DOE/RW-0035/1
Volume 1 of 3

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Monitored Retrievable Storage Submission to Congress

Volume II

Environmental Assessment for a Monitored Retrievable Storage Facility

February 1986

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

This document contains only part of the MRS submission to Congress. There are three volumes, which should be read together. Volumes 1 and 3 have been updated to reflect program changes through March 1987.

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ERRATA OF THE MRS PROPOSAL
DOE/RW-0035/1, Volume 2

Cover	Printed as Volume 1 of 3. Should be Volume 2 of 3.
p. xxv	1.7 "References" should be shown in all caps.
p. xliv	Title for Table 6.54 should read "Natural" Background Radiation rather than "national".
p. 5.5	First sentence in last paragraph: delete the word "which".
p. 5.10	The appendix callout in the third paragraph should be Appendix A, not B.
p. 5.54	Table 5.17, Caption and Footnote (b): Replace reference citation for Tennessee Division of Community Development "1985a-m" to "1985a-g", section 5.1.6.
p. 5.79	Figure 5.16 Insert the word "some" before "monitoring wells" in the caption.
p. 5.83	Paragraph 2, Line 10: Replace "monitoring wells" with "some monitoring wells in Bear Creek Valley", section 5.2.3.
p. 5.84	The Drinking Water Standards in the Table for As, Cd, and Pb should be 0.05, 0.01, and 0.05 rather than 0.5, 0.1 and 0.06.
p. 5.88	Paragraph 4, Line 1: Insert "show" after "Fish communities in Bear Creek", section 5.2.4.
p. 5.100	Last paragraph: "60^{o}F" should be changed to "45^{o}F".
p. 5.121	One "the" needs to be deleted in the first sentence.
p. 5.131	Table 5.47, Caption: Replace reference citation for Tennessee Division of Community Development "1985a-1985m" with "1985h-1985m", section 5.3.6.
p. 6.7	Paragraph 2, Line 4: Delete "are," section 6.1.1.
p. 6.8	Paragraph 1, Line 7: Replace cross reference to "page 6.5" with "page 6.6"
p. 6.8	Paragraph 3, Line 5: Delete "(~3 m)."
p. 6.28	Paragraph 4, Line 5: Replace "10 to 60 mrem" with "10 to 60 rem," section 6.1.9.
p. 6.76	Table 6.29, Caption: interchange "of" and "from", section 6.3.1.

SUMMARY ANALYSIS OF THE EFFECTS OF PROGRAM DEVELOPMENTS SINCE FEBRUARY 1986 ON VOLUME 2 THE DEPARTMENT'S ENVIRONMENTAL ASSESSMENT TO ACCOMPANY THE MRS PROPOSAL TO CONGRESS

Since Volume 2, the Environmental Assessment to accompany the Department's Monitored Retrievable Storage (MRS) Proposal was printed in February, 1986, and its submission to Congress was delayed due to litigation, the Department's Program for Civilian Radioactive Waste Management has progressed and undergone various changes. These changes range from the programmatic changes and proposals outlined in the January 1987 draft Mission Plan Amendment to further refinements of the program's analytical data base. While the program as presented in the draft Mission Plan Amendment represents the Department's current plan for the Federal waste management system, it must be recognized that the plan could change in response to comments from affected parties or other events.

The programmatic changes outlined in the draft Mission Plan Amendment, other than the delay of the submission of the MRS Proposal, are as follows:

1. Indefinite postponement of site specific work for a second repository which would be required in endeavoring to meet the July 1, 1989 date for selecting sites for characterization (Section 112 of the NWPA). The Department believes site-specific work should be reconsidered in the mid-1990's which would allow ample time to implement a second repository program prior to the first repository receiving 70,000 metric tons of uranium (MTU), its mandated capacity limit.

2. Extension of the date for the start of operations at the first repository from January 31, 1998 to 2003. The extension is needed to carry out an extensive high quality site characterization program, to prepare licensing documents to comply with Nuclear Regulatory Commission (NRC) requirements that have yet to be promulgated in their entirety, and to provide additional opportunity for consultation and cooperation with affected States and Indian Tribes.

The refinements of the analytical data base include:

1. Updating the Department's Energy Information Administration (EIA) projections of spent nuclear fuel generation.

2. Minor changes in transportation system assumptions, including variations in spent fuel cask capacities and in the relative amounts of fuel to be moved by truck casks and rail casks.

3. Updating the Department's analysis of the total system life cycle costs for the waste management system.

The above identified changes resulted in the following modifications to the waste system assumptions regarding the MRS:

A. 5-year extension in the schedule for initial operation of the first repository.

B. Nearly a 2-year extension in the schedule for initial operation of the MRS.

C. For most of its operating period, MRS facility annual throughput increases from 2500 MTU to 2650 MTU.

D. Inventory of spent fuel at the MRS for most of its operating period increases to 14,700 MTU.

E. Total MRS facility throughput changes from 53,000 MTU to 59,760 MTU.

F. Incorporation of updated EIA spent fuel projections and identified changes in transportation system assumptions.

G. Reevaluation of the impact of an MRS facility on total system life cycle costs for the waste management system resulting in a revised cost increase estimate in the range of $1.5 to $1.6 billion as compared to the April 1986 estimated range of $1.6 to $2.6 billion.

Summary of Effects on Volume 2

The impacts related to annual waste throughput of the MRS facility were conservatively analyzed at a level of 3600 MTU per year. This level bounds the new estimated throughput level of 2650 MTU per year. Impacts related to the transportation of spent fuel in a waste management system which includes an MRS facility were assessed on the basis of a conservative throughput of 62,000 MTU over a 26 year operational period. This bounds the transportation system impacts which are now estimated at a throughput of 62,000 MTU spread over 31 years.

The MRS facility total throughput increases under the latest estimates from 53,000 MTU to 59,760 MTU and the facility will remain operational for five additional years (26 to 31 years).

Since the majority of ecological impacts result from the construction of the facility, limited additional throughput and additional operating time are not expected to cause significant additional impacts over those analyzed in the environmental assessment. The MRS has been shown to be a facility which can be operated without significant threat to the public health and safety. It is not expected that an additional five years of operation would change that conclusion.

As a result, the program changes recommended in the draft Mission Plan Amendment and the changes in the technical bases over the last year do not alter the conclusions of the environmental assessment in such a manner as to require issuance of a supplement to or an updated environmental assessment. A more detailed analysis of the effects on Volume 2 is given below.

Effects on Volume 2, Part 1 - The Need for MRS

In evaluating the impact of the above system changes to the assessed need for an MRS in the waste management system, the Department has reviewed its findings in each of the four major areas presented in the analysis contained in Volume 2, Part 1. These four areas are System Development, System Operations, System Cost and Radiation Dose Effects.

System Development

In the area of System Development, Section 2.1.1 of Volume 2 of the Proposal states:

"Adding an MRS to the authorized system would result in more complete and more certain information with which to implement waste-acceptance, transportation and packaging functions. Separating these functions from repository development would allow their planning and development to proceed at an advanced schedule and independent from the uncertainties of repository siting and geologic site characterization.... As a result, the MRS system would provide earlier certainty about the location for the transportation control point and more definite technical design information for use in planning system interactions, including fuel acceptance and packaging decisions."

With the changes in the schedule for the initial operations of the first repository and the MRS, the system development effects of adding an MRS remain essentially unchanged. MRS operations continue to precede the first repository by several years (five years with the revised schedule instead of two years) and provide similar benefits of early system development as presented in the Proposal. In addition, the revised schedule for the system will continue to allow the Department to derive institutional benefits from the interactions with the MRS host state. Institutional benefits to the repository program are also expected to result from the early opportunity to demonstrate that facilities developed under the NWPA are safe and that in developing these facilities the Department is a responsible corporate citizen and neighbor.

System Operations

Section 2.1.2, of Volume 2 states:

"The MRS facility would increase the flexibility of and DOE's control over transportation activities and fuel-acceptance and emplacement strategies and thereby increase operating efficiency and reliability relative to the no-MRS system. By centrally locating the MRS facility to the eastern nuclear reactors, the MRS would act as a staging area and control point for transporting spent fuel from reactors to the first repository. Having a control point closer to the reactors would simplify the control of the transportation function compared to the no-MRS system. The control point also would significantly reduce the number of cross country shipments through the use of larger rail casks and multi-cask shipments. The overall transportation activities would be reduced, although waste transportation activities would increase in the area immediately surrounding the MRS facility."

"Locating storage capability at the MRS site would improve the reliability and efficiency of the waste management system. The MRS facility would permit a larger spent-fuel receipt rate in the initial years of operation. The larger receipt rate would reduce the buildup of stored spent fuel at reactors and improve the efficiency and timeliness of the waste acceptance process. The storage capability at the MRS site would also provide relatively inexpensive contingency storage in case of changes to the repository emplacement schedule. Storage would also provide an operational buffer between waste-acceptance and waste-emplacement operations, which would give the overall system greater flexibility and reliability because operating disruptions would not quickly cascade through the system. The emplacement operation could also be more efficient because waste package heat loads could be easily tailored to emplacement characteristics of the repository medium."

As in the case of system development, the benefits of the MRS to the overall operations of the waste management system have not been changed to any great extent by the revised system assumptions. The main departure from the basis for the original analysis stems from the example waste acceptance schedule presented in the draft Mission Plan Amendment. This acceptance schedule increases the MRS annual receipt rate to 2650 MTU, increases the total throughput of the facility to 59,760 MTU and changes the manner in which the storage field at the MRS is filled. The revised schedule also changes the peak amount of spent fuel that is placed in storage at the MRS from 11,150 MTU (February 1986 Proposal) to 14,700 MTU (draft Mission Plan Amendment).

With the schedule changes outlined in the draft Mission Plan Amendment, the MRS facility becomes critical to the Department's ability to receive spent fuel from utilities starting in 1998. Without an MRS in the system, utilities will not be able to begin shipment of their spent fuel inventories until the first repository begins operation in 2003, and then initially at a rate substantially less than the requirement for additional storage at reactor sites. The revised schedule essentially fills the MRS storage field to near the proposed 15,000 MTU limit, ten years after the system begins operation in 1998. The revised waste acceptance schedule presented in the draft Mission Plan Amendment provides less flexibility than the February 1986 Proposal's waste acceptance schedule. However, the draft Amendment schedule is only the current best estimate of how the system may operate and is subject to variation, possibly as a result of comments on the draft Amendment from the States and Tribes and other interested parties. The Department will be continually reviewing waste acceptance schedules with the intent of operating the waste management system in the most effective and efficient manner possible.

Regarding the changes in spent fuel projections, the updated EIA spent fuel projections are accommodated in the example waste acceptance schedule addressed above. Although a 15,000 MTU storage limit is being proposed for the MRS, the effects of the updated data are minimal on the assessed need for an MRS, since the amounts of at-reactor storage that could be offset by the MRS storage field do not differ greatly between the two sets of data projections.

System Cost

Executive Overview, Volume 2 of the Proposal states:

"Adding a site at which spent fuel preparation and packaging operations take place also has some costs relative to the no-MRS system. While costs are reduced at the repository site with the addition of an MRS facility, there is a net increase in facility construction and operating costs and transportation costs in the federal portion of the system of $1.4 to $2.0 billion because of the provision of site support services at both the MRS and repository sites."

The costs of the MRS facility have not changed during the past year. These costs were based on the conceptual design of the MRS facility that was completed in late 1985. The costs for the total waste management system and the integration of the MRS into the waste management system are annually addressed by the Department in the Total System Life Cycle Cost (TSLCC) estimate. The April 1986 TSLCC estimate for the cost impact of MRS on the waste management system indicated that the incorporation of MRS would increase total system costs in the range of $1.6 to $2.6 billion. The 1987 TSLCC estimate, that will be formally published later this year, addresses the cost effects of the draft Mission Plan Amendment of the first repository along with the different operating schedule being proposed for the MRS in servicing the first repository. In addition, the 1987 TSLCC analysis incorporates changes in the analytical data base regarding transportation system assumptions. Consistent with prior years, the 1987 TSLCC estimate continues to be based on the February 1986 Proposal's estimate for the total MRS facility cost with appropriate escalation factors. The 1987 TSLCC estimate for the cost impact of the MRS will show that the incorporation of MRS would increase total waste management system costs by about $1.5 to $1.6 billion, less than 5% of the total system costs. The reduction in the cost impact of MRS on the waste management system from the 1986 TSLCC estimate to the 1987 estimate was brought about by the use of repository site specific waste canisters at the MRS that are less costly and result in increased cost efficiency in the transportation system. Given the total costs of the waste management system, the new TSLCC results have not altered the Department's original conclusion regarding the total system cost impact of the inclusion of the MRS as presented in the Proposal that the incremental costs due to the inclusion of an MRS constitute a small percentage of the total system cost and are within the uncertainty range of current cost estimates for a waste management system without an MRS facility.

Radiation Dose Effects

Section 2.1.4, Volume 2 of the Proposal states:

"In the MRS system, additional spent-fuel-handling operations would slightly increase occupational exposure, although the doses received by individual workers would be strictly regulated in either system. Public exposure, on the other hand, would be reduced slightly because of reductions in exposure from spent-fuel transportation."

Although some of the operating parameters of the MRS have been modified, the overall conclusions of the total exposure analysis originally prepared for the Proposal remain unchanged, since the analysis was done for a transportation system throughput of 62,000 MTU which bounds the new estimated level.

Second Repository Deferral

In reevaluating the need for an MRS facility in the waste management system using the revised system assumptions presented in the draft Mission Plan Amendment, the Department did not identify any impact on the MRS arising from the indefinite postponement of site specific work for a second repository. This conclusion is consistent with the original intent of the MRS Proposal, which did not assume any relationship between the MRS and the second repository.

Effects on Volume 2. Part 2-Detailed Site-Design Evaluation

The impact of those system changes identified above has been evaluated and reviewed by the Department with respect to the conclusions drawn regarding the environmental impacts associated with the site-design combinations. These environmental areas include: radiology, air quality, water quality and use, ecology, land use, socioeconomic, resource, aesthetic and transportation impacts, and the relative advantages and disadvantages of the six site-design combinations.

Section 6.5, Volume 2 of the Proposal states, in part:

"These incremental impacts are estimated for a bounding annual throughput of up to 3,600 MTU. Since the planned throughput is about 2,500 MTU per year, use of the design throughput of 3,600 MTU per year yields conservative results. In addition, transportation impacts are estimated for a total 26-year throughput of 62,000 MTU. Most impacts vary only slightly among the three candidate sites and two storage designs; exceptions to this are noted, and relative advantages and disadvantages are identified."

Under the draft Mission Plan Amendment, the annual MRS facility throughput increases from 2500 MTU to 2650 MTU per year. Since annual throughput related impacts were evaluated at the level of 3600 MTU per year,the existing analysis remains conservative and impacts at the new levels are bounded by the analyses done at the 3600 MTU levels.

Likewise, changes in total MRS facility throughput from 53,000 MTU to 59,760 MTU over a 31 year rather than 26 year operating time period are believed to be little changed or bounded by the existing analyses.

Radiological Impacts

Preliminary analyses showed that radon released from soil excavation during construction would be orders of magnitude below regulatory limits. Since construction plans have not changed, other than to be delayed by approximately 1 year, these levels are expected to remain unchanged.

The environmental analysis concluded that: "The doses to an individual are below annual regulatory limits [0.025 rem annually to the maximally exposed individual for normal operations and 5 rem for any design basis accident (10 CFR 72)]. For normal operations, the dose to the maximally exposed individual for normal operations from transportation is not expected to exceed 0.005 rem from each prolonged exposure event." The design basis accidents at the MRS remain unchanged, thus the analysis of their projected impacts remains unchanged. Since the transportation impacts were analyzed for total shipments of 62,000 MTU this bounds the updated estimated shipment level of 59,760 MTU.

The draft Mission Plan Amendment does not change the total amount of the spent fuel to be shipped to the geologic repository from the reactors. Improvements in the transportation system, e.g. larger capacity truck casks, may slightly lower impacts estimated in the assessment with respect to total population doses due to shipment of spent fuel.

Air Quality Impacts

Air quality impacts assessed in the environmental analyses were based on "worst case" emissions or maximum impact for each phase of facility activity. Since the proposed design and sites have not changed, construction impacts should remain as estimated in the present analyses.

Operational impacts were analyzed on an annual basis for operation at a level of 3600 MTU throughput. Thus, operational emissions already estimated as non-significant, should remain within those levels. Operation will continue for five years longer should the draft Mission Plan Amendment be implemented. This continuance of operations is not expected to result in any significant additional impacts.

Plans for decommissioning activities have not changed. Thus, estimated air impacts remain unchanged.

