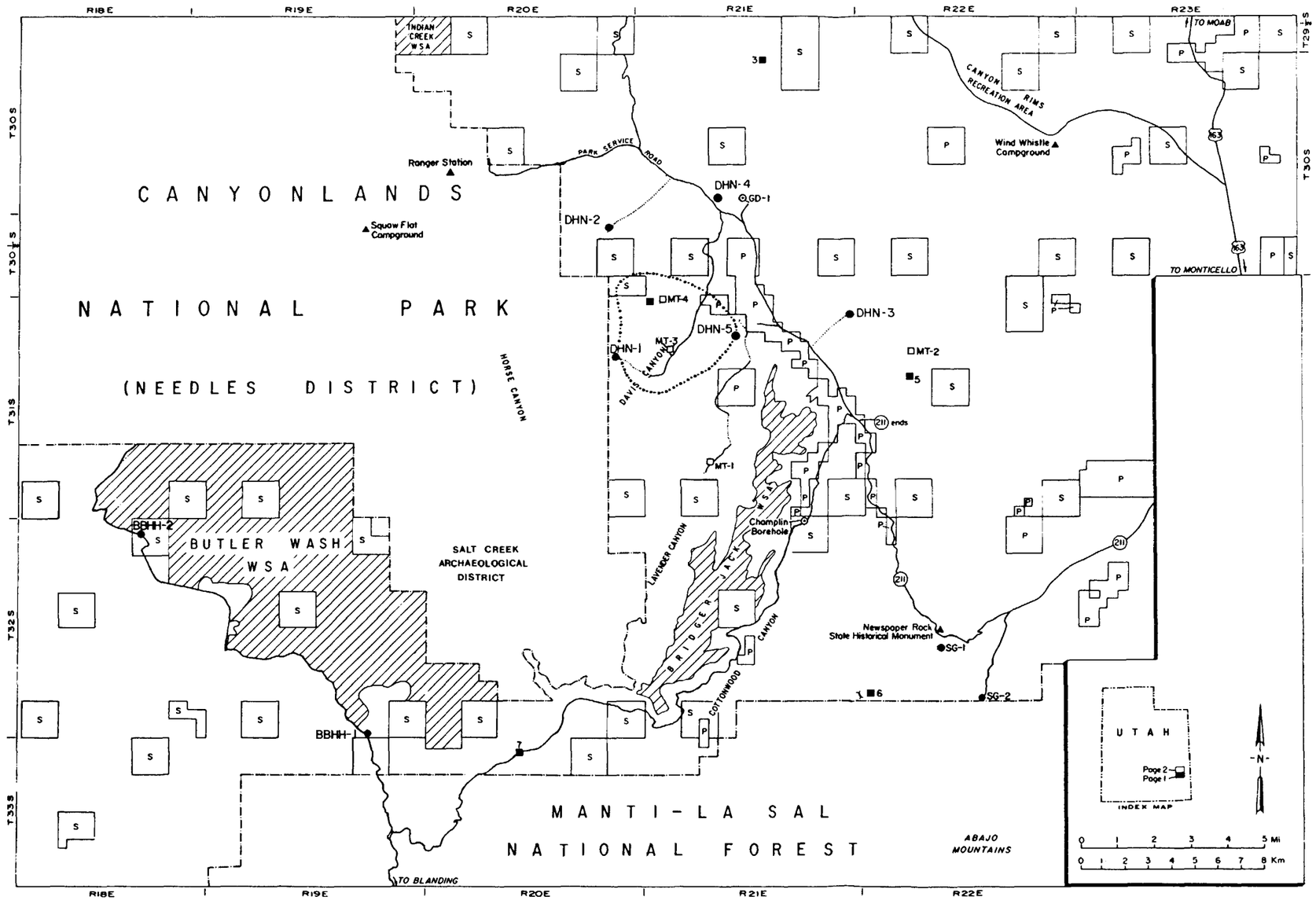
- ⊙ Engineering Design Boreholes (2)
- ○ Shaft Monitoring Wells (6)
- X Foundation Borings
- △ SB Stratigraphic Boreholes (3)
- ○ SHN Shallow Hydrologic Nests (5)
- ○ SHOW Shallow Hydrologic Observation Well (1)
- ⊡ DHN Deep Hydrologic Nests (5)
- X ICS Indian Creek Syncline Borings (10)
- X CC Cross Canyon Borings (12)
- ▪▪▪▪ Access Route

Feet 0 2000 4000
Meters 0 600 900
Scale

N

Proposed Location of Drilling Activities, Davis Canyon Site

Figure 4-2



Explanation

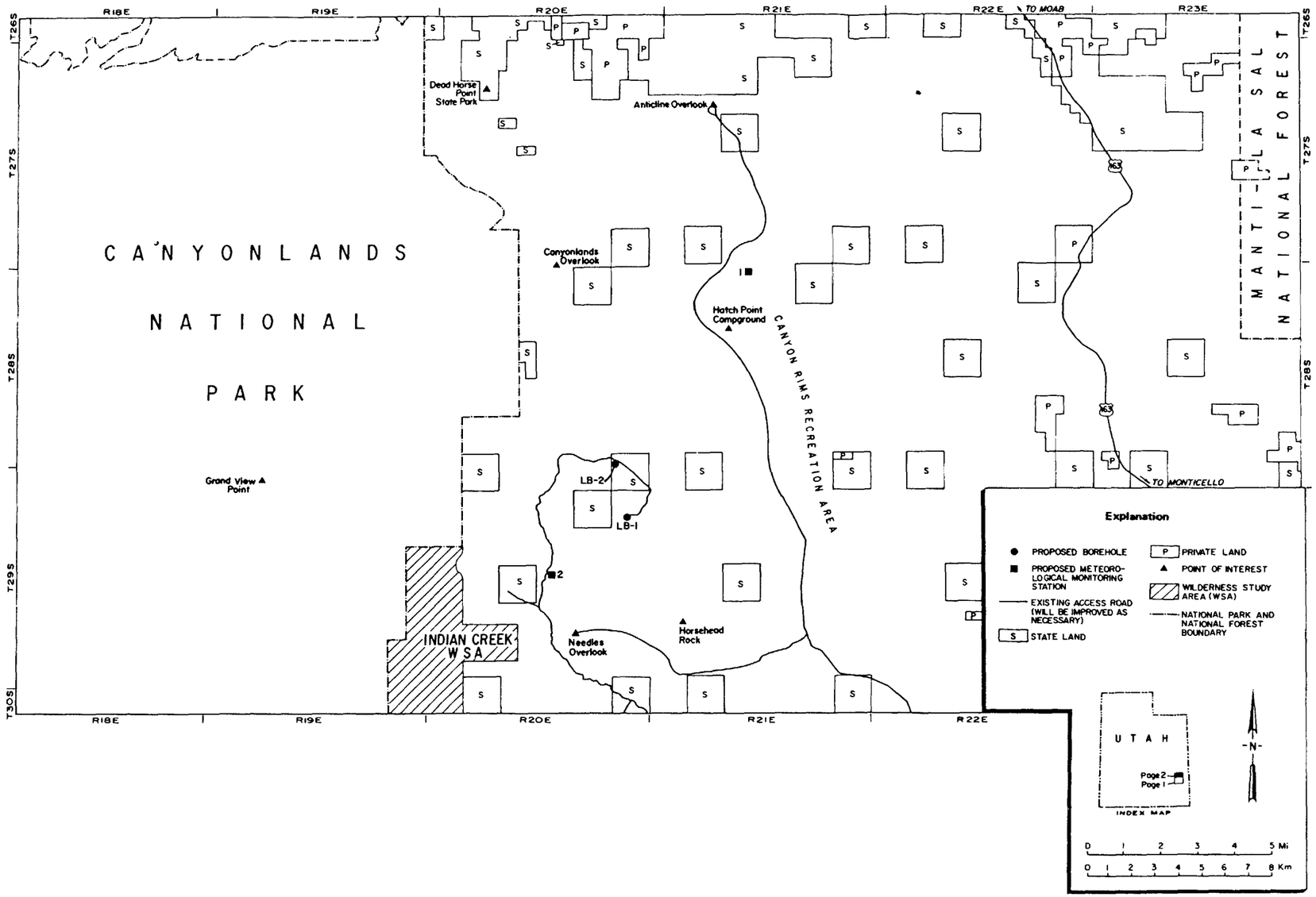
- ● Proposed borehole
- ⊙ Existing borehole
- Proposed trench
- ■ Proposed meteorological monitoring station
- □ Proposed meteorological tower (MT)
- Existing access road (will be improved as necessary)
- New access road
- S State land
- P Private land
- ▲ Point of interest
- Wilderness study area (WSA)
- National park and national forest boundary