Water Quality and Use Impacts

Plans for construction and decommissioning have not changed. Estimated water quality and use impacts are expected to remain at existing estimated levels.

Annual operational water impacts will remain at or below the previously evaluated levels, since operation was assumed to be at 3600 MTU. Operation for five additional years at those levels is not expected to cause any additional significant impact.

Ecological Impacts

The greatest part of the ecological impact of an MRS facility is the clearing of land and subsequent loss of the land to production and ecological processes. No change in the site area is contemplated. Thus, the ecological impacts are expected to remain as previously estimated.

Land Use Impacts

The proposed sites and designs for the MRS facility have not changed. As a result, land use impacts will remain as previously estimated, with the exception that the land is expected to be used for an operational facility for five years longer.

Socioeconomic Impacts

Socioeconomic impacts postulated to arise from facility construction, operation and decommissioning are expected to remain at or very near the levels previously estimated in the environmental assessment. The impacts would begin approximately two years later due to the two year delay in operating the MRS facility. Annual operational impacts would remain at or below the previously estimated levels for operation at 3600 MTU per year; however, cumulative operational impacts could increase slightly due to the five year increase in operating time.

Resource Impacts

The resources necessary to build the facility remain unchanged. Resources to operate the facility remain the same on an annual basis and will increase slightly on a cumulative basis due to the additional five years of operation. This slight increase is not expected to generate any significant impacts.

Aesthetic Impacts

Noise levels and visual impacts of the MRS facility remain unchanged as neither the sites nor designs have been changed.

Transportation Impacts

Transportation impacts estimated in the environmental assessment were done for a "bounding case" where shipments related to the MRS were assumed to be at a level of 62,000 MTU with shipping modes either 100% rail or a split of 30% truck and 70% rail. Shipments from the MRS to a repository were estimated to be by dedicated trains. Transportation impacts included both reactor-to-MRS and MRS-to-repository.

The transportation cask capacities are expected to be somewhat increased for the reactor-to-MRS leg. Since the expected increase in the amount of fuel to be shipped through the MRS (59,750 MTU from 53,000 MTU) is bounded by the existing analysis at 62,000 MTU, impacts due to increases in transportation cask capacities remains bounded by the existing analysis. Some impacts may be slightly reduced. Estimated costs for shipments are similarly bounded.

Transportation cask capacities for the MRS-to-repository shipment of spent fuel may be slightly reduced. This could either increase the number of rail casks needed to accomplish similar shipment levels or increase the number of shipments. The estimated impact levels for the MRS-to-repository shipments were very low and even the addition of a few shipments over a longer period of time should not increase impacts to a level of significance.

Annual traffic impacts should remain within those analyzed in the environmental assessment since the analyses were done with a bounding annual receipt rate of 3600 MTU. However, traffic impacts will continue to occur for a five year period longer than that considered in the environmental assessment. This is not expected to cause a significant increase in the traffic impacts estimated in the assessment as the traffic impacts were already quite minimal.

Radiological and nonradiological impacts of transportation increase proportionate to the number of shipments. These impacts for annual shipment rates of 3600 MTU and total shipments of 62,000 MTU were not significant and indeed were very small. The change in the number of years of MRS operation (an additional five years) should spread the impacts of the shipments over a slightly longer period which is not expected to result in a significant change in transportation impacts.

Relative Advantages and Disadvantages of the Six Site-Design Combinations

The relative advantages and disadvantages of the site-design combinations are expected to remain as analyzed in the environmental assessment because all changes which could affect the environmental impacts of each combination would cause the same relative changes in impacts at each site.

Conclusion

The impacts related to annual waste throughput of the MRS facility were conservatively analyzed at a level of 3600 MTU per year. This level bounds the new estimated throughput level of 2650 MTU per year. Impacts related to the transportation of spent fuel in a waste management system which includes an MRS facility were assessed on the basis of a conservative throughput of 62,000 MTU over a 26 year operational period. This bounds the transportation system impacts which are now estimated at a throughput of 62,000 MTU spread over 31 years.

The MRS facility total throughput increases under the latest estimates from 53,000 MTU to 59,760 MTU and the facility will remain operational for five additional years (26 to 31 years). Since the majority of ecological impacts result from the construction of the facility, limited additional throughput and additional operating time are not expected to cause significant additional impacts over those analyzed in the environmental assessment. The MRS has been shown to be a facility which can be operated without significant threat to the public health and safety. It is not expected that an additional five years of operation would change that conclusion.

As a result, the program changes recommended in the draft Mission Plan Amendment and the changes in the technical bases over the last year do not alter the conclusions of the environmental assessment in such a manner as to require issuance of a supplement to or an updated environmental assessment.

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Monitored Retrievable Storage Submission to Congress

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Environmental Assessment for a Monitored Retrievable Storage Facility

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

PREFACE

On January 7, 1983, President Reagan signed the Nuclear Waste Policy Act (NWPA) of 1982, which establishes the federal policy for disposal of commercial spent nuclear fuel and high-level radioactive waste. The NWPA instructs the Secretary of Energy to start accepting spent fuel and high-level waste for disposal in a deep geologic repository by January 1998. The NWPA also states that storage of high-level radioactive waste or spent fuel in a monitored retrievable storage (MRS) facility is an option for providing safe and reliable management of such waste or spent fuel.

Section 141 of the NWPA instructs the Secretary of Energy to prepare a proposal for construction of one or more MRS facilities. The NWPA states that the proposal to Congress shall include the establishment of a federal program for the siting, development, construction, and operation of such facilities; a plan for funding the construction and operation of such facilities; a plan for integrating the facilities with other storage and disposal facilities authorized in the NWPA; and site-specific designs and cost estimates. The proposal is to be accompanied by an environmental assessment.

In response to these requirements, the Office of Civilian Radioactive Waste Management in the Department of Energy (DOE) has prepared this submission to Congress. The submission consists of three volumes, described below. The required site-specific designs and cost estimates are incorporated by reference.

The first volume, The MRS Proposal, describes the DOE's proposal to construct and operate an MRS facility at the Clinch River Site in Roane County, Tennessee. The proposed MRS facility would be an integral part of the federal waste management system and would perform most of the waste-preparation functions before emplacement in a repository.

The second volume, The Environmental Assessment, is divided into two parts. Part 1 examines the need for and feasibility of constructing an MRS facility as an integral component of the waste management system. Part 2 includes descriptions of two facility design concepts at each of three candidate sites, and a detailed assessment and comparison of the environmental impacts associated with each of the six site-design combinations.

The third volume, The Program Plan, describes the activities, costs and schedules for establishing a federal program to site, develop, construct, and operate an MRS facility, if approved by Congress. It includes plans for funding the construction and operation of an MRS facility and for integrating the facility with other waste management facilities authorized in the NWPA.

EXECUTIVE OVERVIEW

The Department of Energy (DOE) has prepared this Environmental Assessment (EA) to support the DOE proposal to Congress to construct and operate a facility for monitored retrievable storage (MRS) of spent fuel at a site on the Clinch River in the Roane County portion of Oak Ridge, Tennessee. It was prepared in compliance with the requirements of the Nuclear Waste Policy Act (NWPA) of 1982. The first part of this document is an assessment of the value of, need for, and feasibility of an MRS facility as an integral component of the waste management system. The second part is an assessment and comparison of the potential environmental impacts projected for each of six site-design combinations (two MRS facility design concepts and three candidate sites). The MRS facility would be centrally located with respect to existing reactors and would receive and canister spent fuel in preparation for shipment to and disposal in a geologic repository.

The decision to recommend or approve the construction and operation of the MRS facility described in this environmental assessment must be based on a judgment about whether the value the MRS facility adds to the waste management system outweighs the potential impacts. The DOE has judged that the system development and operating improvements clearly outweigh the slight fiscal and environmental impacts which would be incurred. The evaluations that led to this judgment are reported in this volume and summarized below.

OVERALL CONCLUSIONS

The DOE has concluded that adding an MRS facility at the Clinch River site makes the overall waste management system easier to implement and operate. The value of these improvements is difficult to quantify in terms of cost or schedule reductions. They directly increase confidence in the timely operation of the system and spent-fuel disposal. System development is made easier because more complete and more certain information is available earlier to implement the waste acceptance, transportation, and packaging functions. For example, judgments about routing and logistics of transporting spent fuel from reactors can be based on a known destination point and made independent from the selection of the first repository site. System operation is made easier and more reliable by increasing the amount of operational control exercised by the DOE and by making the pre-emplacement operations independent of the waste emplacement operations. For example, physical transfer of spent fuel from utilities to the DOE and packaging for disposal can proceed independent of any short-term disruptions of the waste emplacement operations. While there are other ways to achieve the operational advantages of the MRS facility, none of the alternatives or combination of alternatives examined provide the system development benefits and the same level of managerial control or ease of implementation.

Specific system improvements include:

- a clear single focal point for system integration and planning of waste receipt, packaging and transportation
- early and clearer identification of potential transportation routes and more time to work with state and local governments to resolve technical and institutional issues
- more certain information on design and schedule for key decisions about waste acceptance and transportation routing and logistics
- reduced opportunity for delays in the development of transportation, acceptance, and packaging functions to affect repository schedules
- more flexibility and control over schedules for unloading fuel from reactor storage and for repository loading
- greater DOE control over transportation logistics and fewer opportunities for the public to experience impacts from spent fuel transport.

The negative effects of making the system easier to develop and more reliable are: 1) an increase of $1.4 to $2.0 billion in construction and operating costs for facilities in the federal portion of the system,[a] and 2) a potential for temporary degradation (nonradiologic) of ambient air and water quality in the immediate vicinity of the Clinch River site during construction activities (e.g., site clearing and excavation) and loss of 320 acres of land at the Clinch River site for ecological processes. These environmental impacts are less than or equivalent to those expected for any moderately sized industrial facility. In addition, there is the loss of a site to the city of Oak Ridge for industrial diversification and resulting potential loss of tax revenues. The impacts of spent-fuel transportation are redistributed within the national system. They are reduced overall but increased in the vicinity of the Clinch River site.

<u>The DOE has concluded, with reasonable assurance, that the MRS facility and program are feasible</u>:

- The technical and engineering requirements can be met with current technology.

(a) Utility storage expenditures are expected to be reduced $0.15 to $0.45 billion assuming an operating repository in 1998.

- The facility can be developed for $970 million and operated for approximately $70 million annually.
- The facility can meet NRC regulatory requirements and can gain license approval.
- The facility can be operated and decommissioned without adverse effects on public health and safety.
- The facility can meet all environmental and land-use requirements of the federal government.[a]
- The facility can be constructed and begin operations 10 years after approval.

CONCLUSIONS RELATED TO THE VALUE OF AN MRS FACILITY

The DOE believes that the need for or value of the proposed MRS facility derives from its ability to improve the overall performance of the waste management system with small and acceptable adverse effects. The waste management system could be operated safely without an MRS facility, but including the facility improves the DOE's ability to develop and operate the functions of the system: acceptance of spent fuel; transportation of spent fuel from reactor sites to disposal sites; preparation and packaging of wastes for disposal; and permanent disposal in geologic repositories. The DOE based its assessment of the value of the MRS facility on comparisons between waste management systems with and without an MRS facility, shown in Figure 1. The comparisons were structured to evaluate the capability of those systems to meet the objectives and requirements of the waste management system. The potential improvements to the system were compared to projected system costs and potential changes in radiation exposure to the public and workers.

Both the no-MRS system and MRS system are capable of meeting the functional requirements of the waste management system, but in different ways and with different vulnerabilities. For the no-MRS system, all of the pre-waste emplacement functions are performed at the repository or reactors. The DOE would start accepting spent nuclear fuel for direct shipment to the first repository in 1998. All preparation and packaging for disposal would be done at the repository, although some utilities may consolidate their spent fuel before acceptance by the DOE. The transportation system would move spent fuel

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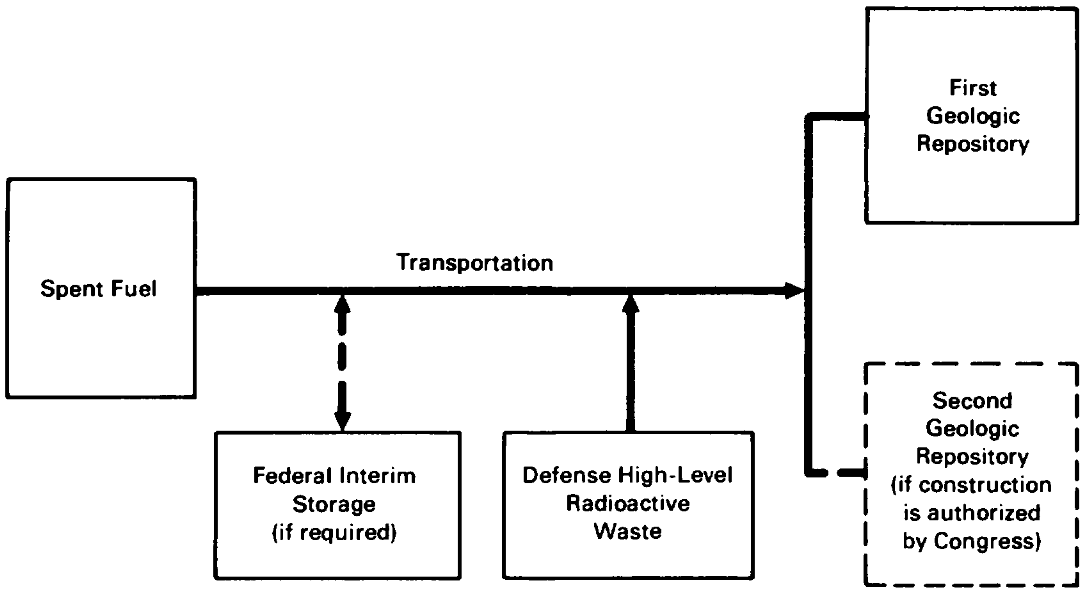
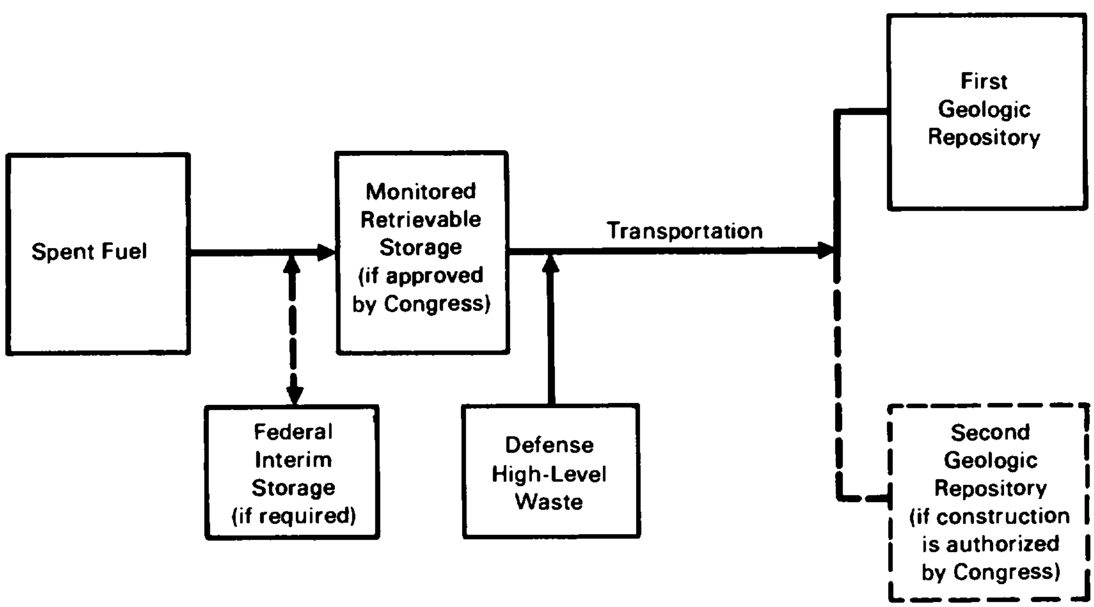
(a) The facility would also be designed to meet the applicable land-use and environmental requirements of the State of Tennessee and local jurisdictions.



No - MRS System



MRS System

FIGURE 1. Alternative Federal Waste Management Systems

from more than 80 reactors sites, mostly in the eastern part of the United States, to the first repository. No significant amounts of storage would be provided in the federal portion of the no-MRS system.