DHN: Denotes Deep Aquifer Hydro-Nest
SG: Shay Graben hydrologic/geologic holes
LB: Lockhart Basin hydrologic/geologic holes
BBHH: Beef Basin hydrologic/geologic holes

Proposed Field Activities in the Davis Canyon Candidate Area

Page 1 of 2

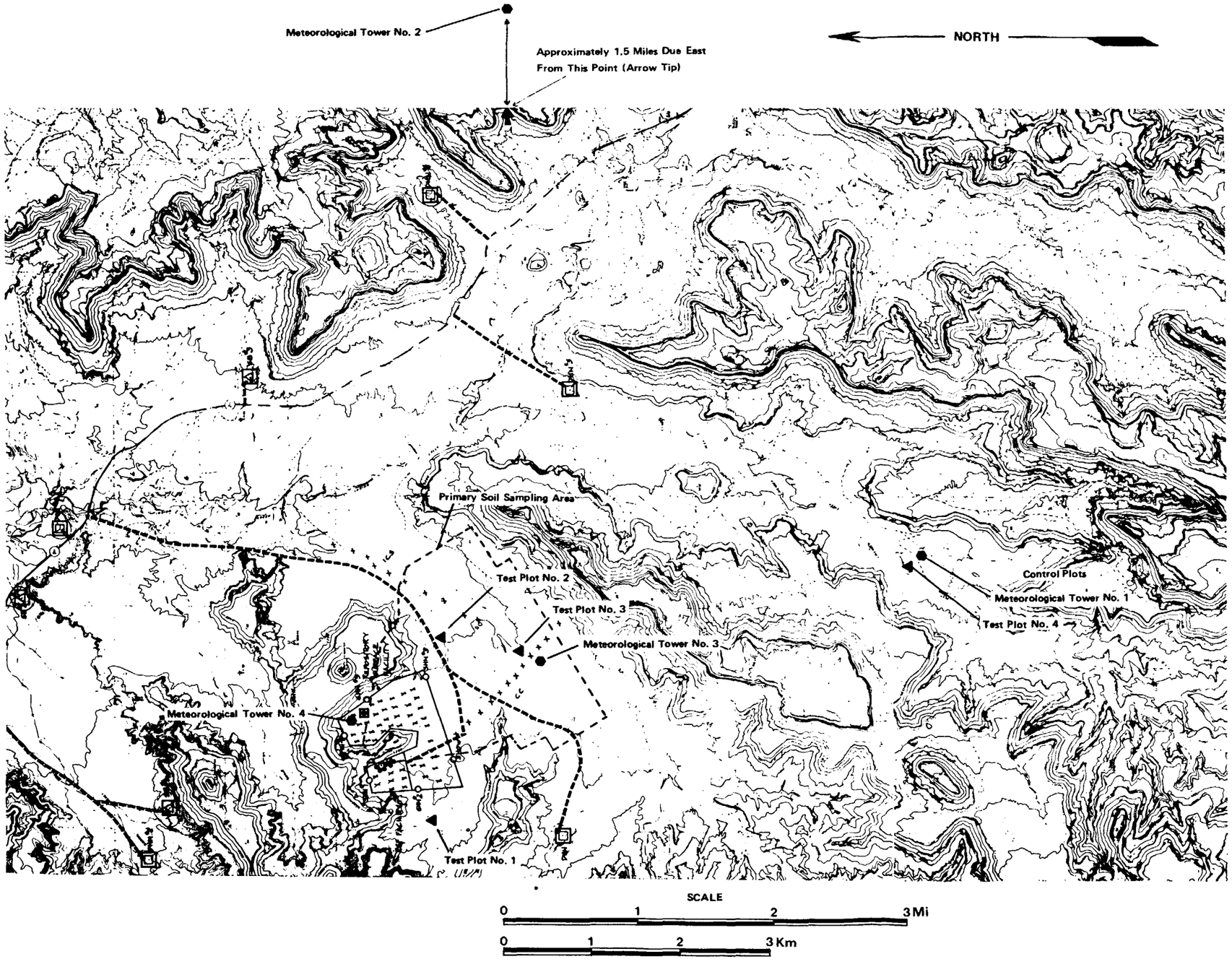
Figure 4-3



Page 2 of 2

Proposed Field Activities in the Davis Canyon Candidate Area

Figure 4-3



Explanation

- Approximate Location, Foundation Boreholes
- 10 Acre Soil Sampling Area For Remote Boreholes (4 Samples Per Borehole Location)
- Salt Particulate Monitoring Station

*Note : Radiological monitoring (i.e. grab samples and pole mounts) will coincide with these and other mapped sampling locations.

Source: Woodward - Clyde Consultants, 1984

Proposed Locations (Approximate) For Environmental Study Sampling: Soils, Radiological, Meteorological/Air Quality, and Salt Impacts