In contrast to the no-MRS system, the MRS system would have a separate facility centrally located to the majority of reactor sites that would provide packaging for spent fuel shipped from eastern and mid-western reactors and scheduled for disposal in the first repository. The MRS facility could begin in 1996 to receive and package spent fuel for disposal. Present plans call for fuel consolidation and canistering to occur at the MRS facility. Spent fuel consolidated into standard canisters would be shipped from the MRS facility to the repository in large rail casks and dedicated trains. A final disposal container (or overpack) would be added at the repository to the MRS-prepared canister. These changes result in fewer total transportation shipment-miles traveled relative to the no-MRS system.

The projected (non-environmental) effects (positive and negative) of adding the proposed MRS facility to the waste management system are summarized in Table 1. These effects derive from two principal differences from the no-MRS systems:

- The MRS facility requires a site separate from the repository and central to most reactors for preparing spent fuel for disposal.
- The MRS system adds a spent-fuel storage capability of up to 15,000 metric tons of uranium (MTU).

Adding a facility separate from the repository for preparing spent fuel for disposal allows the reactor unloading and the repository loading functions to be planned and developed independently. This separation would allow the DOE to accept spent-fuel more than a year earlier and at an increased rate during the first years of operation. The MRS site would be known with certainty four to five years before the selection of the site for the first repository. In addition, the MRS facility design is expected to be licensed by the NRC about three years earlier than the repository. As a result, the MRS system would provide a more certain location for integrating system functions and better technical design information and experience for use in planning system interfaces. A disadvantage, or cost, would be incurred, however, in developing and operating two facilities.

By being located central to most nuclear reactors, the MRS facility would act as a staging area and control point for the transportation of spent fuel from reactors to the first repository. This would reduce the total shipment-miles traveled and thereby lessen the interaction of the transportation

TABLE 1. System Effects of Adding an MRS Facility to the Authorized System

	System Development (Section 2.2)	System Operations (Section 2.3)	System Cost (Section 2.4)	Radiation Exposure (Section 2.5)
Overall	Makes system functions easier to develop by simplifying decisions and applying more certain information. Provides focal point for integrating all pre-emplacement functions.	Improves system efficiency and reliability because acceptance and emplacement can be operated independently.	Increases costs of facilities and transportation in the federal portion of the system by $1.4 to 2.0 billion.	Slightly lower public exposure and potential slight increase in occupational exposure.
Waste Acceptance	Provides better information for setting acceptance commitments; MRS facility design leads the repository design by 2 or more years.	Allows higher initial spent-fuel receipt from utilities, which reduces the need for some supplemental storage by utilities. Provides flexibility in meeting commitments if emplacement rates are reduced or disrupted.	Storage costs avoided by utilities would vary from $150 to $450 million with on-time repository and could be as much as $0.6 to $1.7 billion with changes in the repository availability.	No change.
Transportation	Allows longer lead-time for route/logistics planning, but requires earlier full-scale operation.	Improves DOE control over spent-fuel transportation and reduces the number of shipment miles and resulting physical interactions with the public. Reduces number of accidents.	Decreases transportation costs by as much as $0.2 billion depending upon repository location.	Slightly decreases public exposure--already very low.
Packaging	Provides focus for applying on-going rod consolidation experience.	Requires some duplication of handling and packaging capability.	Increases facility costs about $1.6-$2.0 billion, which includes a storage inventory of 12,000 MTU costing $0.4 billion.	Potential for slight increase in occupational exposure due to additional cask-handling steps. The latter would be within regulated limits, however.
Disposal	Reduces potential for repository operation to be constrained by pre-emplacement functions, but requires MRS operation for system operation and disposal (adds another potential pinch point).	Simplifies surface facilities at the repository.	Insufficient information to identify differences.	No change.

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function with the public. However, while the overall transportation effects would be reduced, the transportation effects would increase in the area surrounding the MRS facility.

The storage capability of the MRS facility would have three effects. First, it would provide a better basis for utilities to plan for their storage needs, reduce the buildup of spent fuel at reactors, and improve the efficiency of the waste acceptance process by increasing the spent fuel receipt rate in the initial years of system operation. Second, it would provide relatively inexpensive contingency storage in case of delays in the repository.[a] Third, it would provide an operational buffer between waste acceptance and waste emplacement operations which would allow both operations to operate independently, thus giving the overall system greater flexibility and reliability. Operating disruptions would not cascade through the system. The emplacement operation could also be more efficient since waste package heat loads could be tailored to decrease emplacement costs. During early years of system operation, this buffer allows flexibility in balancing waste acceptance commitments made to utilities in 1991 (which will likely be lower than the MRS system acceptance capabilities) with start-up considerations and still somewhat uncertain repository acceptance rates and operating considerations. The majority of operating efficiencies gained in later years could also be achieved by increasing at-repository buffer storage. The early-year benefits are unique to the MRS system.

Adding a site at which spent fuel preparation and packaging operations take place also has some costs relative to the no-MRS system. While costs are reduced at the repository site with the addition of an MRS facility, there is a net increase in facility construction and operating costs and transportation costs in the federal portion of the system of $1.4 to $2.0 billion because of the provision of site support services at both the MRS and repository sites. This cost includes $0.4 billion for 12,000 MTU of storage capacity that would result from anticipated facility operation schedules and a reduction in transportation costs of up to $0.2 billion. There are also some additional spent fuel handling operations in the MRS system which contribute to its higher total cost and could lead to a slight increase in occupational exposure even though the dose received by individual workers would be strictly regulated in either system. Public radiation exposure, on the other hand, would be reduced slightly from reductions in both routine exposure and accident exposure from spent-fuel transportation.

The increased federal costs will be somewhat balanced by avoided storage costs by utilities ranging from $0.15 to 0.45 billion assuming repository

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(a) The relative cost advantages of at-reactor or MRS contingency storage depend upon the length of the potential delay in repository availability.

startup in 1998. The MRS system, thus, would reduce storage expenditures by nuclear utilities whose fees generate the Nuclear Waste Fund. The MRS system would provide storage capacity which could be used to accelerate the initial rate at which spent fuel could be unloaded from reactors or to provide contingency storage in case of delays in the repository program. The cost of spent fuel storage at the MRS facility is $35 to $40 per kilogram while the cost to utilities of spent-fuel storage beyond the capacity attainable with maximum reracking of existing storage pools is $40 to $110 per kilogram. Thus, the actual cost savings of storage provided by the MRS facility would depend upon the amount of at-reactor storage that is offset and the cost to the utilities of providing that storage.

In comparing the relative merits of the no-MRS and MRS systems, a specific configuration for each system was assumed. To provide a more complete perspective for comparison purposes, variations in the arrangement of both systems were considered.

The DOE examined alternative improvements in the no-MRS system in three generic categories that align with equivalent improvements obtained from deploying an MRS facility. These are:

- expanded lag storage at the repository to provide a buffer between waste acceptance and waste emplacement

- expanded storage at reactor sites, either by adding modular dry storage or in-pool consolidation of spent fuel, to provide contingency storage if repository operations were delayed

- use of larger shipping casks and multi-cask shipments, thereby increasing the tonnage per shipment and reducing the number of discrete shipments

The general conclusion of this analysis is that while some of these alternatives could potentially improve individual aspects of waste management system performance, no single alternative or combination of alternatives gains the equivalent or better system improvements that can be achieved in the MRS system. In particular, none of these alternatives would provide the system development benefits which are a key advantage of the MRS system relative to the no-MRS system.

CONCLUSIONS RELATING TO THE FEASIBILITY OF THE MRS FACILITY

The DOE has concluded that the MRS facility is feasible because it is based on established technologies and its design, licensing and construction are typical of, but less demanding than activities that have been well demonstrated with many other nuclear facilities.

Technical Maturity

The three principal technologies needed in the MRS facility are 1) the handling and loading/unloading of large shielded shipping casks, 2) the disassembly, consolidation and canistering of spent fuel, and 3) the storage of spent fuel. Handling and canistering are required regardless of whether there is an MRS facility. Shielded casks have been used in the nuclear industry since its inception and the equipment for handling and loading/unloading these large heavy casks has been regularly demonstrated.

The removal of fuel rods from assemblies has been carried out in reactor storage pools and hot cells for many years, both for fuel rod inspection and for reconstitution of fuel assemblies for further utilization in reactors. Devices and techniques for the consolidation of rods in a canister have been demonstrated for spent fuel in reactor pools and for unirradiated fuel in a dry environment. Inserting inert gas into the canister voids, welding (sealing) the canister, and helium leak testing are operations that have been performed in the nuclear power industry for many years but not at the production rates proposed for the MRS facility. Spent nuclear fuel has been inspected and stored dry in hot cells, casks, and drywells and shipped dry in casks. Encapsulation and storage of radioactive waste is routine practice at federal government nuclear facilities. Ongoing utility, industry and federal government programs are further refining the application of consolidation and dry storage technologies to the production levels anticipated in both the MRS facility and repository.

Design, Licensing, and Construction

The DOE has evaluated the issues involved in the design, and construction of an MRS facility, has completed a preliminary design of the MRS, and has developed a schedule for completing the design, licensing, construction and startup of the MRS facility. Based on these evaluations, it is judged that the design, licensing and construction activities for an MRS facility are similar to, but less demanding than activities for many other nuclear facilities. Site characterization and analyses of impacts on the environment around an MRS facility will be performed for the most part to the same level of detail as analyses for the licensing of a commercial nuclear power plant. Because there are no new technologies involved in the licensing of an MRS facility and because an MRS facility does not contain a self-sustaining nuclear chain reaction, its safety features are much less complex and licensing complexities are expected to be similarly less than those experienced with a nuclear power plant.

It is therefore believed that, starting from the date of congressional authorization of an MRS facility, a license application can be submitted in 2.5 years, an MRS license can be received within 5 years, and the facility can be constructed and be in the startup phase within 10 years.

CONCLUSIONS RELATED TO ENVIRONMENTAL IMPACTS OF AN MRS FACILITY

The DOE evaluated the environmental impacts of six MRS site-design combinations, i.e., three candidate sites and two design concepts. This evaluation was designed 1) to compare the environmental effects of specific site-design combinations and 2) to reveal specific risks or impacts that derive from particular elements of the MRS facility design.

The notable effects of developing any of the site-design combinations include: 1) a potential for temporary degradation of ambient air quality (from total suspended particulates--TSP) and water quality (from high-suspended solids) during construction; 2) the clearing of several hundred acres of land and its subsequent loss to production and ecological processes; and 3) the loss of the site to the community for development of other industries and resulting potential loss of additional tax revenues. For the Clinch River site, the economic development plans of the City of Oak Ridge seek diversification away from DOE facilities. Thus, the cost of development at these sites is qualitatively different than for the Oak Ridge Reservation and Hartsville sites. In no other areas (including radiologic impacts, land and water use, availability of utilities and other resources, aesthetic characteristics or transportation impacts) were effects found that exceeded regulatory limits. The DOE found no design features (for either storage concept) that created significant adverse impacts nor any that resulted in significantly different effects across the three candidate sites. Thus, the DOE found no environmental reason to prefer one site-design combination over any other.

The DOE has concluded that the environmental effects reported here represent the additional environmental effects incurred by adding the MRS facility to the authorized system. The DOE did not directly compare the environmental impacts of the proposed MRS system to the environmental impacts of the authorized system. First, there is insufficient information at present to satisfactorily identify the full range of environmental effects of the authorized system since the repository facilities, waste package specifications, and other parts of the system are still in conceptual stages of development. Second, the environmental impacts of the authorized system were implicitly judged to be acceptable in the congressional approval of that system. The range and types of effects of the authorized system have been evaluated and are reported in three sets of analytic reports.[a] Third, the addition of the MRS facility in the system either has little effect or has the potential to reduce the impacts in other components of the system. Changes in the operations at the utilities are largely independent of the MRS facility. The modifications to the transportation system are reported in this document. The modifications to the repository by adding an MRS are likely to reduce the environmental impacts at the repository since functions are removed from that facility. Thus, the effects identified in this document can conservatively be considered additions to a baseline of effects from the authorized no-MRS system.

The three sites identified by DOE as candidate sites in April 1985 are all located in Tennessee and include: the Clinch River Breeder Reactor Site (Clinch River site); a site on the DOE's Oak Ridge Reservation (Oak Ridge site); and the Tennessee Valley Authority's (TVA's) Hartsville Nuclear Power Plant site (Hartsville site). The process by which these sites were identified and evaluated for purposes of candidate site selection is reported in detail in three documents: DOE/RW-0023; PNL-5424; and DOE/NBB-0071.

The two design concepts evaluated are based on identical receiving and handling concepts but different spent-fuel storage concepts: sealed storage cask and field drywell. These concepts are fully described in Part 2 and differ in use of construction materials and in storage of fuel above and below ground, respectively. Both are modular concepts which allow for operating flexibility.

Radiological Impacts

The radiological doses received by the public for all site-design combinations from normal facility operation, postulated accidents, and transportation of spent fuel to and from the facility are below the regulatory limits set by the NRC [0.025 rem annually for the maximally exposed individual for normal operations, and 5 rem for any design basis accident (10 CFR 72)]. The population doses are consistently less than 1% of the dose received by the same population group from naturally occurring background radiation.

There is little difference in the effects between site-design combinations. The projected population dose from normal operations is indistinguishable across the site-design combinations and calculated to be 20 person-rem. The maximally exposed individual for all combinations is projected to receive less than 0.001 rem per year during normal operations. During accident

(a) 1) DOE's Generic EIS on the Management of Commercially Generated Radioactive Waste (DOE/EIS-0046F), 2) DOE's EAs on the nine potential candidate first repository sites, and 3) the Nuclear Regulatory Commission's Final Waste Confidence Decision.

conditions, the population dose ranges from 0.03 to 0.6 person-rem for sealed storage cask at all three sites and field drywell at Oak Ridge, respectively. The maximally exposed individual receives a dose during accident conditions ranging from 0.0027 to 0.29 rem for the storage cask at Hartsville and the field drywell at Oak Ridge, respectively. The population dose from transportation is expected to be 200 person-rem for all site-design combinations. Table 2 presents a summary of the projected radiological doses to the public from different categories of events.

Air Quality Impacts

Preconstruction and construction activities are expected to degrade, temporarily, the ambient air quality in the immediate vicinity of the site. A preliminary assessment indicates that short-term total suspended particulate (TSP) standards may be exceeded at the fenceline at the Clinch River and Oak Ridge sites due to fugitive dust from land disturbance and heavy vehicle traffic. During operation of the MRS facility, no significant quantities of emissions (as defined in 40 CFR 51) are anticipated from any stationary source. A summary of emission rates[a] from construction and operation of an MRS facility is given in Table 3.

Waste heat generated by the facility is expected to include about 22 MW from the storage area and 25 MW (rated capacity) from the cooling tower. This is less than the waste heat generated by the primary aluminum smelter plant located near Knoxville. Environmental effects from waste heat are difficult to predict. No perceptible changes in the downwind environment are anticipated.

Decommissioning activities do not include major demolition or regrading. Therefore, impacts from postulated decommissioning activities are negligible. Decommissioning of the drywell storage concept will require some regrading to fully cover the drywells.

The air quality impacts for the various combinations of sites and concepts are mainly a function of air dispersion factors for each site. Since these dispersion factors do not differ significantly among the three sites, the DOE determined that no site-design combination exhibited an advantage over the other site-design combinations regarding air quality.

(a) Air quality impacts are based on emissions from "worst case," or maximum impact, for each phase of activity at the site.

TABLE 2. Summary of Radiological Impacts from an MRS Facility as Compared to Natural Background Radiation

Activity/Population Group	Sealed Storage Cask: Clinch River	Sealed Storage Cask: Oak Ridge	Sealed Storage Cask: Hartsville	Field Drywell: Clinch River	Field Drywell: Oak Ridge	Field Drywell: Hartsville
Normal Operations (Annual Dose)						
Maximally exposed individual (rem)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Population (person-rem)	20	20	20	20	20	20
Natural Background at the Site (person-rem)[a]	160,000	160,000	120,000	160,000	160,000	120,000
Operational Accident[b]						
Maximally exposed individual (rem)	0.0044	0.022	0.0027	0.17	0.29	0.075
Population (person-rem)	0.03	0.03	0.03	0.5	0.6	0.5
Transportation (Annual Dose)[c]						
Population (person-rem)	200	200	200	200	200	200
Natural Background Along Transportation Route (person-rem)[d]	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Transportation Accident[e]						
Maximally exposed individual (rem)	60	60	60	60	60	60

(a) Values reported for background represent the annual dose received by the local population (within 50 miles) from natural sources. Population values represent the dose received from one year of normal operation by the same population group. The individual doses represent the dose received by the maximally exposed individual (usually the nearest resident).

(b) The worst operational accident for the sealed storage cask design is a fuel assembly drop in the R&H building. For the field drywell design, the worst operational accident is a canister shearing incident. (See Section 6.1.1.3 for a description of these and other accidents).

(c) The transportation impacts result from spent fuel shipments to the MRS site and then to a geologic repository site. The impacts are from routine exposure estimates for a bounding scenario (3600 MTU/year by 30% truck/70% rail).

(d) Values reported for background represents the annual dose received by the population located within 800 m (0.5 miles) of the projected truck and rail spent-fuel shipment routes. The estimated population is 10-15 million and the average background radiation dose is 0.1 rem/person-year (i.e., 10 million people multiplied times 0.1 rem/person-year equals 1 million person-rem).

(e) This severe transportation accident has a probability of about one in one million accidents (Wilmot et al. 1983). It is assumed that the cask contains 84 PWR fuel assemblies (150-ton cask).

TABLE 3. Estimated Emissions from Construction and Operation and EPA's "Significant" Levels for Emission from 40 CFR 51 (tons/yr)

Pollutant	Annual Emissions: Construction[a]	Annual Emissions: Operation[a]	Significant Level
TSP	>50	<5	25
NO_x	--	9	40
SO_x	--	15	40
CO	--	3	100

(a) Mobile sources are not considered in 40 CFR 51.

Water Quality Impacts

During construction, water quality could be temporarily degraded from high-suspended solids content of the runoff. This will be mitigated by settling solids in runoff ponds prior to discharging the water to surface waters.

The MRS facility is designed so that there are no radioactive waterborne effluents discharged to the environment. Nonradioactive operations water (22,500 gallons per day) and sanitary sewage water (14,000 gallons per day) will be treated and released to surface water. Sludge from operational wastewater treatment and sanitary sewage treatment will be disposed of in appropriate offsite landfills.

Effluents from wastewater treatment will meet all State of Tennessee and United States Environmental Protection Agency (EPA) standards for industrial wastewater disposal and municipal and domestic wastewater disposal. Because all wastewater streams are to meet all applicable standards, effluents are expected to have minimal impact on surface water or ground water.

Ecological Impacts

The largest ecological impact at any of the three sites will be the clearing of land and subsequent loss of this land to production and ecological processes. Up to 320 acres (130 ha) are needed for the sealed storage cask design, and up to 465 acres (188 ha) for the field drywell concept. At both the Clinch River and Hartsville sites, significant portions of the area have already been affected by previous construction; thus, the loss of natural habitat will be less at these sites than if the facility were sited at Oak Ridge. In this respect, the Clinch River and Hartsville sites have an ecological advantage over the Oak Ridge site.

Socioeconomic Impacts

One of the major concerns expressed by Tennessee state and local officials has been socioeconomic impacts. Sensitivity to these concerns has led the Department to somewhat more extensive analysis in this area than is common in a standard environmental assessment. The major socioeconomic impact resulting from development of any of the site-design combinations is the loss of the site to other commercial development and resulting potential loss of additional tax revenues. In the absence of offsetting financial compensation, any demands the MRS facility or its employees create on public services would have to be met out of the general tax base. In the case of the Clinch River and Oak Ridge sites, this general effect is exacerbated because the city of Oak Ridge and Anderson and Roane counties are already heavily dependent on the federal government. The city of Oak Ridge has a clear goal to diversify its economic base away from dependence on federal government spending. Thus, the loss of potential tax base resulting from the development of the MRS facility at the Clinch River site is especially significant. There might also be losses in the level of local control over the economic base and accompanying feelings of loss of financial independence. Commercial development could also be impacted by the creation of an adverse development image for the local area, either through perpetuation of economic uncertainty or through fear of environmental hazards.

Some "standard" socioeconomic impacts, common to all industrial development projects, may be expected as a result of the MRS activities. The addition of a new facility causes economic growth through direct employment at the facility and through indirect effects on local employment and income. Depending on the skills needed at the facility, the jobs and incomes that are created attract people into the area (or reduce their out-migration) and create demands for housing, community services, and capital services such as utilities, roads, sewers, and schools. These standard socioeconomic effects are very similar for the two storage concepts and virtually identical for the Clinch River and Oak Ridge sites. The areas most likely to be affected noticeably by these standard socioeconomic effects are Anderson, Loudon, Morgan, Roane, and Knox counties (primary impact area) for the Clinch River and Oak Ridge sites. For the Hartsville area, the primary impact area consists of Trousdale, Macon, Smith, Sumner, and Wilson counties. Some impacts would also be felt in Davidson county. Table 4 summarizes some of the key standard socioeconomic effects for the three sites analyzed for the sealed storage cask design. The impacts are very similar for the field drywell concept.

The Clinch River/Oak Ridge region may have a greater technical labor force available locally, while the Hartsville site may have a greater construction labor force (if Davidson county is included in the comparison).

The Hartsville area has a lower assessed value per capita, more pupils per teacher, lower expenditures per pupil, and fewer medical staff per capita. In addition, some nearby cities have sewage systems already near capacity.

TABLE 4. Summary of Standard Socioeconomic Effects of a Sealed Storage Cask MRS[a]

Impact Area/ Socioeconomic Factor	Peak Construction Year Impact	Average Operating Year Impact	Average Decommissioning Year Impact
Clinch River/Oak Ridge primary impact area (including Knox County)			
Employment	2,800	1,200	480
Income (million 1985 $)	$78	$40	$16
Population	5,100	2,000	1,200
School enrollment	840	320	140
Local government revenues (million 1985 $)	$4.7	$2.0	$1.1
Local government expenditures (million 1985 $)	$4.3	$1.7	$0.9
Hartsville primary impact area (including Davidson County)			
Employment	2,700	1,300	600
Income (million 1985 $)	$76	$42	$18
Population	4,200	1,900	1,000
School enrollment	710	310	120
Local government revenues (million 1985 $)	$3.0	$1.5	$0.7
Local government expenditures (million 1985 $)	$3.7	$1.6	$0.8

(a) Includes all direct, indirect, and induced effects. Values are rounded to two significant figures.

Both the Hartsville area and the Clinch River/Oak Ridge areas would benefit from the increased employment generated by an MRS facility. The Clinch River/Oak Ridge region has stated a need for job diversification (less dependence on a single employer or industry). This could result from growth in indirect services, such as robotics.

There is clear potential for attracting ancillary firms specializing in remote handling, robotics applications in harsh environments, high-level equipment quality assurance, monitoring and survey instruments, remote heavy loading, and transport cask maintenance. The location of these firms is unknown; not all of them would necessarily be near the MRS site.

A potential nonstandard socioeconomic effect of an MRS arises out of the facility's perceived characteristics as a site where dangerous materials are handled and temporarily stored. Regardless of whether there are any actual health risks from radiation exposure, the MRS facility may still generate socioeconomic impacts because of behavioral reactions by the public to the perceived risk.

Some members of the public might choose to avoid perceived risk by avoiding particular products and locations. If this were to occur with an MRS, this could lead to local economic losses because of consumer avoidance of agricultural products grown near the MRS site, loss of tourism, or loss of outdoor recreation dollars from the economy.

Water, Land, Utilities, and Resource Availability

The requirements for water, land, utilities and other resources including fuel, concrete, and steel were evaluated against availability. No constraints or potential constraints were identified.

Aesthetic Characteristics

Aesthetic characteristics of the MRS site include projected noise levels and visual impacts. Noises originating at each site would be attenuated by distance and natural barriers. Although no studies of noise from the facility have been performed, levels at nearby residences are not expected to exceed a day/night sound level of 55 dB, a level designed to protect against interference and annoyance.

Visual impacts will be similar to that of any multi-story building complex. The largest building at the facility will be the Receiving and Handling (R&H) building, a concrete structure, 97 feet (30 m; about 9 stories) high. The main stack, which is 165 feet (50 m) above ground level, is on top of the R&H building. The 36-acre storage area of this facility will consist of an array of concrete casks about 22 feet (6.7 m) tall. A field drywell facility will have buildings similar to a sealed storage cask facility. The storage area, although larger than that of the cask facility (about 93 acres), will have no visible structures.

An MRS facility at the Clinch River site will be visible from the Clinch River, some sections of highway, and several residences. A facility located at the Oak Ridge site would be visible from roads, mainly for commuters to the Oak Ridge National Laboratory. However, the Oak Ridge site may be relatively advantageous because nearby residential areas are protected from view and noise by trees and hills. A facility at Hartsville would be visible from several locations, including roads and residences around the site and from the Cumberland River.

Transportation Impacts

Transportation impacts include radiological (discussed previously under "radiological impacts"), nonradiological, cost, and traffic impacts. Nonradiological risks are measured in terms of fatalities and injuries from transportation accidents that would occur regardless of the nature of the commodity. With or without an MRS facility in the waste management system, truck and rail shipment of spent fuel would constitute a very small fraction (less than 1/1000th) of the normal commercial freight shipping mileage and would not cause an appreciable change in the number of this type of transportation-related fatalities or injuries.

Transportation costs from reactor sites to an MRS are essentially the same for all three candidate MRS sites. In addition, the total costs during the 26-year MRS operational lifetime are nearly identical for any combination of truck and rail transport. The total costs depend on the capacity of the shipping cask and the distance to the repository. The total cost for shipment of all spent fuel to an MRS and then to the most distant repository is about $1.0 and $1.5 billion (in 1985 $) for the conceptual 150-ton and 100-ton shipping casks, respectively.

Traffic impacts were estimated for a bounding spent fuel throughput of 3,600 MTU per year. The number of spent fuel transport trucks and trains that would be received at the MRS each year is 1,200 and 360, respectively. The number of rail shipments from the MRS facility to the repository each year would be about 30, depending on the capacity of the shipping cask. The increase in the local average daily traffic would be about eight trucks (four arriving and four leaving) and up to three trains. The number of additional commuter vehicles is about 700 during construction (2 workers per vehicle) and 400 during operation of the MRS facility. This increase in commuter traffic could result in some local traffic problems during MRS facility construction and operation, because many potential routes at all three MRS sites are already near capacity traffic flow.

The DOE determined that projected impacts for all site-design combinations are environmentally acceptable (i.e., each complies with applicable regulations). Total impacts for each of the six combinations were compared in order to identify any relative advantages and disadvantages. No single site-design combination emerged as being noticeably better or worse than others, based on total environmental impacts.

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Part 1

Need and Feasibility

1.0 BACKGROUND TO THE NEED AND FEASIBILITY OF MONITORED RETRIEVABLE STORAGE

The Nuclear Waste Policy Act (NWPA) of 1982 affirmed that the federal government is responsible for the disposal of spent fuel and high-level radioactive waste resulting from civilian nuclear activities.[a] The primary objective of the federal waste management system is to dispose of this waste in a manner that protects the health and safety of the public and maintains the quality of the environment. The NWPA assigned to the U.S. Department of Energy (DOE) the responsibility for operating the waste management system. The federal waste management system includes all activities associated with waste acceptance, transportation, preparation and packaging, and emplacement in the repository for permanent disposal. The repository authorized by Congress is a deep underground facility where radioactive material can be permanently isolated without significant risk to present or future generations.

The NWPA also states that monitored retrievable storage (MRS) is a safe, reliable option for the long-term storage of waste. However, the NWPA does not clearly define the role of an MRS facility nor authorize its construction. Rather, it directs the DOE to complete a detailed study of the need for and the feasibility of such a facility and to develop a proposal for construction of such a facility. This part of the Environmental Assessment (EA) presents the DOE's analysis of the need for and value of an integral MRS facility and the feasibility of deploying the MRS facility in the waste management system.

In this chapter, background information to the need and feasibility study is presented, and the scope and approach taken in assessing need and feasibility are described. Section 1.1 discusses the functions of the waste management system. Sections 1.2 through 1.4 all relate to the assessment of the need for and value of an MRS facility. Section 1.2 discusses the alternative waste management systems that were evaluated. Section 1.3 discusses the basis for the assessment, and Section 1.4 discusses the assumptions that were made in assessing need. The basis for assessing the feasibility of an MRS facility is discussed in Section 1.5. The contents of the remaining chapters of Part 1 and the associated appendices are briefly discussed in Section 1.6.

(a) For simplicity and brevity, the term "waste" is frequently used in this report to mean both high-level waste and spent nuclear fuel. Spent fuel consists of assemblies of sealed metal tubes (rods) containing the uranium oxide pellets that previously powered the reactors.

1.1 WASTE MANAGEMENT SYSTEM FUNCTIONS

To provide a basis for determining the effects of an MRS facility on the waste management system, this section describes the two portions of the waste management system, the system's primary functions to provide disposal of waste, and the activities that are associated with each function.

The waste management system is divided into two portions: the utilities that own reactors are responsible for one portion and the federal government is responsible for the other portion. The storage of spent fuel at the reactor site and its loading into transportation casks for shipment to a federal facility are and will remain the utilities' responsibilities. The transportation casks, certified by the Nuclear Regulatory Commission (NRC), will be provided by the DOE. The DOE will accept title to the spent fuel at the reactor site and transport it to either the MRS facility or the repository. Accepting the spent fuel is the principal interaction between the federal and utility portions of the system.

The primary functions of the waste management system are 1) to accept waste from the owners and generators according to the standard contract with the DOE for disposal services; 2) transport the waste from reactor sites or other locations to disposal sites or other intermediate facilities; 3) prepare the waste for permanent disposal; and 4) provide permanent disposal in geologic repositories. In developing and operating these functions, the DOE recognizes the primary needs to protect the health and safety of the public and the quality of the environment. In addition, the program must operate in a fiscally sound manner with the costs borne equitably by the owners and generators of the waste.

Design and development of a waste management system to accomplish these functions will be a difficult and complex process. Some of the major activities that are associated with developing and operating each of these functions are discussed below.

1.1.1 Waste Acceptance

According to the standard contract for disposal of waste (10 CFR 961) between DOE and utilities, beginning in 1987 the DOE must issue an annual report on projected receipt capacity for the waste management system. Four years later, in 1991, DOE must also issue an annual acceptance priority ranking for these wastes. The annual reports and priority ranking will provide important planning information to utilities for adjusting their existing spent-fuel storage capacities.

Determining the appropriate overall quantity of spent fuel to accept in each year of operation will depend on both short-term and long-term objectives. In the short-term, the acceptance rate should be high enough to provide relief to utilities with potential at-reactor storage problems, but should also allow for an orderly testing and phase-in period for the waste management system. In the long-term, the acceptance rate should be sufficient to deplete the backlog of spent fuel at reactors.

1.1.2 Transportation

Three key activities must be completed before the spent fuel is transported to a federal site. One activity would be acquiring transportation casks, which would involve defining the physical specifications for the casks for both modes of transport, truck and rail; determining the number of casks required; contracting with vendors for cask fabrication; testing the casks for safety and operability under normal and accident conditions; and licensing the casks. A second activity would be establishing transportation routes, which would involve determining the preferred routes, resolving institutional issues with the involved states, and establishing emergency response systems or organizations. A third activity would be procuring private shipping services, which would require establishing contractual relationships between the DOE and various truck and rail carriers.

1.1.3 Waste Preparation and Packaging

The DOE must prepare and package spent fuel 1) to substantially contain the waste for 300 to 1000 years after it has been emplaced, 2) to protect the health and safety of occupational workers, 3) to design the waste package to most efficiently use repository space and to meet all licensing requirements, and 4) to provide the capability to retrieve the waste.

Packaging includes the activities needed to prepare spent fuel for disposal, including consolidation and canistering of spent fuel and placement of canisters into the disposal container. The term "canister" is used to mean the first material envelope that surrounds a waste form (such as spent-fuel rods) to provide containment for handling and storage purposes. The term "container" is used here to mean the metal barrier placed around a waste canister prior to disposal to meet the requirements of 10 CFR 60; the container provides the second level of containment. "Waste package" is defined as the system of engineered components surrounding the waste and includes the container, canister, packing, and borehole sleeve and cover, as appropriate.

The final waste package design will depend on the physical characteristics of the geologic medium selected for the first repository. Waste package design will be closely integrated with technical specifications imposed by the geologic repository.

1.1.4 Disposal

The objective of the key technical criteria for the disposal of commercial radioactive wastes in geologic repositories is to isolate the emplaced waste for at least 10,000 years without undue risk to public health and safety, according to requirements promulgated by the Environmental Protection Agency (40 CFR 191) and administered by the NRC.

The process of selecting candidate sites for the first geologic repository is currently under way. Nine potentially acceptable sites in three geologic media (basalt, salt and tuff) have been identified by the DOE through a methodical screening process that included site-specific surveys supported by laboratory studies. For each of the identified nine sites, draft EAs were prepared to present the results of environmental analyses and data collected.