Figure 4-18

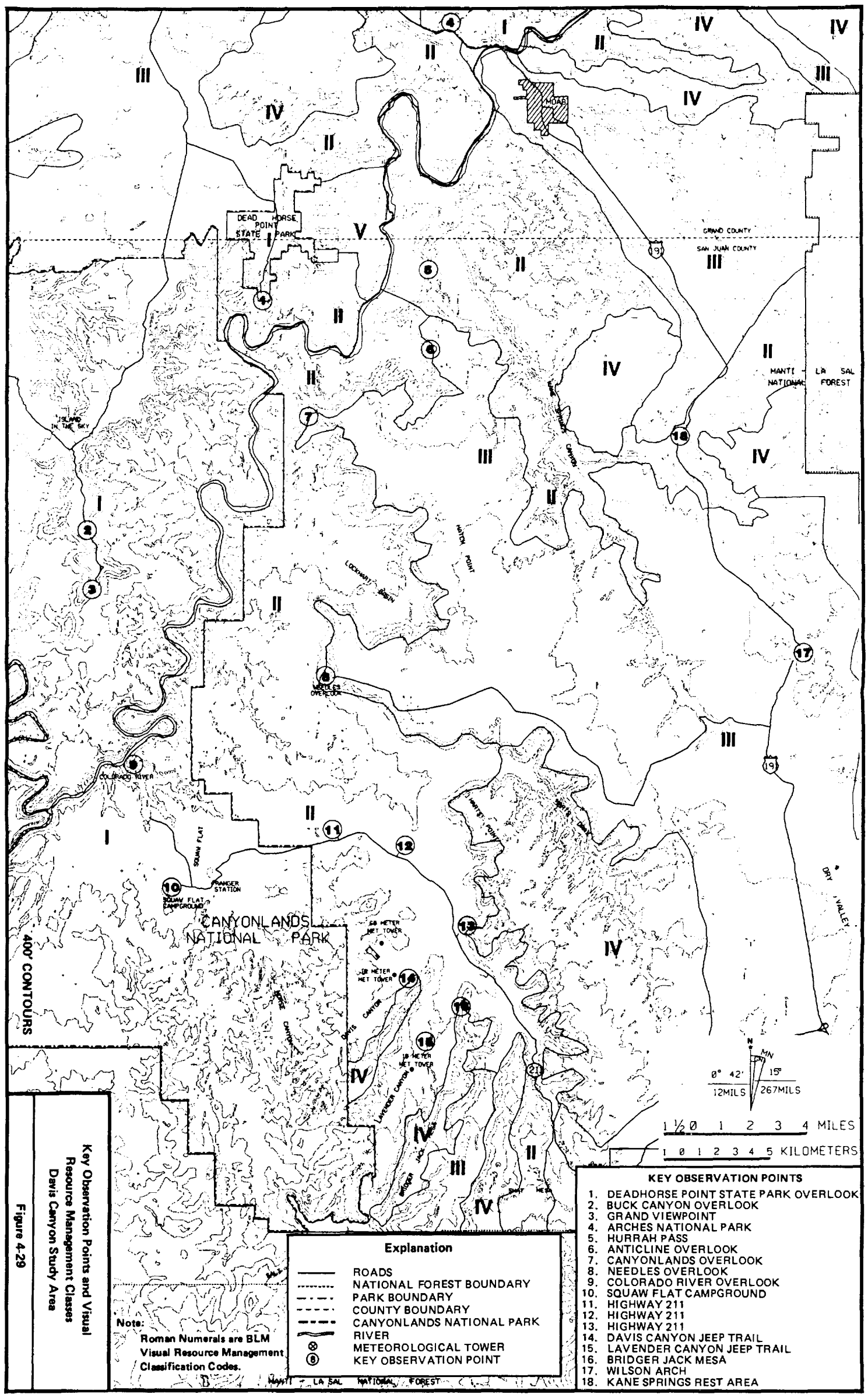


Figure 4-29

Key Observation Points and Visual Resource Management Classes Davis Canyon Study Area

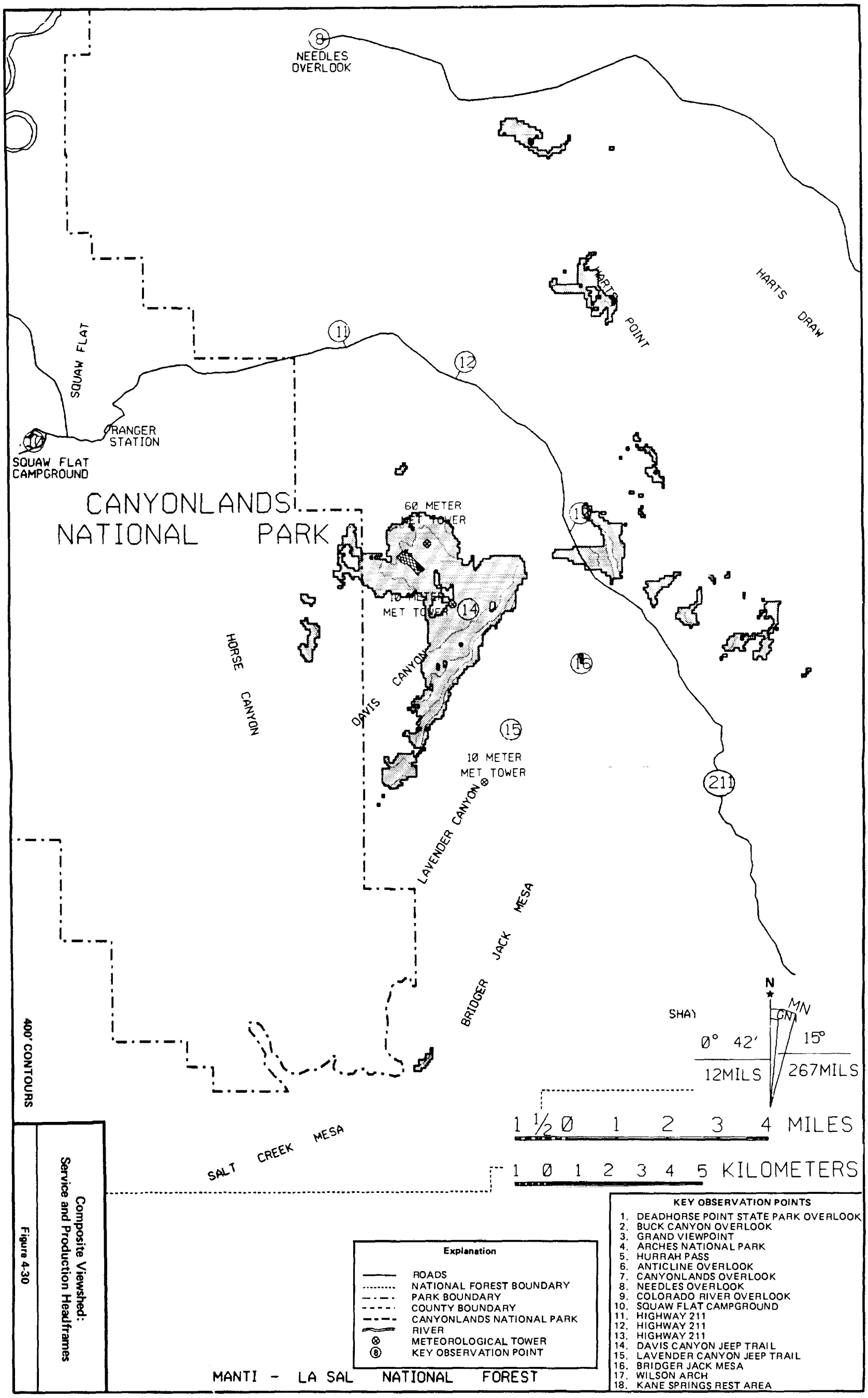


Figure 4-30

Composite Viewshed: Service and Production Healframes

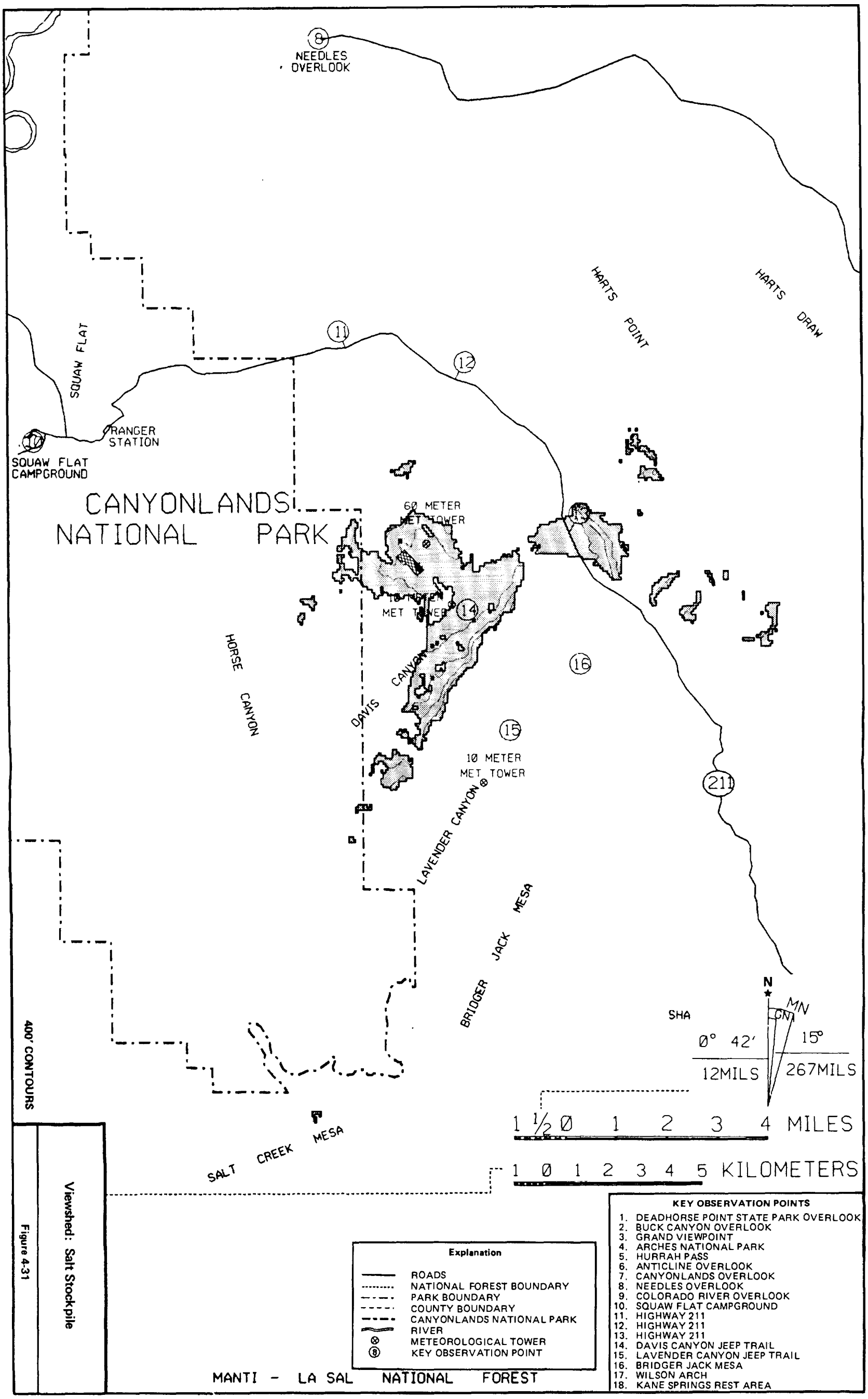


Figure 4-31

Viewshed: Salt Stockpile

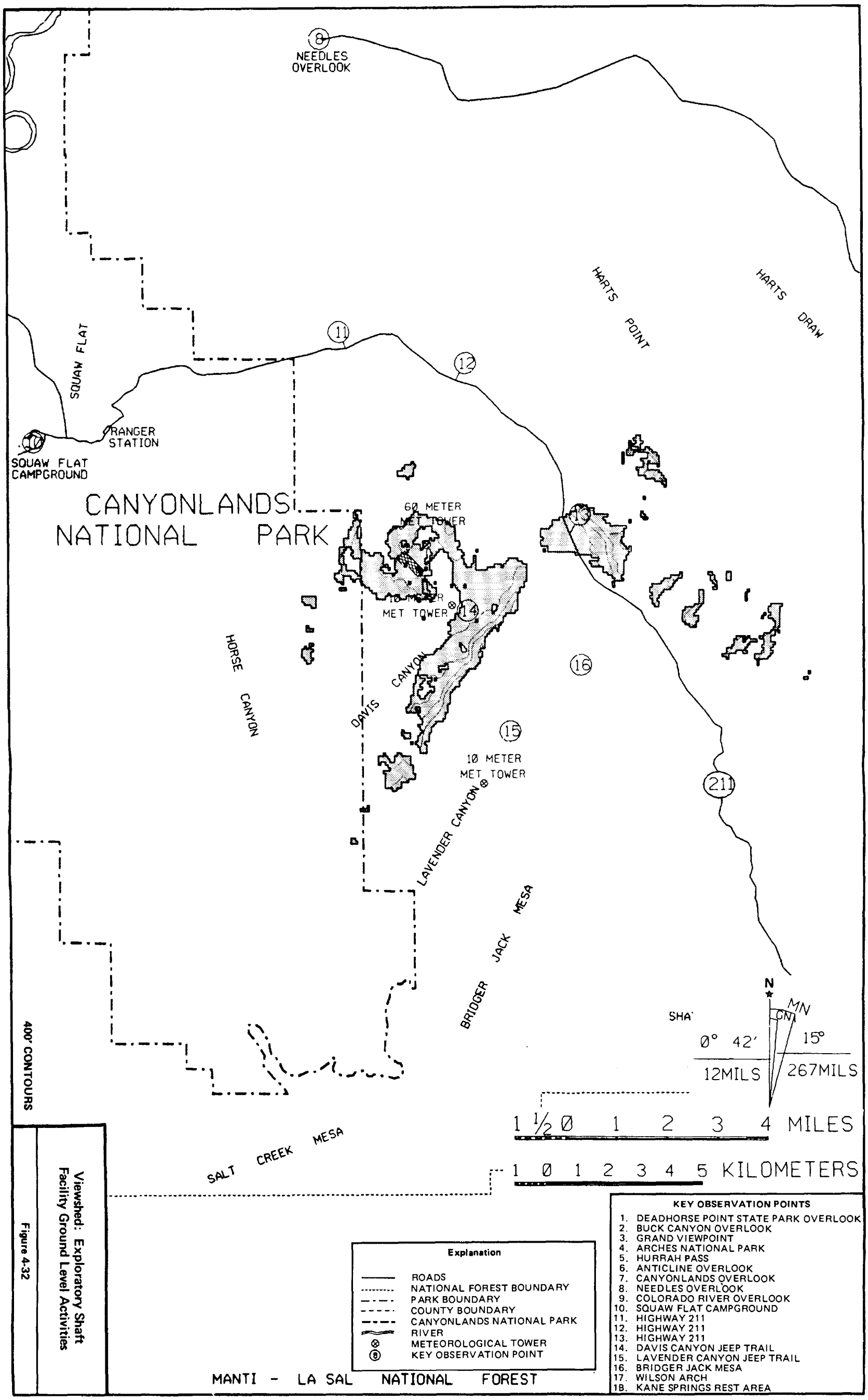


Figure 4-32