According to the requirements of the NWPA, in early 1986, the DOE will nominate for site characterization five sites to the President. Of the five sites nominated, the President will select three for site characterization. Based on the draft EAs of the five sites preferred for nomination by the DOE, three sites are located in salt media, one in tuff and one in basalt. The site characterization process will be undertaken to provide in-depth site-specific geologic information on such matters as ground-water travel time, rock formation competency and stability, and potential for geologic disturbances in the future. Based on the results of the site-characterization activities and on final environmental impact statements, the President will recommend a site for the first repository to Congress in March 1991.

1.2 ALTERNATIVE WASTE MANAGEMENT SYSTEMS

This section describes the alternative waste management systems that were evaluated. In considering the proper role for MRS in the waste management system, the DOE has evaluated a range of alternative system configurations. Of these, three options were analyzed in more detail: the reference or no-MRS system (the authorized system); the integral MRS system (the improved performance system); and the backup MRS system. Variations to the no-MRS and MRS options were also evaluated.

The third option, the back-up MRS system, was evaluated in the preliminary need and feasibility study (DOE 1985). The primary function of the backup MRS would be to provide contingency spent-fuel receiving and storage if the repository schedule were to change significantly. The preliminary study (DOE 1985) concluded that the backup MRS system would not provide advantages beyond those of the integral MRS facility, but rather had several disadvantages relative to it. For example, the backup MRS facility would duplicate the spent-fuel receiving and consolidation capability of the repository. Both the backup MRS facility and the repository would have very similar capabilities to receive and handle casks from all reactors, whereas the integral MRS facility would allow the repository to have simplified capability for cask receiving and spent-fuel handling. Furthermore, the DOE continues to feel that the schedule for repository startup is achievable, therefore reducing the value of a backup MRS system.

In this analysis, the no-MRS system has been examined in greater depth by considering options for achieving "MRS-like" system performance benefits (Appendix A). The DOE examined selected alternative improvements in the no-MRS system to compare their impacts with those described for deploying an MRS facility. The alternatives considered were in three generic categories that align with equivalent improvements of adding an MRS facility to the waste management system:

- expanded lag storage at the repository to provide a buffer between waste acceptance and waste emplacement
- expanded storage at reactor sites, either by adding modular dry storage or in-pool consolidation of spent fuel, to provide contingency storage if repository operations were delayed
- use of larger shipping casks and multicask shipments, thereby increasing the tonnage per shipment and reducing the number of shipments.

The tradeoffs resulting from alternative configurations of the MRS system also have been studied in more detail (Appendix B). Alternative configurations considered included the handling of fuel from western reactors, the installation of the final disposal container, and options for configuring the transportation leg between the MRS facility and the repository.

The results of additional analysis of the no-MRS system and the integral MRS system (hereafter called "MRS system") options have been re-evaluated in this part of the EA from the preliminary need and feasibility study (DOE 1985) and are discussed in detail in Chapter 2.0. Figure 1.1 shows the two system options. The no-MRS and MRS options and their essential functions are described in the following sections.

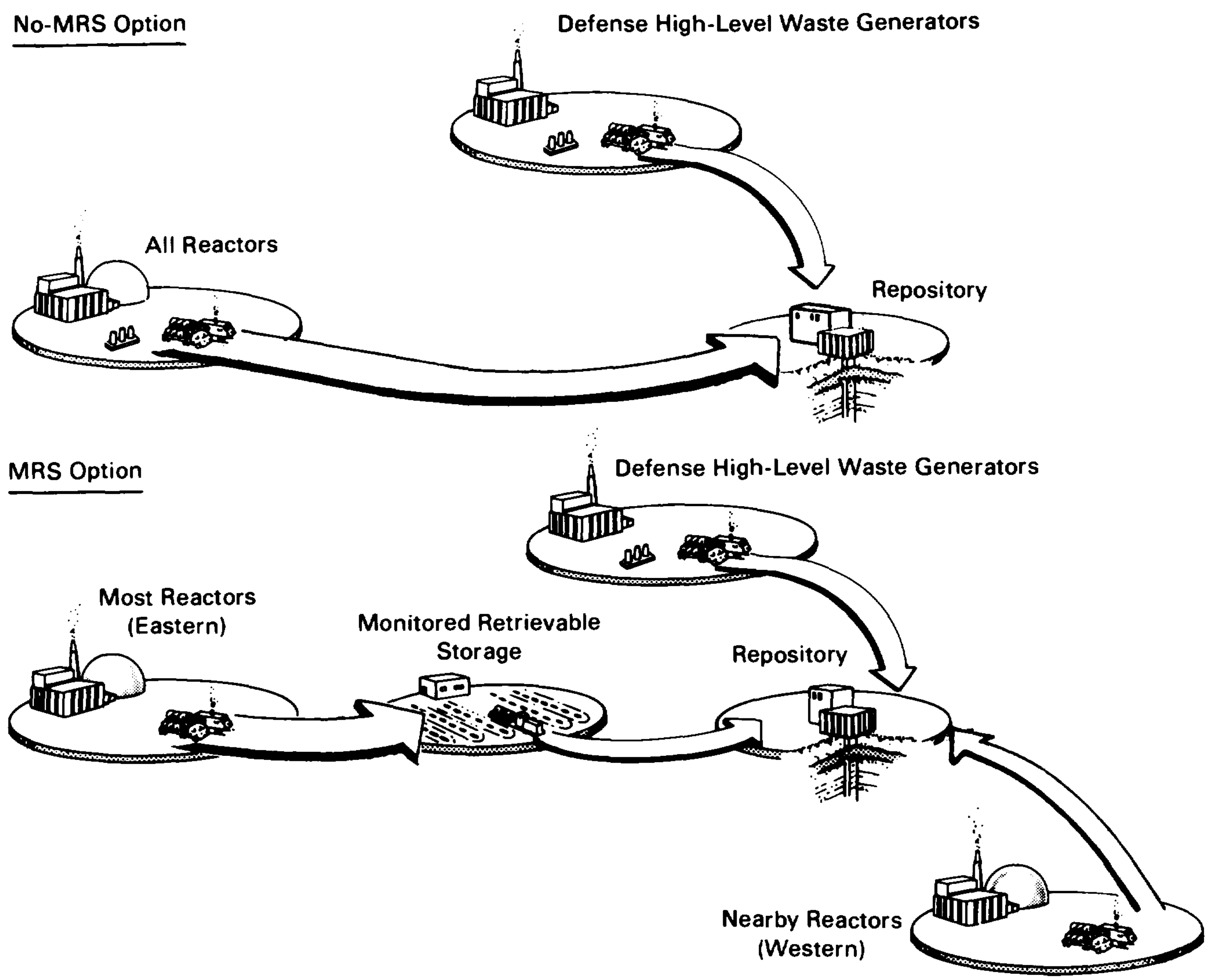

FIGURE 1.1. No-MRS and Integral MRS System Options

1.2.1 No-MRS System

This option is currently authorized by Congress through the NWPA. Utilities would be responsible for the onsite storage of spent fuel until the DOE takes title to the fuel at the reactor site for shipment to the repository. The DOE is to begin accepting spent fuel no later than January 31, 1998, when the first repository is scheduled to begin operations. However, some additional storage capability would be needed, whether at the reactor sites or at the repository, for several years following 1998 because the inventories of spent fuel would continue to grow faster than fuel could be emplaced in the repository.

The essential functions of the waste management system are waste acceptance, transportation, preparation and packaging, and disposal. Waste acceptance, transportation, and preparation and packaging in the no-MRS system are discussed below. The disposal function is the same in the MRS and no-MRS systems because disposal would be provided at the repository in both cases. Because disposal at the repository was discussed in Section 1.1.4, it will not be discussed here.

Waste Acceptance

The DOE would accept spent nuclear fuel at the reactor sites for direct shipment to a repository. Waste acceptance would begin once the repository receives its operating license (scheduled for January 1998). The waste-acceptance rate would be closely coupled to the rate that the repository can emplace the waste. The repository could provide only a small amount of storage [approximately 750 MTU (metric tons of uranium)] to allow waste acceptance to continue if the emplacement process were slowed or interrupted. If the schedule for repository startup is delayed, spent fuel would stay at the reactor sites.

Transportation

The transportation system would move spent fuel from more than 80 reactor sites, mostly in the eastern part of the country, to the first repository. Spent fuel from most reactors would be shipped by rail, whereas fuel from reactors without rail access would be shipped by truck. If the first repository is located in the west, most of the shipments would be cross-country.

Preparation and Packaging

All preparation and packaging for disposal would be done at the repository, although some utilities could have already consolidated their spent fuel before DOE accepts it in order to alleviate space shortages in their spent-fuel pools. The consolidated fuel may require repackaging at the repository to fit into the disposal container.

1.2.2 MRS-System

The construction of an MRS facility would require congressional approval. If approved, the MRS facility would serve as a centralized receiving, preparation, and packaging facility for spent fuel. Starting in 1996, spent fuel from commercial nuclear power plants would be shipped to the MRS facility, prepared and packaged for disposal, temporarily stored at the MRS facility, if necessary, and shipped by train to the geologic repository. Almost all of the material handled at the MRS facility would be spent fuel from commercial nuclear power reactors. Figure 1.2 depicts the operation of the MRS facility.

The MRS facility would have two main components--the receiving and handling (R&H) building and the storage area. The R&H building is the main operating area of the MRS facility. Spent fuel would arrive either by truck or rail in heavily shielded transportation casks. The spent fuel would be unloaded into the R&H building and prepared and packaged for shipment to a repository or for transfer to the storage area for temporary storage. The principal operations within the R&H building would start with disassembling spent-fuel assemblies and placing the fuel rods into tightly packed bundles. Packaging would then consist of inserting the spent-fuel bundles into canisters, evacuating and backfilling the canisters with an inert atmosphere, welding the canisters closed, leak testing and examining the weld quality, and decontaminating the exterior surface of the canister as necessary.

Storage could be provided if the quantity of spent fuel received exceeds the amount that can be emplaced at the repository or if the spent fuel is not suitable for immediate disposal. The MRS facility would have capacity to store up to 15,000 MTU of spent fuel but is expected to have a maximum inventory of 12,000 MTU. If temporary storage is required, canisters of consolidated spent fuel would be placed into sealed storage casks. Volume 3 of the MRS Program Plan contains a more detailed description of MRS facility characteristics and operations.

The MRS system differs from the no-MRS system in the way in which the essential waste management functions of waste acceptance, transportation, and preparation and packaging are performed. Each of those functions in the MRS system is discussed below.

Waste Acceptance

The MRS facility would accelerate the DOE's waste-acceptance capability, especially in the early years of system operation. Since an MRS facility could begin operations in 1996, the DOE could start to accept fuel at or near the rate of spent-fuel generation by 1998. The actual quantity of spent fuel stored at the facility would depend on the DOE's waste-acceptance contract with utilities. However, the 15,000 MTU storage capability at the MRS facility would provide the DOE with more flexibility in setting the acceptance schedules. The schedule could be set so as to balance the desire to unload reactor pools with the desire to maintain some contingency storage capability in case of changes in the repository's emplacement capability.

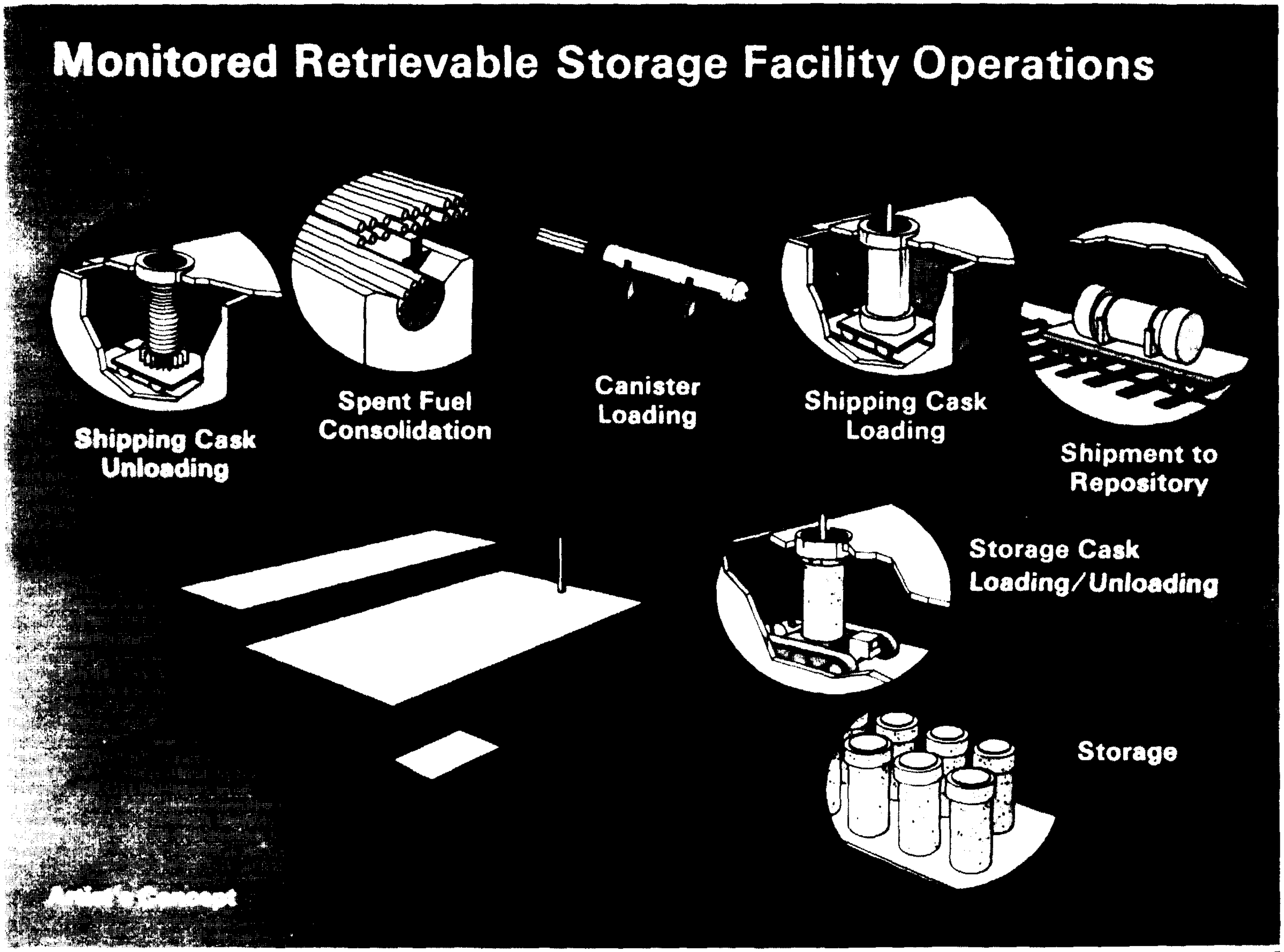

FIGURE 1.2. Monitored Retrievable Storage Facility Operations

Transportation

Centrally locating the MRS facility to most existing reactors would significantly reduce transportation requirements. The distances for truck and rail shipments from most of the approximately 80 reactor sites to an MRS facility would be much shorter than shipments to a repository. Therefore, an MRS system would require a smaller transportation fleet and less material in transit at any given time. From the MRS facility, the spent fuel, consolidated into standard canisters, could be shipped to the repository in large rail casks and in multicask shipments by dedicated trains. The large rail casks and standard canisters would reduce the receiving facility requirement at the repository.

Preparation and Packaging

The MRS facility would consolidate spent fuel from eastern reactors and package it for disposal by placing the fuel rods into canisters, which would later be placed into disposal containers at the repository. The repository would also receive spent fuel directly from western reactors and place that fuel into disposal containers. The MRS facility would reduce the preparation and packaging requirements at the repository.

1.3 BASIS FOR ASSESSING THE NEED FOR AN MRS FACILITY

In this section, the DOE's basis for assessing need is discussed, and the specific factors that were used in the assessment are defined. The DOE believes that the need for and value of an MRS facility derives from its ability to significantly improve the overall performance of the waste management system at acceptable costs. The waste management system could be operated without an MRS facility, but including the facility improves several important performance characteristics of the system. The DOE based its assessment of need on comparisons between a waste management system with an MRS facility and a system without an MRS facility. The DOE compared the no-MRS and MRS systems in terms of their implications for developing and operating the functions of the waste management system. These implications were balanced against projected system cost effects and potential changes in radiation exposure to both the public and workers.

The specific factors that were used to compare the MRS and no-MRS systems are defined below:

- System Development - the ease with which all system functions can be developed and implemented. The development phase includes technology development and testing, and regulatory and institutional activities that are associated with implementing disposal, the MRS Program, the transportation system, and the waste acceptance process.

- System Operations - the operating efficiency and reliability of all system functions, including waste acceptance, transportation, preparation and packaging, and disposal.

- System Cost Effects - the life-cycle cost of developing and operating the system functions. In particular, transportation costs and the capital and operating costs of the surface facilities of an MRS facility and repository are compared. Costs incurred by utilities to expand their storage capacity are also included.

- System Radiation Dose Effects - for both the public and occupational workers, the expected radiation exposure effects from system operations.

1.4 ANALYTICAL AND PROGRAMMATIC ASSUMPTIONS

The primary components and assumptions that are made in comparing system performance with and without an MRS facility are listed in Table 1.1. The assumed spent-fuel acceptance schedules for both the no-MRS and MRS systems are shown in Table 1.2. These schedules illustrate the expected receipt capability; actual spent-fuel acceptance schedules will be set under the guidelines specified in the standard contract with utilities (10 CFR 961). For the schedules shown in Table 1.2, the spent-fuel inventory at the MRS facility would reach a maximum of 11,150 MTU. As noted in Table 1.1, however, the facility would have a maximum storage capacity of 15,000 MTU.

1.5 BASIS FOR ASSESSING THE FEASIBILITY OF AN MRS FACILITY

This section discusses the DOE's basis for assessing the feasibility of an MRS facility. In this report, feasibility refers to the ability to carry out or accomplish all components of the MRS system as proposed. The components of the MRS facility were evaluated separately and as a system. One measure of feasibility is the technical feasibility of the major functions of the MRS facility. Another measure is the confidence in the cost projections and funding analysis, which were largely based on conceptual designs and DOE-sponsored studies and annual reviews. Costs examined included equipment, staffing,

TABLE 1.1. Analytical and Programmatic Assumptions Used in Comparing the MRS and no-MRS Options

Waste Generation and Storage

- Spent fuel from commercial nuclear reactors would be the only waste form to be received by the MRS facility.
- Spent-fuel generation rates are based on EIA middle-case projections (see Section 2.3), which assume constant fuel burnup level.
- Spent fuel would be stored at reactor sites until accepted by the federal waste management system for disposal. Estimates of reactor's storage requirements are based on current utility storage plans (see Section 2.3).
- Defense and commercial high-level waste is not discussed in this report because the current plan is to ship such waste directly to the repository.
- Federal Interim Storage (FIS) will not be deployed unless there is utility request and the NRC determines that the utility qualifies for such storage under the provisions of 10 CFR 53. FIS would not significantly affect the comparison of system performance with and without an MRS facility in any case.

System Logistics

- The first repository would receive 62,000 MTU of spent fuel and an amount of defense high-level waste equivalent to approximately 8,000 MTU of spent fuel. The MRS facility would receive 53,000 MTU of spent fuel from eastern reactors, which, in the no-MRS system, would be shipped directly to the first repository. The remaining 9,000 MTU of spent fuel shipped to the first repository would be from reactors in the western portion of the U.S.
- Spent fuel would be received according to the criteria in the standard contract with utilities (10 CFR 961), with the oldest fuel and fuel from decommissioned reactors having highest priority. Also, because utilities are allowed to exchange acceptance commitments among each other, fuel from reactors losing full-core reserve (storage space for all assemblies in the core) capability would actually be the first fuel received for purposes of estimating storage requirements.

Transportation

- Spent-fuel shipments from reactors to a repository or an MRS facility would be 70% (by weight) by rail and 30% by truck. Shipment from the MRS facility to the repository would be 100% by rail. (Appendix F contains a full set of assumptions, which were used in these analyses.)
- The federally managed transportation system would use commercial truck and rail carriers for transporting spent fuel in NRC-certified casks.

MRS Facility

- The MRS facility, which the DOE proposes to locate at the Clinch River site near Oak Ridge, Tennessee, would have the capability of receiving spent fuel from reactors located in the east, consolidating the fuel rods and encasing them in canisters, and shipping the completed canisters to the first repository for any further packaging required prior to disposal. All fuel prepared at the MRS facility would be sent to the first repository for disposal.
- The maximum authorized storage capacity would be 15,000 MTU.
- The MRS facility could begin operating as early as 1996 and could reach full operation of 2,500 MTU per year, or more, by 1998.
- The MRS facility would not begin to receive spent fuel until the first repository received a construction permit from the NRC.

Geologic Repositories

- The first repository will begin operating in 1998, with full-scale operation of 3,000 MTU per year reached in 2003.
- Consolidated spent fuel will be the desired waste form. Consolidation offers system advantages oy providing more compact packages of waste, thus reducing the number of packages to be handled, transported, and emplaced underground.
- To evaluate the need for MRS, three potential first repository sites were assumed. These sites represent three geologic media (salt, tuff and basalt) and cover a wide range of repository locations. The three sites are Deaf Smith County, Texas (salt), Yucca Mountain, Nevada (tuff), and Hanford, Washington (basalt). The three sites used throughout the analysis in Part 1 of this EA should not be construed as having any bearing or influence on ultimate decisions concerning the sites to be nominated or recommended to the President for site characterization.
- The second geologic repository is not currently authorized for construction by Congress, and any assumptions made about its timing or location would be highly uncertain. Its potential receipt of spent fuel from existing or new reactors could modify somewhat the logistics that are assumed for analyses in this report, but these changes are not expected to change the analytical results sufficiently to alter the conclusions reached from them.

TABLE 1.2. Spent-Fuel Acceptance Schedules for the No-MRS and MRS System[(a)]

Year	No-MRS System All Reactors to First Rep.	MRS System Eastern Reactors to MRS	Western Reactors to Repos.	MRS to Repos.	MRS Inventory[(b)]
1996	0	400	0	0	400
1997	0	1,800	0	0	2,200
1998	400	2,500	50	350	4,350
1999	400	2,500	50	350	6,500
2000	400	2,500	75	325	8,675
2001	900	2,500	75	825	10,350
2002	1,800	2,500	100	1,700	11,150
2003	3,000	2,500	200	2,800	10,850
2004	3,000	2,500	350	2,650	10,700
2005	3,000	2,500	450	2,550	10,650
2006	3,000	2,500	450	2,550	10,600
2007	3,000	2,500	450	2,550	10,550
2008	3,000	2,500	450	2,550	10,500
2009	3,000	2,500	450	2,550	10,450
2010	3,000	2,500	450	2,550	10,400
2011	3,000	2,500	450	2,550	10,350
2012	3,000	2,500	450	2,550	10,300
2013	3,000	2,500	450	2,550	10,250
2014	3,000	2,500	450	2,550	10,200
2015	3,000	2,500	450	2,550	10,150
2016	3,000	2,500	450	2,550	10,100
2017	3,000	2,500	450	2,550	10,050
2018	3,000	800	450	2,550	8,300
2019	3,000	0	450	2,550	5,750
2020	3,000	0	450	2,550	3,200
2021	3,000	0	450	2,550	650
2022	1,100	0	450	650	0
	62,000	53,000	9,000	53,000	

(a) These schedules reflect expected receipt capability and have been used for analytical purposes. Actual spent-fuel-acceptance schedules will be set beginning in 1991 in accordance with the standard contract with utilities (10 CFR 961).

(b) For estimating costs, the expected maximum MRS inventory of 11,150 MTU has been rounded to 12,000 MTU.

operating, and decommissioning costs. The level of certainty of scheduling estimates, which includes the schedule for design, construction, and operational testing, is another feasibility measure. Another measure is the DOE's confidence that the MRS facility would comply with NRC regulations and the efforts that have been taken and would be taken to ensure compliance.

1.6 CONTENTS OF PART 1

Part 1 of this Environmental Assessment is comprised of 3 chapters and 6 appendices (A through F). In Chapter 2.0 the need for an MRS facility is discussed in detail. The DOE based its assessment of need on comparisons between a waste management system having an MRS facility and a system not having an MRS facility. Chapter 3.0 discusses the feasibility of implementing all system components using the bases described above.

Six appendices support the study of need and feasibility. Appendix A evaluates the alternative options that could be implemented in the no-MRS system to potentially achieve some of the same beneficial effects of the integral MRS system. Appendix B evaluates the alternative arrangements for the preparation and packaging functions in an MRS system. A preferred arrangement has been identified in which the MRS facility receives and consolidates spent fuel from eastern reactors only and the repository prepares the final disposal container; however, other arrangements were considered and are discussed. Cost information and analyses used in evaluating cost impacts for the MRS and repository facilities are discussed in Appendix C. In Appendix D, spent-fuel generation, storage requirements, and costs are discussed in detail. Included in the discussion are projections of the amount of spent fuel that will be discharged by reactors, the amount of additional at-reactor spent-fuel storage capacity that will be required, and the potential costs for providing that storage. Appendix E discusses the radiation dose effects of the MRS and no-MRS systems as well as the options that were evaluated for improving the no-MRS system. The advantages and disadvantages of each option are discussed along with each option's potential to achieve some of the same beneficial effects of the integral MRS system. Finally, Appendix F discusses and lists in tabular form the relative costs and risks of transporting spent fuel from individual reactor sites, either directly to a repository site or to an MRS facility and then to any one of nine potential repository sites.

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2.0 THE NEED FOR MONITORED RETRIEVABLE STORAGE

The DOE believes that the need for and value of an MRS facility derives from its ability to significantly improve the overall performance of the waste management system. In determining need and value, the DOE compared the advantages and disadvantages of a waste management system that includes an MRS facility with a system that does not include an MRS facility.

The components and functions of the two systems were described in Chapter 1. In this chapter, the developmental and operational characteristics, and the costs and potential radiation dose characteristics of the two systems are compared. Section 2.1 summarizes the comparison. Section 2.2 compares the two systems in terms of their relative developmental characteristics for each of the primary functions of the waste management system: waste acceptance, transportation, preparation and packaging, and disposal. In Section 2.3, the operational characteristics of the two systems are compared for each of the primary functions. The two systems' cost effects are compared in Section 2.4, and the systems' radiation dose characteristics are compared in Section 2.5.

2.1 SUMMARY

The MRS and no-MRS systems have two principal differences which lead to their relative advantages and disadvantages:

1. For preparing and packaging spent fuel for disposal, the MRS system would use a site that is separate from the repository and located centrally to the reactors. In the no-MRS system, these operations would be performed at the repository. This separate site would allow the functions of the MRS system to be developed sooner than the repository and independent of uncertainties in the repository program. The MRS system would provide a central location to the reactors for controlling spent-fuel transportation and would reduce the number of cross-country shipments to the repository.

2. The MRS facility would add the capability for storing up to 15,000 MTU of spent fuel (maximum inventory is expected to be 12,000 MTU). This storage capability could be used to decouple the operation of the waste-acceptance and waste-emplacement functions, to increase the quantity of spent fuel accepted in the initial years of system operation, and to provide contingency storage in case of changes in the repository's emplacement schedule.

The two principal differences in the MRS and no-MRS systems affect the waste management system's development, operations, cost and radiation exposure characteristics. Those effects are summarized in Table 2.1 and in the following sections, and are described in detail in the remainder of this chapter. Table 2.1 also indicates which section contains further discussion of each topic.

2.1.1 System Development

Adding an MRS facility to the authorized system would result in more complete and more certain information with which to implement waste-acceptance, transportation, and packaging functions. Separating these functions from repository development would allow their planning and development to proceed at an advanced schedule and independent from the uncertainties of repository siting and geologic site characterization. The MRS site would be selected four to five years before the first repository site is selected. The MRS receiving and packaging facility design would be licensed by the NRC about three years earlier than the repository. As a result, the MRS system would provide earlier certainty about the location for the transportation control point and more definite technical design information for use in planning system interactions, including fuel-acceptance and packaging decisions. Although a cost would be incurred in developing and operating an independent facility, the additional cost provides needed functions at a much earlier date than if they were developed at the first repository.

2.1.2 System Operations

The MRS facility would increase the flexibility of and DOE's control over transportation activities and fuel-acceptance and emplacement strategies and thereby increase operating efficiency and reliability relative to the no-MRS system. By centrally locating the MRS facility to the eastern nuclear reactors, the MRS facility would act as a staging area and control point for transporting spent fuel from reactors to the first repository. Having a control point closer to the reactors would simplify the control of the transportation function compared to the no-MRS system. The control point also would significantly reduce the number of cross-country shipments to the repository through the use of large rail casks and multicask shipments. The overall transportation activities would be reduced, although waste transportation activities would increase in the area immediately surrounding the MRS facility.

Locating storage capability at the MRS site would improve the reliability and efficiency of the waste management system. The MRS facility would permit a larger spent-fuel receipt rate in the initial years of operation. The larger receipt rate would reduce the buildup of stored spent fuel at reactors and improve the efficiency and timeliness of the waste-acceptance process. The

TABLE 2.1. System Effects of Adding an MRS Facility to the Authorized System

	System Development (Section 2.2)	System Operations (Section 2.3)	System Cost (Section 2.4)	Radiation Exposure (Section 2.5)
Overall	Makes system functions easier to develop by simplifying decisions and applying more certain information. Provides focal point for integrating all pre-emplacement functions.	Improves system efficiency and reliability because acceptance and emplacement can be operated independently.	Increases costs of facilities and transportation in the federal portion of the system by $1.4 to 2.0 billion.	Slightly lower public exposure and potential slight increase in occupational exposure.
Waste Acceptance	Provides better information for setting acceptance commitments; MRS facility design leads the repository design by 2 or more years.	Allows higher initial spent-fuel receipt from utilities, which reduces the need for some supplemental storage by utilities. Provides flexibility in meeting commitments if emplacement rates are reduced or disrupted.	Storage costs avoided by utilities would vary from $150 to $450 million with on-time repository and could be as much as $0.6 to $1.7 billion with changes in the repository availability.	No change.
Transportation	Allows longer lead-time for route/logistics planning, but requires earlier full-scale operation.	Improves DOE control over spent-fuel transportation and reduces the number of shipment miles and resulting physical interactions with the public. Reduces number of accidents.	Decreases transportation costs by as much as $0.2 billion depending upon repository location.	Slightly decreases public exposure--already very low.
Packaging	Provides focus for applying on-going rod consolidation experience.	Requires some duplication of handling and packaging capability.	Increases facility costs about $1.6-$2.0 billion, which includes a storage inventory of 12,000 MTU costing $0.4 billion.	Potential for slight increase in occupational exposure due to additional cask-handling steps. The latter would be within regulated limits, however.
Disposal	Reduces potential for repository operation to be constrained by pre-emplacement functions, but requires MRS operation for system operation and disposal (adds another potential pinch point).	Simplifies surface facilities at the repository.	Insufficient information to identify differences.	No change.

storage capability at the MRS site would also provide relatively inexpensive contingency storage in case of changes in the repository emplacement schedule. Storage would also provide an operational buffer between waste-acceptance and waste-emplacement operations, which would give the overall system greater flexibility and reliability because operating disruptions would not quickly cascade through the system. The emplacement operation could also be more efficient because waste-package heat loads could be easily tailored to emplacement characteristics of the repository medium.

2.1.3 System Cost

Adding an MRS facility would result in a net cost increase of $1.4 to $2.0 billion to the federal portion of the waste management system because site-support services would have to be provided at two locations, the MRS and repository sites, instead of one. This cost includes approximately $0.4 billion to provide 12,000 MTU of storage, which would result from the waste-acceptance and facility operating schedules assumed for this analysis. However, the MRS facility would reduce the utilities' storage expenditures. Avoided utility storage costs would range from $150 to $450 million, assuming repository startup in 1998. The MRS system would provide storage capacity which could be used to increase the initial rate of removing spent fuel from reactor storage or to provide contingency storage in case of delays in the repository program. The incremental unit cost of spent-fuel storage at the MRS facility would be $35 to $40 per kilogram. The utilities' unit cost for spent-fuel storage beyond the capacity they can attain with maximum reracking (replacing old racks with new racks that provide greater storage capacity) of existing storage pools would range from $40 to $110 per kilogram. Therefore, the actual cost savings to the ratepayer of storage provided by the MRS facility would depend on the amount of at-reactor storage that would be offset and the utilities' cost for providing that storage.

2.1.4 Radiation Dose Effects

In the MRS system, additional spent-fuel-handling operations would slightly increase occupational exposure, although the doses received by individual workers would be strictly regulated in either system. Public radiation exposure, on the other hand, would be reduced slightly because of reductions in exposure from spent-fuel transportation.

2.2 SYSTEM DEVELOPMENT EFFECTS

System development includes the technology development and testing, and regulatory and institutional activities that are associated with implementing the repositories, the MRS Program, the transportation system, and the federal waste-acceptance process. An important basis for the DOE's proposal to include an MRS facility in the waste management system derives from the opportunity that the facility offers for developing and integrating system functions independently from the current uncertainties of siting and licensing the first repository.