Viewshed: Exploratory Shaft Facility Ground Level Activities

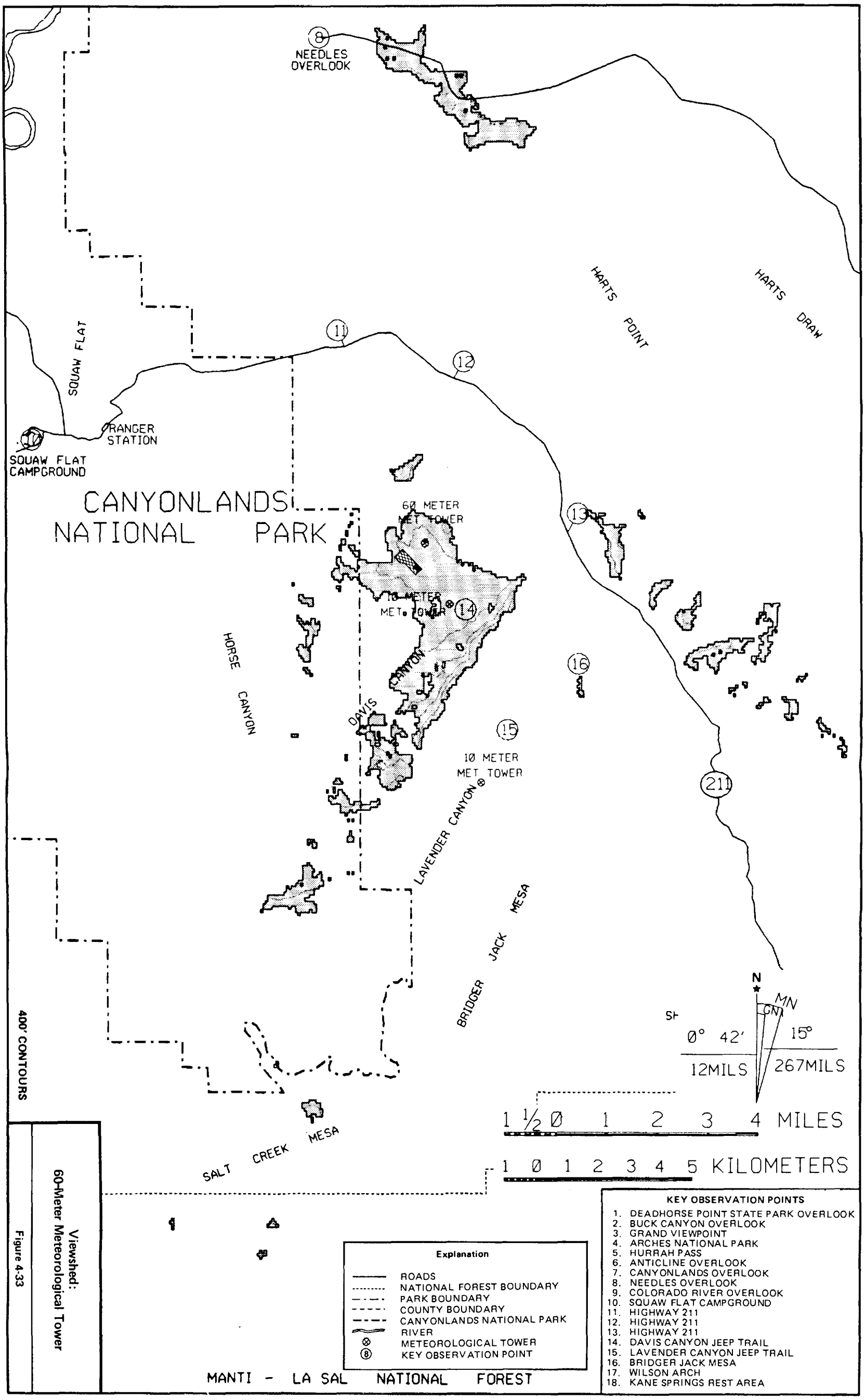


Figure 4-33

Viewshed: 60-Meter Meteorological Tower

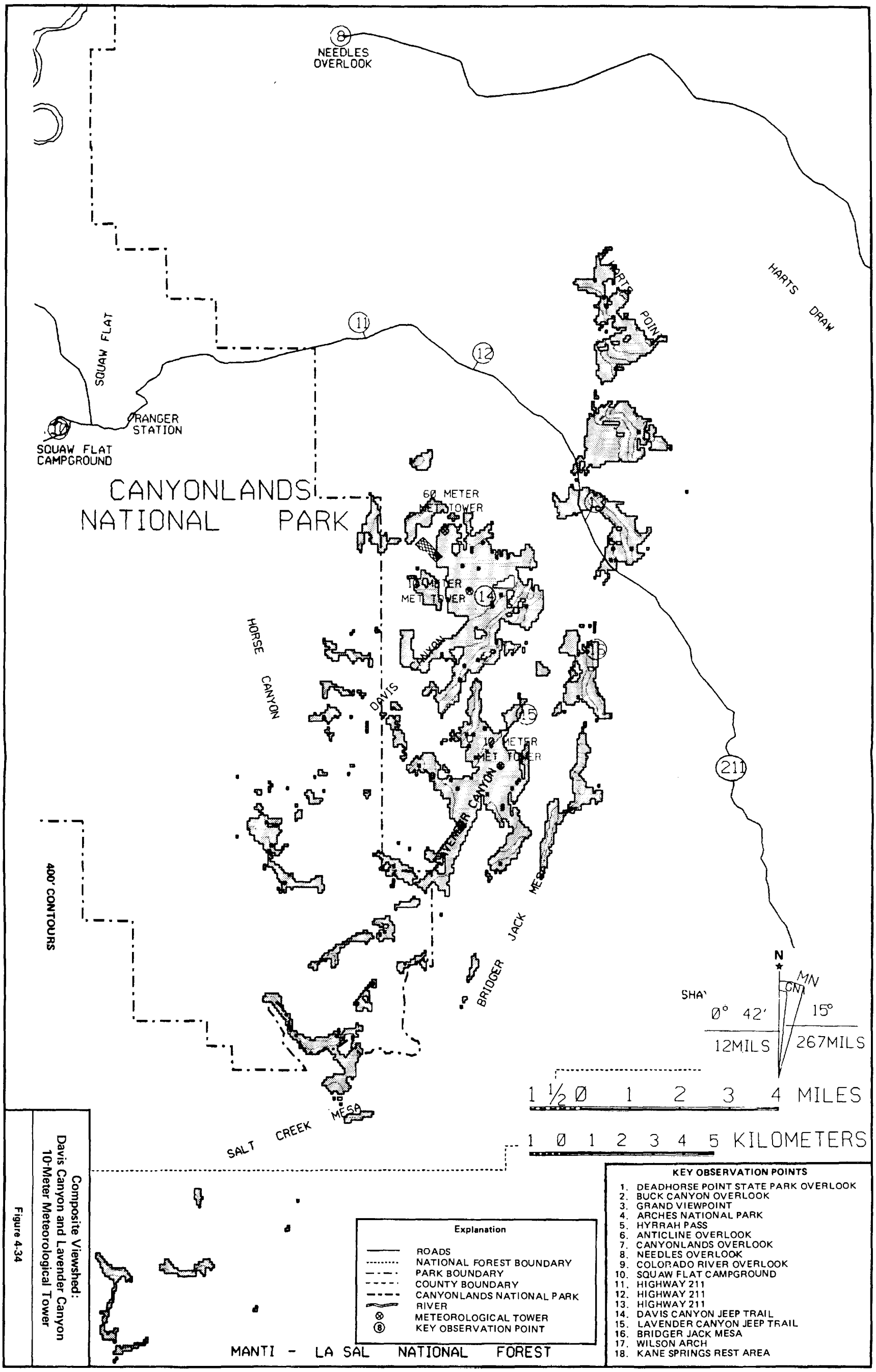


Figure 4-34

Composite Viewshed:
Davis Canyon and Lavender Canyon
10-Meter Meteorological Tower

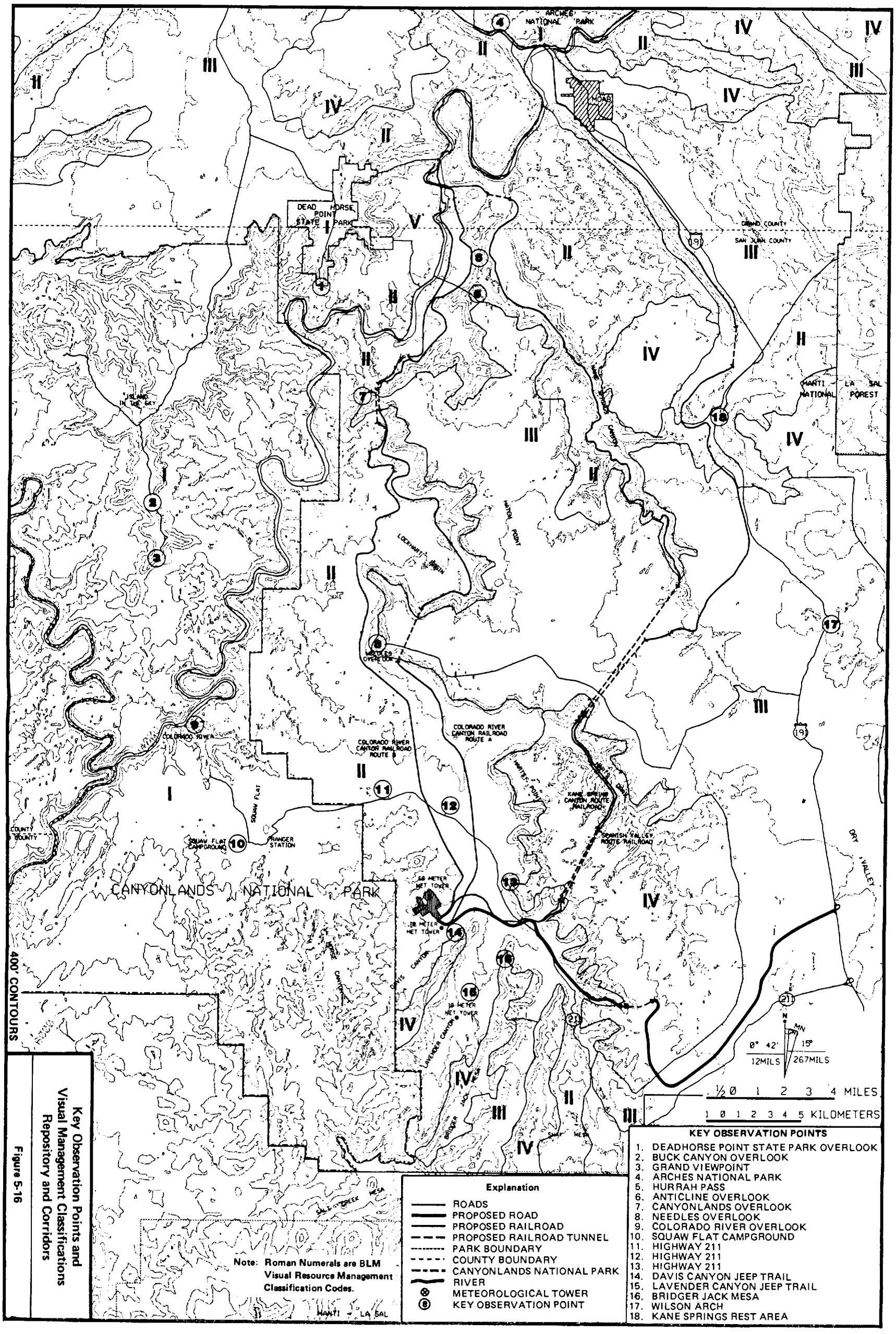
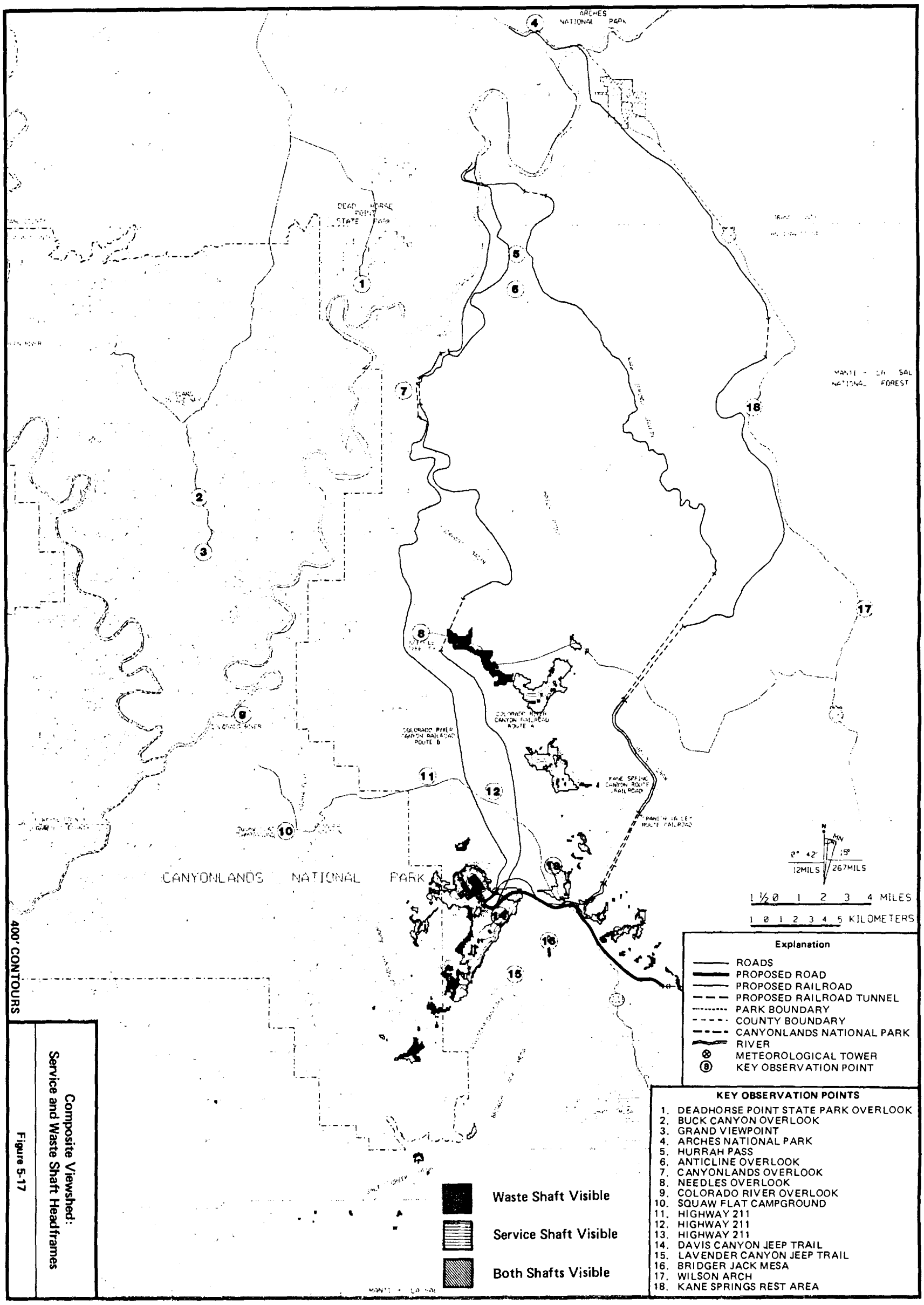


Figure 5-16

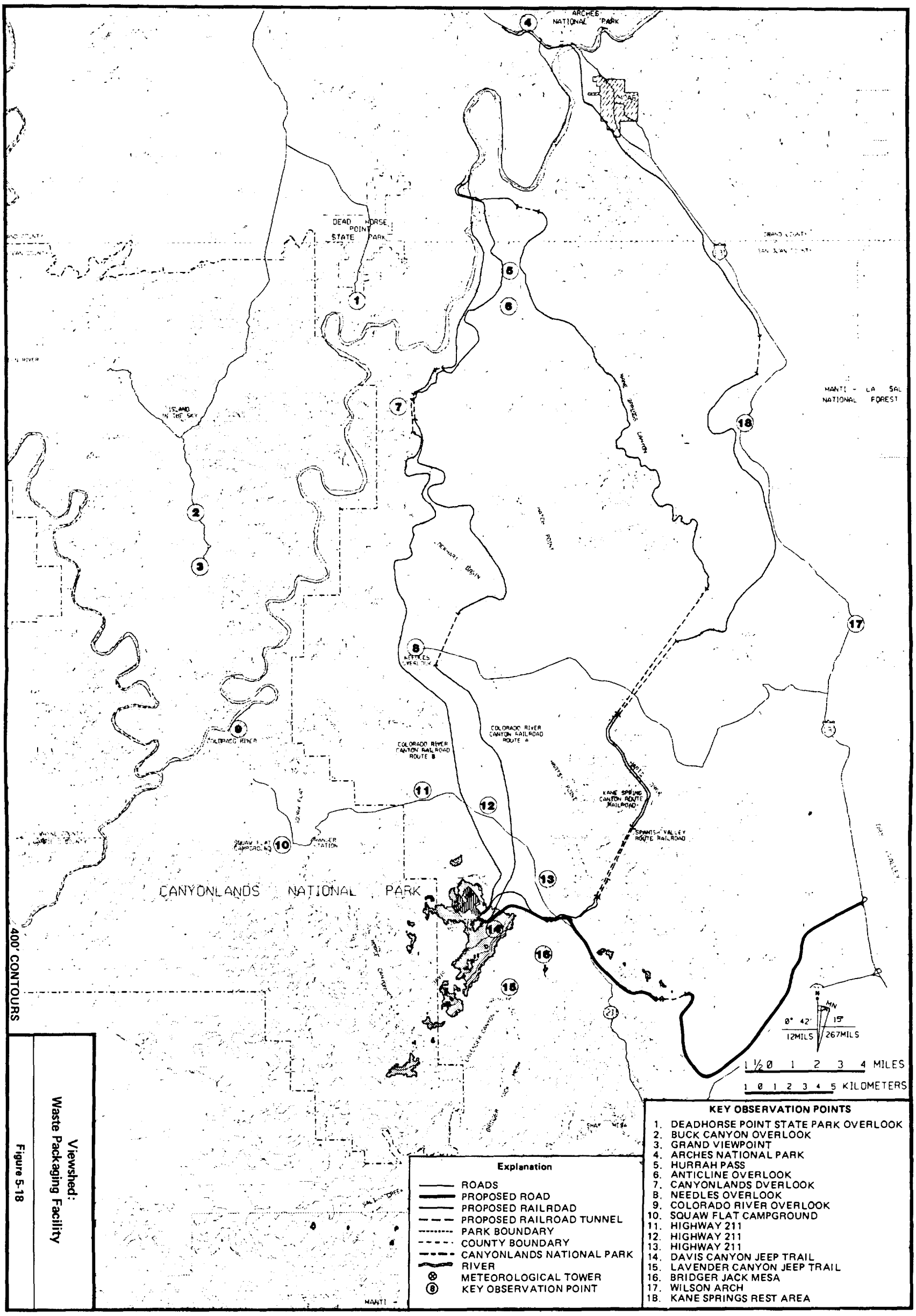
Key Observation Points and Visual Management Classifications Repository and Corridors