Two features distinguish the MRS system from the no-MRS system and affect the development of the waste management system. First, because the MRS site would be approved four to five years earlier than the repository site, greater lead time would be available for route-specific planning for spent-fuel shipments from the reactors and other interactions between the DOE and state and local governments. Secondly, the MRS facility design would be fully licensed by the NRC at least two years earlier than would the repository's surface facility design. As a result, more complete information on facility designs and schedules would be available for setting waste-acceptance commitments and for defining physical specifications, such as for equipment required to handle and unload casks between the federal and utility portions of the waste management system.

Table 2.2 summarizes the effects that an MRS facility would have on the development of the waste management system. The following sections expand on the developmental impacts discussed in the table by describing the effects the MRS system would have on developing 1) the overall waste management system, 2) waste acceptance, 3) transportation, 4) spent-fuel preparation and packaging, and 5) disposal.

2.2.1 Overall System Development Effects

The earlier implementation schedules of the MRS system would help to develop and implement the respective roles and responsibilities of all parties to the pre-emplacement functions. The state, local, and DOE interactions that would occur in implementing the MRS system would offer advantages for similar interactions that would occur during repository site development and facility construction. For example, during the development of the MRS facility, impact assistance and monitoring, environmental monitoring, and transportation access would be arranged with the State of Tennessee. The resulting relationship between the DOE and the state and local governments could provide precedents and experience for the repository program in this important area. With the MRS facility, many traditional construction and site-development issues could be resolved without the additional complications that could result from the long-term safety issues related to geologic isolation.

TABLE 2.2. Effects of an MRS Facility on the Development of the Waste Management System

System Function	Developmental Impact of the MRS Facility
Overall System	Becomes a clear focal point for integrating all pre-emplacement functions, including transfer of responsibility for spent fuel from nuclear utilities to the DOE.
	Provides earlier experience with key institutional interactions between the DOE and state and local governments; those interactions can benefit the repository program.
Waste Acceptance	Provides more definitive facility designs upon which to base spent-fuel acceptance schedules from utilities.
	Reduces the need for the DOE to be involved in decisions between utilities to trade acceptance rights because acceptance capacity would be greater than the capacity required to prevent additions to utility storage.
Transportation	Lengthens the time available for route-specific planning for routes between the reactors and the MRS facility.
	Accelerates the schedule for operating the transportation system that would serve reactors.
Packaging	Provides better definition for information requirements from ongoing and planned demonstrations of spent-fuel consolidation and storage technology and further provides impetus to these demonstrations.
Disposal	Lessens the likelihood that the initial operation of the geologic repository would be affected by delays in developing the pre-emplacement functions because the MRS facilities would be developed much earlier and independently of the repository.

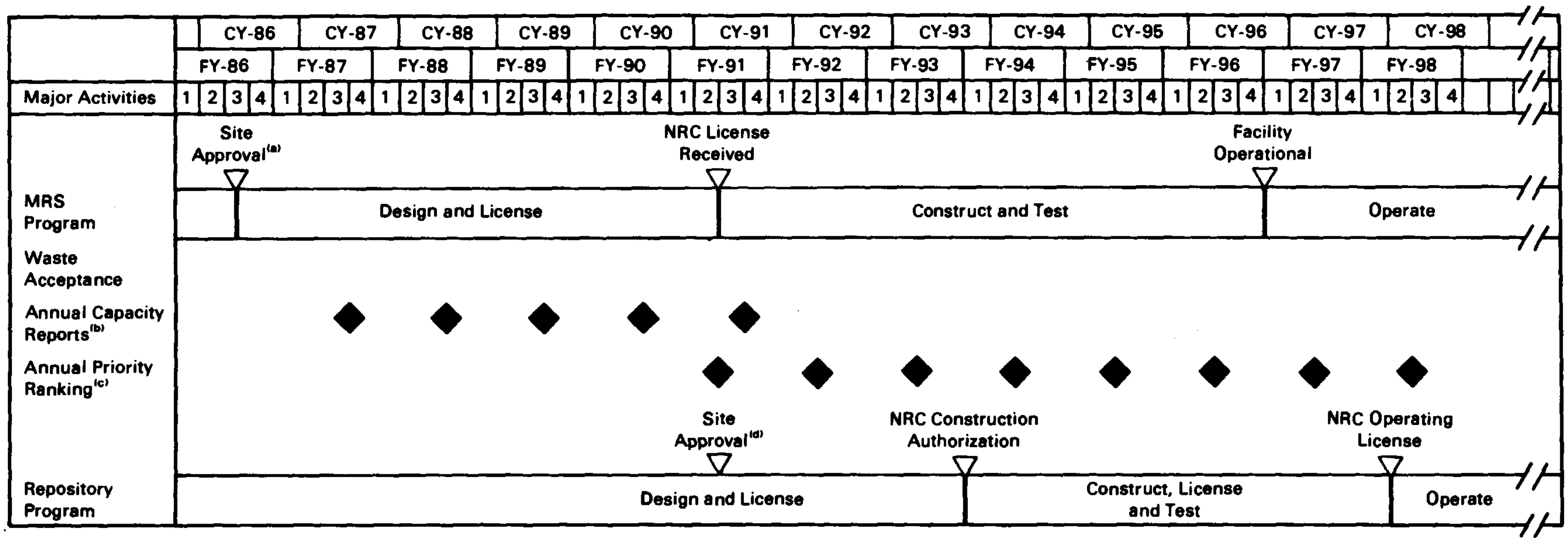
2.2.2 Development of Spent-Fuel Acceptance Capabilities

The MRS facility design, licensing and operating schedule leads that of the repository by about two years. If a license to begin construction of an MRS facility were received as expected in July 1991, definitive facility construction schedules would be available. Those schedules would provide confidence in the date of initial MRS facility operation and could then be used in 1991 by the DOE to provide added certainty to the final schedule for spent-fuel acceptance from utilities.

Figure 2.1 compares the design information available to support waste-acceptance decisions for the no-MRS and MRS systems. Two types of waste-acceptance decisions are shown. In 1987, the DOE must issue the first of a series of "annual capacity reports," which will describe the projected receipt capability of DOE facilities (10 CFR 961). In 1991, the DOE must issue the first annual "acceptance priority ranking" (10 CFR 961), which will set actual acceptance priorities. This latter series of rankings will be viewed as DOE's contractual commitment to utilities.

Although not contractually binding, the annual capacity reports will be DOE's first official statement of its fuel-acceptance intentions. The certainty of the information for estimating receipt capacities would differ significantly between the no-MRS and MRS systems. The MRS facility design schedule shows design verification to be well along and definitive design to be 30% complete in 1987. By comparison, the repository program will be in the advanced conceptual design stage until February 1988, as shown in the Mission Plan (DOE 1985). Because receipt rates in the no-MRS system would be constrained by emplacement rates, the information needed to estimate receipt rates would depend on subsequent site-selection and facility authorization decisions. Thus, the MRS facility would provide a substantially more certain estimate of receipt capability to support the initial system capacity report in 1987.

The fuel-acceptance decision that will have the most impact on the planning of specific utilities will be the annual acceptance priority rankings beginning in 1991. In the MRS system, the DOE could base this ranking on an NRC-licensed final design (June 1991). In the no-MRS system, this decision would be based on the advanced stages of definitive design, submitted as part of the license application in May 1991 but lacking the certainty of a license. Therefore, the MRS system would provide more complete information on facility design and operating schedules for actual allocation decisions in 1991. The improved technical basis for waste-acceptance commitments would also give utilities a better basis for planning their storage needs until spent fuel is accepted by the DOE.



[a]MRS site approval contingent upon Congressional approval; assumed to be 7/86.

[b]Annual projections of DOE waste acceptance capacity; beginning by 7/1/87.

[c]Annual spent-fuel acceptance priority ranking; beginning by 4/1/91.

[d]Repository site nomination by the President.

FIGURE 2.1. Design Information Available in the MRS and No-MRS Systems to Support Waste Acceptance Decisions

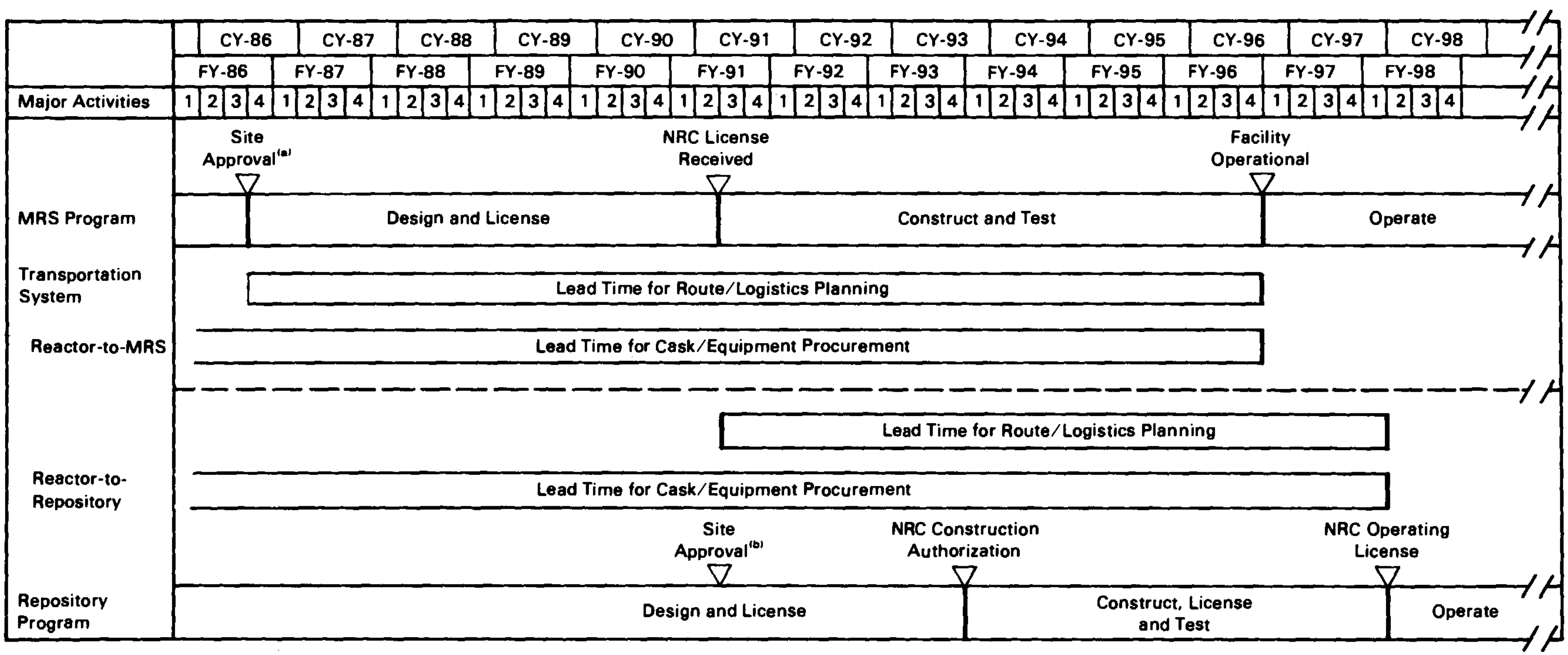
Because of its earlier construction schedule and storage capability, the MRS system's accelerated acceptance capability would simplify the process for allocating acceptance rights to utilities. Priority for spent-fuel acceptance would be based upon oldest-fuel-first and receipt of fuel from decommissioned reactors (10 CFR 961). The acceptance system would allow utilities to trade acceptance rights between themselves. This trading would enable utilities facing storage constraints to obtain additional rights from other utilities. The larger early acceptance capability of the MRS system, however, would reduce the amount of trading required between utilities. Because the DOE must approve all such trades, the greater acceptance capability in the MRS system would lessen the DOE's involvement in such decisions between individual utilities. Section 2.3.2 discusses additional operational advantages that would result from the accelerated acceptance capability of the MRS system.

The MRS system would provide the federal waste management system with added flexibility to accept spent fuel that does not meet the desired heat-output conditions for immediate disposal. In the no-MRS system, the repository would immediately emplace most spent fuel that would be received; present designs call for a small buffer storage of about 750 MTU, which could provide a limited sorting capability. Therefore, the spent fuel that would be emplaced would not be of uniform heat output. In the MRS system, the MRS facility could store some spent fuel to provide the repository with spent fuel having more uniform heat output.

2.2.3 Transportation System Development

The site for the proposed MRS facility would be known following approval by Congress. Immediately after the approval, detailed planning for shipping spent fuel from the eastern reactors to the MRS facility could begin. The planning certainty resulting from early consideration of routes would benefit all participants in the waste management system. Defining logistics, routing, and equipment would also assist utility and state and local agencies in their planning efforts. Identifying and resolving these issues well in advance of the operation of the MRS facility and first repository would ensure sufficient time to gain public confidence in and support for the transportation system and would provide assurances that future spent-fuel transportation would not be delayed by unresolved institutional issues.

Figure 2.2 compares the lead times for route and logistics planning and for cask and equipment procurement between the MRS and no-MRS systems. The difference in the first operation dates between the two systems would be 15 months--October 1996 for the MRS system versus January 1998 for the no-MRS system. Consequently, cask procurement and related transportation system development activities would need to be completed earlier in the MRS system.



[a]MRS site approval contingent upon Congressional approval; assumed to be 7/86.

[b]Repository site nomination by the President.

FIGURE 2.2. Acceleration in Transportation Program Decision Making

The scheduling effect on the transportation program would be greater than the difference in initial operating dates, however, because the no-MRS system would operate at roughly 400 MTU per year until 2001, whereas the MRS system could operate at about 2500 MTU/year by 1998. Thus, cask-fleet procurement would be accelerated by about 36 months with the MRS system.

Although the transportation decisions would have to be made at an earlier date with the MRS system, the information needed to make those decisions would be available up to 5 years earlier. Site information to determine origin and destination pairs from reactors for routing, logistics, and equipment procurement would be available in 1986 with the MRS system versus 1991 with the no-MRS system. Because the MRS system also would operate earlier than the no-MRS system, there would be a net increase of three to four years for route-specific planning activities.

In 1986, the MRS system would have information on potential transportation routes that would be comparable to information that would become available in 1991 in the no-MRS system. The MRS system would allow about two more years for working out mutually acceptable arrangements and would allow early discussions to proceed with far more certain information than would be available in the no-MRS system.

2.2.4 Development of Spent-Fuel Packaging Capability

The MRS facility will provide an earlier focal point for applying the information obtained from ongoing and planned demonstrations of spent-fuel consolidation and storage technology, both by the DOE and the utilities. Specifically, the recently initiated Prototypical Consolidation Demonstration (PCD) Project in support of the repository program will provide information on operating characteristics of consolidation equipment, which would be reoriented to support the MRS facility. Currently, this project is scheduled to be complete when the license application for the MRS facility is to be submitted to the NRC. Thus, the results of this project will be required as soon as they can be made available. The MRS facility design activity would have a more immediate and driving need for these results than would the repository, which faces many other design and development issues. Therefore, the MRS system would better define informational requirements from those demonstrations, making expenditures for these activities more focused and productive.

2.2.5 Development of Geologic Disposal

Adding an MRS facility to the waste management system could affect decisions and schedules concerning the repository program. The potential effects concern 1) the manner in which the waste system would respond to changes in the repository availability, and 2) the opinions that the presence of a federal storage facility would reduce the national commitment to complete and operate a geologic repository.

Concern has been expressed that proceeding with the MRS facility could delay the ultimate disposal of spent fuel by 1) reducing the national resolve for timely disposal, and 2) adding another facility to the "critical path" to disposal, thereby diverting energy and resources away from the repository effort. More specifically, the concern is that with approval of an MRS facility, repository schedule goals would be relaxed, which would have detrimental effects on meeting the repository's schedule. To lessen such concerns and to demonstrate its unwavering commitment to the geologic repository program, the DOE has proposed (see Volume 1) to link the startup of the MRS facility to the repository: no waste would be accepted at the MRS facility until the NRC issued a license to construct the repository. Furthermore, the DOE proposes that Congress limit the MRS storage capacity to 15,000 MTU, which is far less than the capacity of a repository.

The DOE believes that an MRS facility operating in the system prior to 1998 would reduce the potential for repository delay because any pre-emplacement operating problems would have been resolved earlier. The increased information and certainty available for decisions concerning 1) fuel acceptance, 2) transportation routing, logistics, and equipment, and 3) institutional arrangements, and their correspondingly earlier and longer implementation schedules, would make timely repository operation less vulnerable to delays in these pre-emplacement activities.