400' CONTOURS

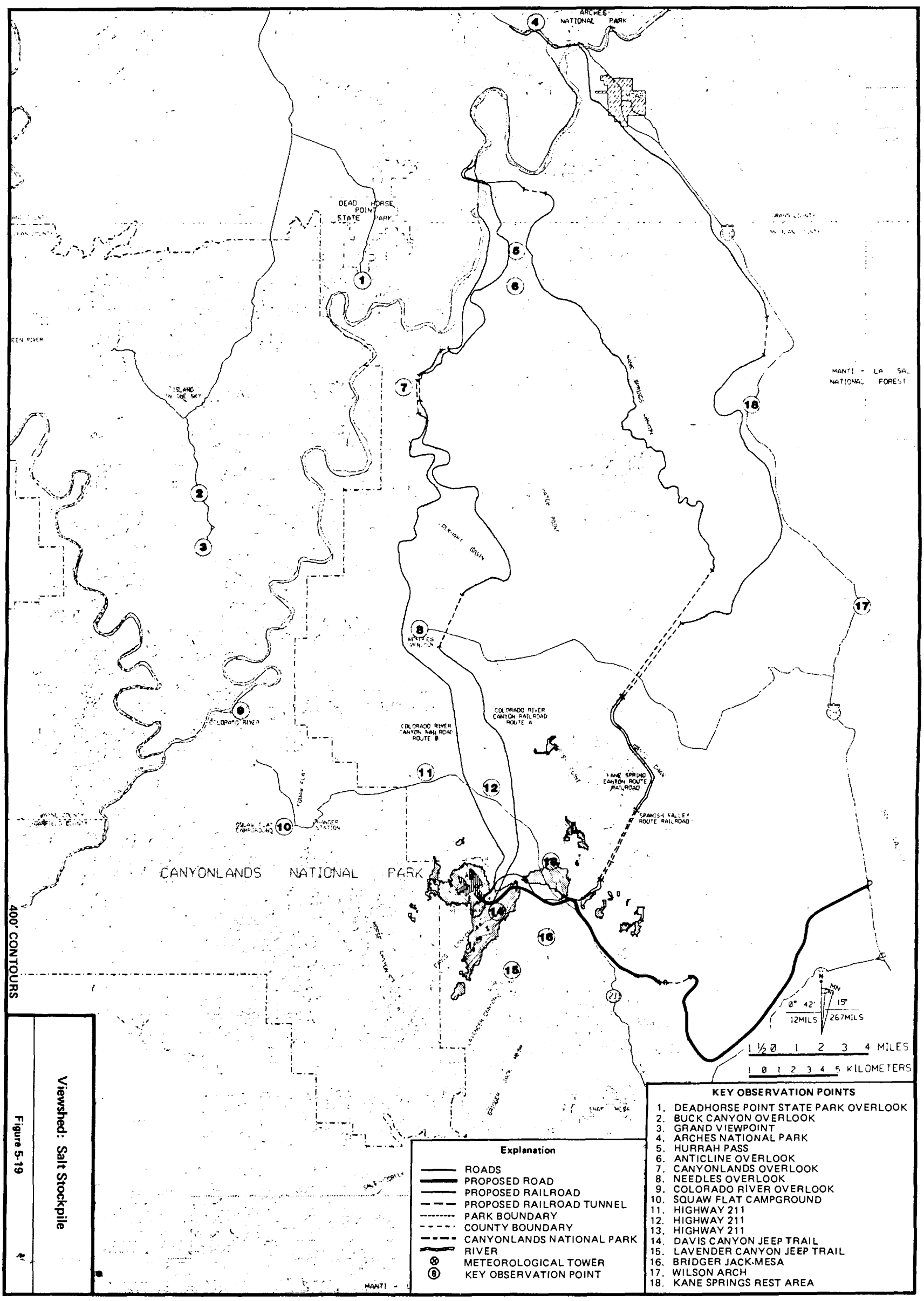
Composite Viewshed:
Service and Waste Shaft Headframes

Figure 5-17



Viewshed: Waste Packaging Facility

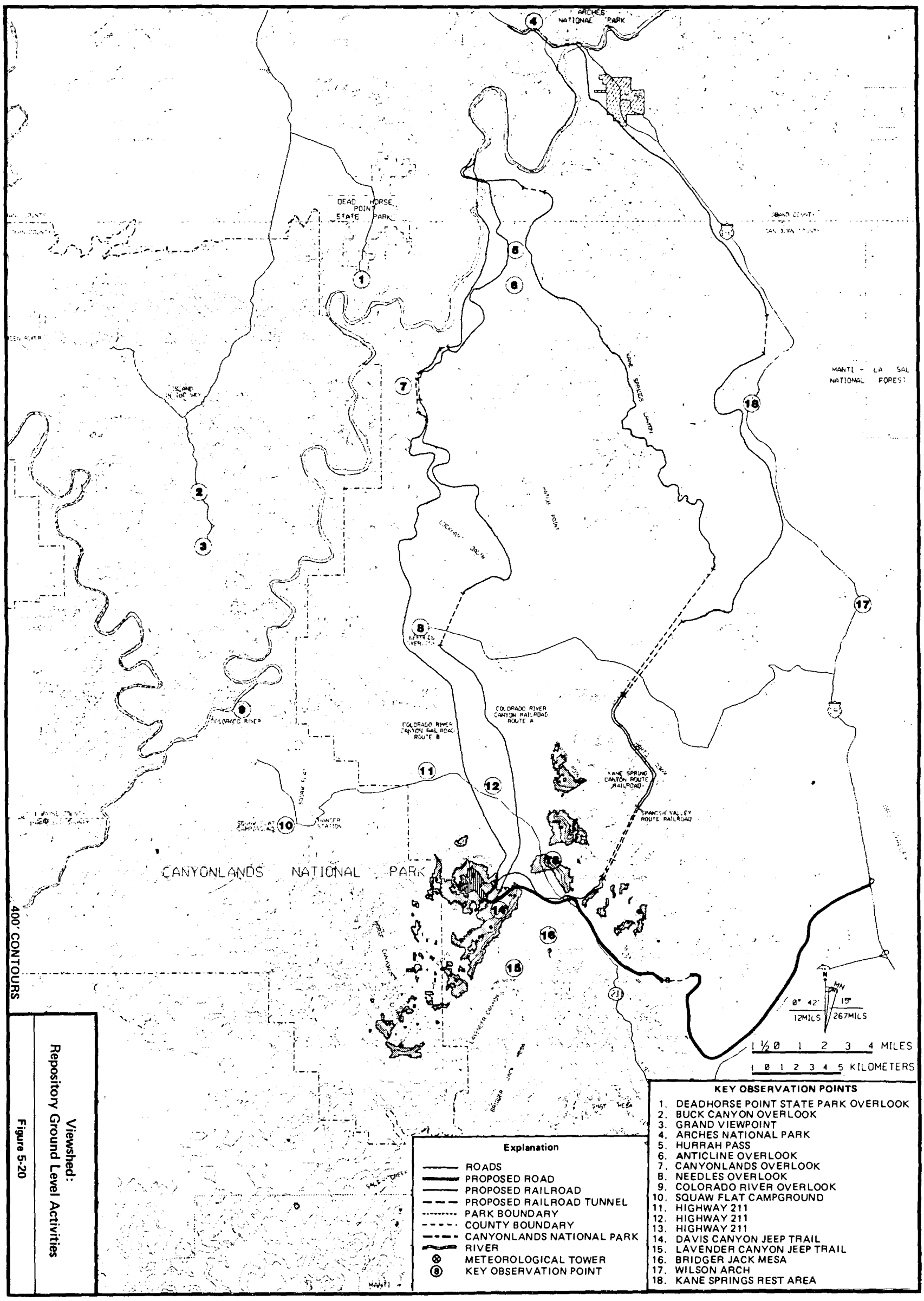
Figure 5-18



400' CONTOURS

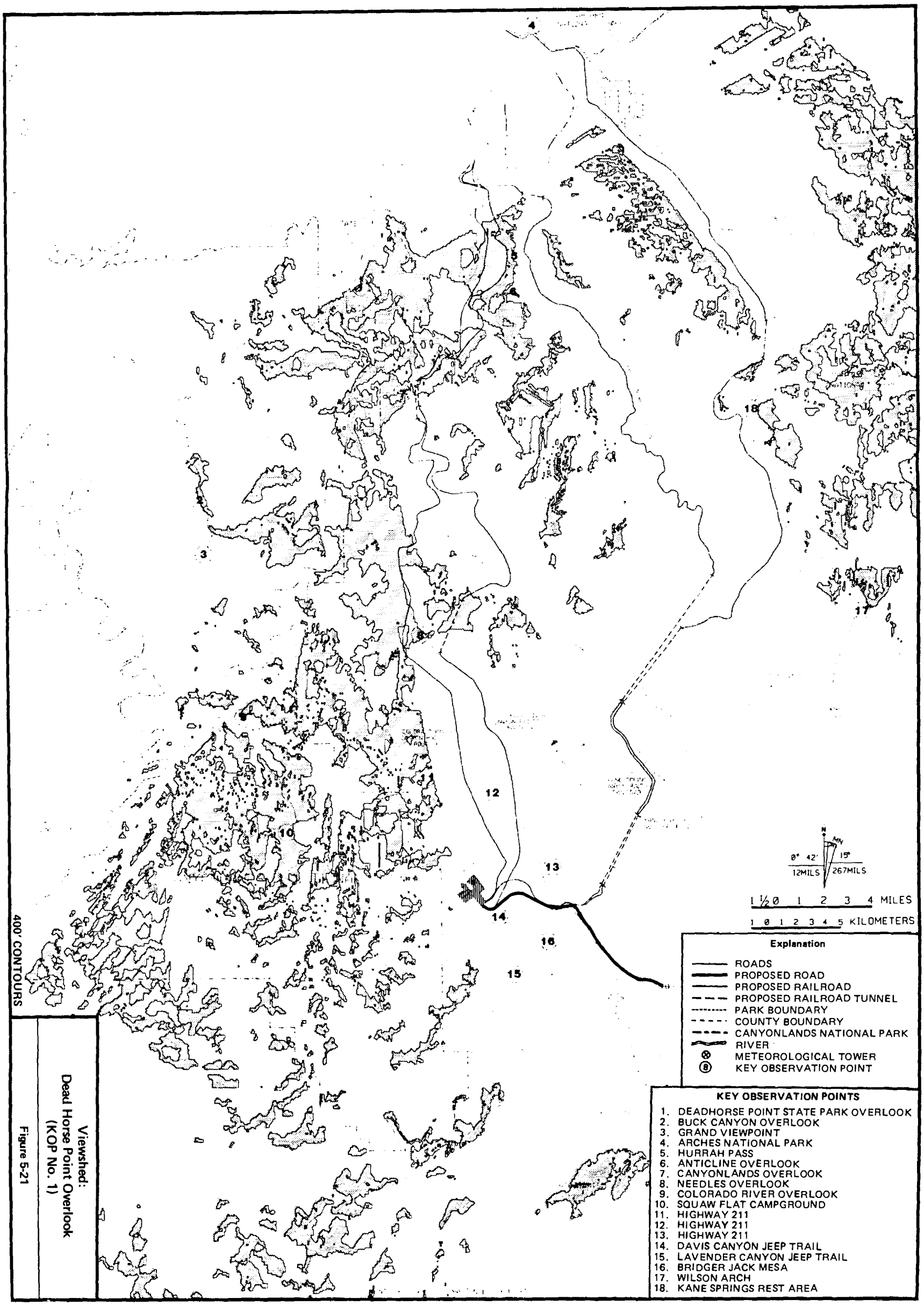
Figure 5-19

Viewshed: Salt Stockpile



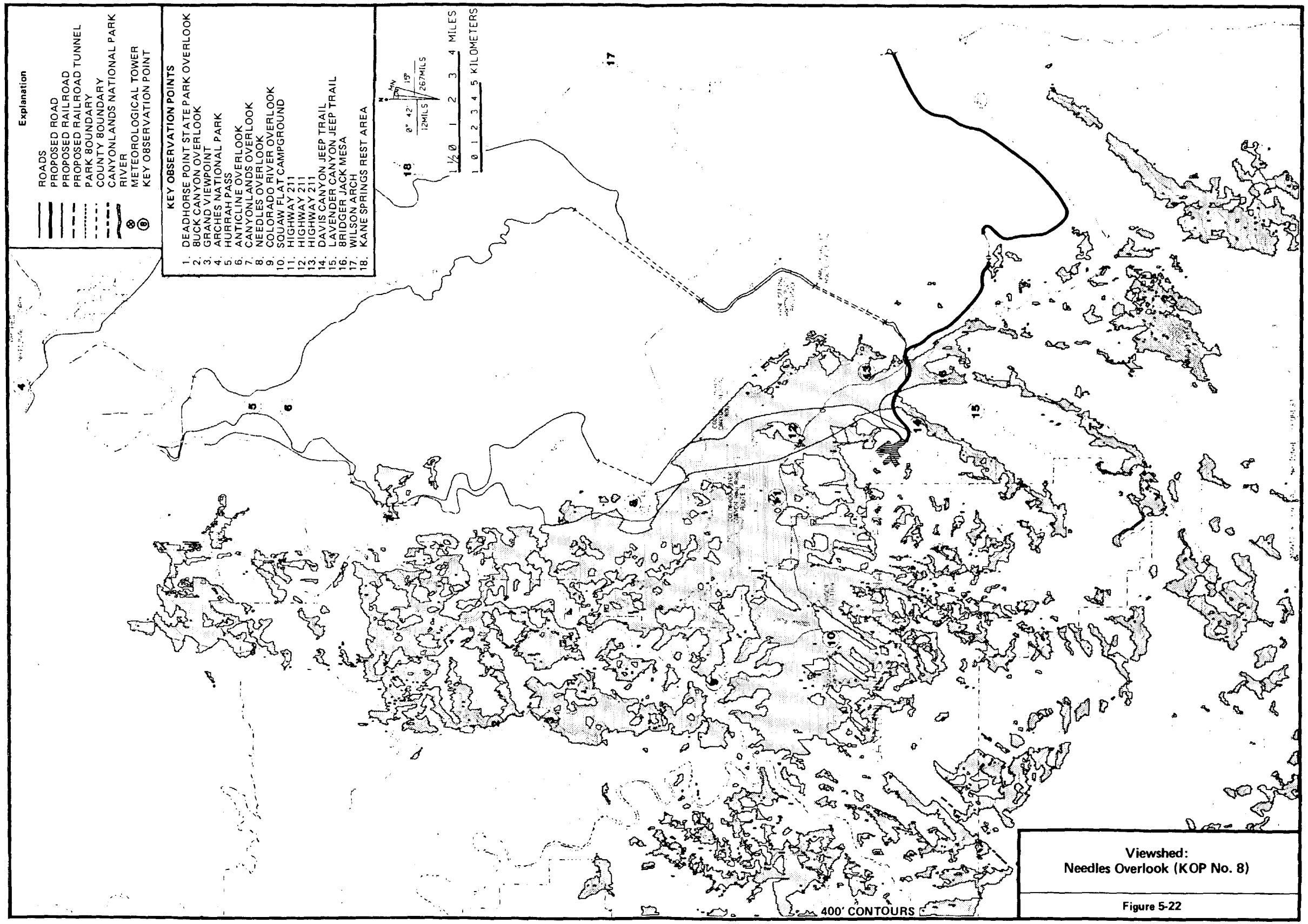
Viewshed:
Repository Ground Level Activities

Figure 5-20



Viewshed:
Deadhorse Point Overlook
(KOP No. 1)

Figure 5-21



Viewshed:
Needles Overlook (KOP No. 8)

Figure 5-22