2.3 SYSTEM OPERATIONAL EFFECTS

Two features distinguish the MRS system from the no-MRS system and affect system operations. First, the MRS facility would provide up to 15,000 MTU of buffer storage, which would decouple the waste-acceptance and waste-emplacement operations. Second, the MRS facility would be located away from the repository site. This difference would divide the transportation of spent fuel from reactors to the repository into two steps, would add another fuel-receiving and handling step, and would redistribute spent-fuel packaging operations within the waste management system. The effects of adding an MRS facility to the waste management system are summarized in Table 2.3 and are discussed in more detail in the following sections.

TABLE 2.3. Effects of an MRS Facility on Waste Management System Operations

System Function	Operational Impact of MRS Facility
Overall System	Increases system efficiency by decoupling operation rates of system functions so they can be separately controlled
	Improves system availability or reliability by allowing continued operations of some system functions despite interruptions in the performance of other system functions
Waste Acceptance	Reduces the requirement for continued expansion of at-reactor storage capacity and allows flexibility for improving the efficiency of waste-acceptance and transportation operations by increasing waste-acceptance capacity in the early years of system operation
	Provides the flexibility to accommodate changes in the repository schedule without affecting waste-acceptance operations by decoupling waste-acceptance operations from repository emplacement operations
Transportation	Makes management and control of transportation operations easier by reducing the number of cross-country shipments and the number of shipments concurrently in progress
	Reduces radiological exposure to the public by decreasing the number of miles traveled by spent-fuel casks
	Reduces the likelihood of trucks or trains being involved in accidents by decreasing the number of miles they travel carrying spent-fuel casks
Packaging	Requires an additional canister for storage of the fuel rods and shipment to the repository by consolidating fuel at the MRS facility
Disposal	Reduces surface facility operations at the repository by receiving fuel for emplacement in large rail casks containing canisters of consolidated fuel rather than in smaller truck and rail casks containing intact uncanistered fuel assemblies
	Improves the efficiency of emplacement operations by selecting fuel from the MRS facility inventory based on its desirability for emplacement

2.3.1 Overall System Operations

This section discusses the effects that an MRS facility would have on the overall operation of the waste management system. In particular, the effects on system efficiency and availability are discussed.

Adding an MRS facility to the waste management system would permit alternative operating modes that cannot be achieved in the no-MRS system. The storage capability of the MRS facility would allow it to operate in three different operating modes: startup, pass-through, and storage/retrieval. The startup mode would allow the waste management system to be deployed earlier than with the no-MRS system and would permit waste to be accepted and stored more than a year before emplacement operations begin. The spent fuel accepted would be consolidated, canistered, and stored for subsequent retrieval and shipment to the repository for any further-required packaging and emplacement. The pass-through mode would be the MRS facility's normal operating mode. In this mode, fuel would flow through the consolidation and canistering steps and then directly to the repository. In the storage/retrieval mode, all or part of the input fuel stream would be diverted to storage, while a different output fuel stream would be retrieved from storage for shipment to the repository. The potential effects that these alternative operating modes have on system efficiency and availability are discussed below.

System Efficiency

Adding the MRS facility to the waste management system, and thereby decoupling the reactor unloading operation from the repository emplacement operation, would allow each waste management system function to be developed and operated according to criteria or objectives that are most relevant to its performance. The objective of the reactor unloading operation is to accept spent fuel at a rate and in a manner that will allow both at-reactor spent-fuel storage and spent-fuel transportation to operate efficiently. The objective of the repository loading operation is to emplace spent fuel in the repository in a safe, cost-effective manner. Distributing the functions associated with waste acceptance and emplacement between the MRS facility and repository would specialize operations within the facilities and would clearly focus the operating goals of each facility. MRS facility operations would focus on acceptance and packaging and the repository would focus on emplacement. By contrast, in the no-MRS system, the repository would have the responsibility of managing all aspects of system operations (for example, waste acceptance and transportation, in addition to geologic disposal).

In the no-MRS system, the waste acceptance rate in the early years of system operation is closely coupled to the repository's limited emplacement rate. The waste-acceptance rate would not be sufficient for utilities to reduce their additional at-reactor storage requirements, even if the federal system were to take only fuel that otherwise would have encroached on full-core reserve or would have required expanding at-reactor storage capacity. The most efficient use of the waste-acceptance and transportation functions would be for the DOE to accept enough spent fuel to both reduce the utilities' storage constraints and to fill several transport casks during any shipping campaign. However, with a low acceptance rate, taking more spent fuel from any single utility would imply that spent fuel would not be accepted from some utilities who also need to reduce their storage constraints.

Operating in the startup mode in its initial years of operation, the MRS system could accept spent fuel, prepare it for subsequent disposal, and store it until the repository is operating and ready to begin emplacement. The MRS facility's capability to operate in this mode until the repository emplacement rate could equal or exceed the acceptance rate would allow the DOE to accept fuel from more reactor sites and in larger increments than would be possible in the no-MRS system. This capability also would allow the DOE to perform the acceptance and transportation functions more efficiently without increasing at-reactor storage requirements at other reactor sites. The relationship between the waste-acceptance rate and the requirement for additional at-reactor storage capacity is discussed in more detail in Section 2.3.3.

The MRS facility also offers the capability to select spent fuel for emplacement based on what is most appropriate for efficiently operating the repository. The MRS facility could sort or select the spent fuel for emplacement from its storage backlog resulting from startup operations. (This operating mode is discussed in more detail in Section 2.3.5.) For example, with the MRS system, spent fuel with the lowest heat output could be selected for emplacement in the repository. This example shows the potential flexibility for selecting fuel for emplacement using different criteria than those used for acceptance and transportation. For example, fuel that is hotter than desired for emplacement could be accepted and stored at the MRS facility. As repository designs and operating strategies are further developed, the incentives for various sorting strategies will be further examined.

System Availability

The decoupling of acceptance and emplacement processes would also be particularly advantageous for sustaining system operations if extended subsystem interruptions were to occur after startup. This decoupling effect would be most important in the early years of system operations because offnormal events can occur in starting up such systems. Offnormal events largely control system availability and productivity in complex engineered systems such as the waste management system. "Normal" operation is approached slowly as equipment and procedures are refined. System failures and their potential effects on MRS and no-MRS system availability are discussed in the following paragraphs.

An extended decrease in the amount of spent fuel accepted and transported from the reactors (called acceptance failure) would have different consequences in the MRS and no-MRS systems. In the no-MRS system, an acceptance failure would quickly extend throughout the system, eventually stopping emplacement operation and idling the entire waste management system. In the MRS system, assuming an adequate spent-fuel inventory existed in storage, waste transport and emplacement at the repository could continue at normal throughput levels for several years.

In the MRS system, failures in the repository or emplacement operations would not affect the acceptance process as quickly as in the no-MRS system because of the MRS facility's storage capability. In the no-MRS system, spent-fuel acceptance could be halted in a few months by a shutdown of the emplacement function.

An interruption in the consolidation process in either the MRS or no-MRS systems would interfere with spent-fuel acceptance and transportation. Spent-fuel casks would begin to accumulate at the MRS facility or repository and would halt waste-acceptance operations. The consolidation process could be bypassed by canistering intact spent fuel, but at a lower rate than for consolidated fuel. However, in the MRS system an interruption in consolidation would not affect shipments to the repository and emplacement operations, whereas in the no-MRS system the interruption would decrease or stop the emplacement rate as well as spent-fuel acceptance and transportation.

The ability of the MRS facility to limit the effect of system failures or interruptions on other functions would depend on its available storage space. For example, to protect emplacement operations from stoppages in spent-fuel acceptance, the MRS facility would need an inventory sufficient to feed the repository. To ensure that acceptance operations would continue if emplacement were to stop, the MRS facility would have to maintain available capacity in its storage area.

2.3.2 Waste-Acceptance Operations

Waste-acceptance operations in the MRS and no-MRS systems would differ because of the MRS facility's earlier availability and storage capacity. As discussed in Section 2.2, the standard utility contract (10 CFR 961) requires the DOE to allocate acceptance rights to individual utilities beginning in 1991. If the MRS facility is approved, a key consideration in allocating waste-acceptance rights will be the use of the facility's storage capacity. The tradeoffs to consider are allocating sufficient waste-acceptance rights to reduce the utilities' need to expand their at-reactor storage capacities and to operate waste-acceptance and transportation functions efficiently, while reserving part of the MRS facility's 15,000 MTU storage capacity as contingency against changes in the repository schedule. These considerations are discussed in the following sections.

Accelerated Acceptance Rate

To determine the effects of an MRS facility on spent-fuel acceptance, the criteria for setting fuel-acceptance priorities must be examined. The standard utility contract (10 CFR 961) bases the allocation of acceptance rights on spent-fuel age and reactor status. Acceptance rights would be granted on an oldest-fuel-first basis with a possible priority for fuel from decommissioned reactors. For some reactors, this initial allocation may not provide sufficient acceptance rights to prevent encroachment on full-core reserve (FCR) (storage reserved to allow a complete discharge of the core, if required). Either additional storage capacity or some reallocation of acceptance rights would be required at those sites. The term "additional storage capacity" refers to the amount of fuel that would require either 1) consolidation for continued storage in the reactor pool, 2) transfer to onsite dry storage, or 3) transfer to offsite storage in order for the utility to maintain FCR capacity in its reactor pool. The standard utility contract provides a method of reallocation of acceptance rights through a trading process, as described in 10 CFR 961. However, the initial acceptance rate must exceed the utilities' need for additional capacity before any allocation process could effectively reduce the utilities' needs for further expanding their at-reactor storage capacity after the waste management system begins to accept spent fuel for disposal.

Table 2.4 compares projected annual requirements for additional at-reactor storage capacity with waste-acceptance rates for the no-MRS and MRS systems. The projection for storage-capacity requirements is based on reactor-by-reactor comparisons of projected spent-fuel generation, pool inventory, and pool capacity. The assumptions for these projections are described briefly below.

The projections for the data in the table are based on the DOE/Energy Information Administration (EIA) "mid-case" forecast, which is the DOE's planning base for the waste management system (Heeb, Libby and Holter 1985; Gielecki et al. 1984). In Appendix D, results are reported for this mid-case scenario, for projections based on utility-supplied data, and for a modification of the EIA mid-case scenario that assumes extended burnup (leaving the assemblies in the reactor core to obtain more of the energy value of the fuel). These projections are updated annually. While the 1985 projections

TABLE 2.4. Comparison of Additional Annual At-Reactor Storage Capacity Requirements and Maximum Waste Management System Acceptance Rate for the EIA Mid-Case Spent-Fuel Generation Scenario (MTU)

		No-MRS System		MRS System	
Year	No Federal Waste Acceptance	Maximum Federal Waste Acceptance[a]	Additional Annual Storage Capacity	Maximum Federal Waste Acceptance[a]	Additional Annual Storage Capacity
1995	2,882[b]	0	2,882[b]	0	2,882
1996	825	0	825	400	425
1997	896	0	896	1,800	0
1998	858	400	458	2,550	0
1999	1,292	400	892	2,550	0
2000	1,349	400	949	2,575	0
2001	1,295	900	395	2,575	0
2002	1,873	1800	73	2,600	0
2003	1,552	3,000	0	2,700	0
2004	1,659	3,000	0	2,850	0
2005	1,918	3,000	0	2,950	0
TOTAL			7370		3307

(a) Waste-acceptance rates are discussed in Section 1.4 and displayed in Table 1.2.
(b) Cumulative requirement through 1995.

were not available for this analysis, they are expected to support the general conclusion that additional storage capacity would be required before the no-MRS system reaches full-acceptance capacity.

Reactor-pool capacities and inventories are based on data collected by the DOE from each utility (DOE 1984). Reactor-pool capacity is assumed to be the capacity that the utilities believe can be achieved by maximum reracking (replacing old racks with new racks that provide greater storage capacity). The projections in Table 2.4 assume that each reactor would maintain sufficient FCR storage capacity. A single FCR is assumed to be maintained for all units at multiple-unit reactor stations that use either a single, common spent-fuel storage pool or separate pools that are interconnected for transferring spent fuel.

For the no-MRS system, Table 2.4 shows that requirements for at-reactor storage capacity would continue to accumulate from 1998, when the waste management system is scheduled to begin accepting spent fuel for disposal through 2002. In 2003, when the repository would reach its planned emplacement rate of 3000 MTU per year, the system acceptance rate (repository emplacement rate) would exceed the requirement for additional at-reactor storage capacity. By contrast, the MRS system could begin accepting spent fuel in 1996 and by 1997 its receipt rate would exceed the requirements for additional at-reactor storage capability.

The MRS system could reduce the reactors' needs to continue their expansion of at-reactor storage capacity after 1996. To reduce the requirements, the MRS facility would have to receive approximately 2000 MTU per year until 2003, assuming that acceptance rights would be allocated to reactors that would otherwise encroach on their FCR storage capacity.

Appendix D contains a detailed comparison of the requirements for additional at-reactor storage capacity from now until the waste management system reaches its equilibrium rates for the MRS and no-MRS systems. Table 2.5 summarizes the results of that comparison for all 3 spent-fuel-generation scenarios. The table shows that an MRS facility can eliminate from 1800 MTU to 6500 MTU of additional at-reactor storage capacity at 16 to 24 reactor sites, depending on which spent-fuel generation scenario is realized.

TABLE 2.5. Effect of an MRS Facility on Requirements for Additional At-Reactor Storage Capacity

Waste Management System	Spent-Fuel-Generation Projection: Utility	EIA Mid-Case	Extended Burnup
Additional Storage-Capacity Requirement (MTU)			
No-MRS	11,400	7,400	4,100
MRS	4,900	3,300	2,300
Number of Reactor Sites Requiring Additional Storage Capacity			
No-MRS	67	57	40
MRS	45	33	24

Tables 2.4 and 2.5 indicate that not all of the MRS facility's early acceptance capacity or storage capacity would be required to reduce additional at-reactor storage capacity once the waste management system begins accepting spent fuel. An acceptance rate of 1000 MTU to 2000 MTU per year out of a maximum rate of over 2500 MTU per year would be sufficient, and 1800 MTU to 4100 MTU out of the maximum storage capacity of 15,000 MTU would be sufficient for achieving this objective.

Waste Acceptance and Transportation Efficiency

The MRS system could receive even more fuel than would be required to reduce the requirement for additional at-reactor storage capacity. This capacity offers the potential for increasing the fuel-acceptance allocation at each reactor, thereby increasing the efficiency of the acceptance and transportation functions. The flexibility to accept more than the minimum fuel required to reduce at-reactor storage requirements makes this practical, because increasing the acceptance allocation of one reactor site would not displace the acceptance allocation of another reactor site. As a result, in the MRS system, the process of accepting spent fuel can be managed for efficiency, rather than as an allocation of a scarce resource.

Contingency Storage Capability

The MRS facility's 15,000 MTU storage capacity could accommodate schedule or emplacement rate changes in the repository. After 1998, approximately 1500 MTU of additional storage capacity would be required per year (EIA midcase) if no fuel were accepted for disposal. Table 2.4 shows these requirements for the first few years after 1998; further details may be found in Appendix D. As Table 2.4 shows, for the no-MRS system, at-reactor storage expansion would continue to be needed until the repository rate levels off at 3000 MTU per year 6 years after initial emplacement.

The combination of the MRS facility's storage capacity and the repository's first 5 years of fuel emplacement capacity would eliminate the need for additional at-reactor storage requirements if the repository reaches full operation within 12 years after the MRS facility begins accepting spent fuel. The MRS facility's storage capacity would be 15,000 MTU and the repository's expected fuel emplacement is 400, 400, 400, 900 and 1800 MTU (3900 MTU total, see Table 1.2) for the first 5 years, respectively. Assuming an average annual requirement for additional at-reactor storage capacity of 1500 MTU for 12 years results in a total requirement of 18,000 MTU for federal spent-fuel acceptance. Over the same time period, 18,900 MTU could be accepted either for storage at the MRS facility (up to 15,000 MTU) or for emplacement at the repository (3,900 MTU from its first 5 years of operation). For a 1996 MRS facility startup, the repository would need to begin emplacing fuel in 2003 and reach full operation in 2008. This corresponds to a five-year delay in the current plan to begin repository emplacement in 1998.

In its proposal for constructing and operating an MRS facility, the DOE has requested that spent-fuel acceptance at the MRS facility begin only after a construction license is issued for the first repository. The current schedule calls for this license to be issued in August, 1993. The planned construction and licensing period for the repository is approximately 4.5 years, leading to initial operation in January, 1998. If the repository construction license is issued by 1996 (a three-year change) and the repository begins operation by 2003 (a five-year change), the storage capacity at the MRS facility would be sufficient to allow the DOE to accept spent fuel at a rate that will eliminate the need for additional at-reactor storage capacity. Those changes could be accommodated without affecting the DOE's ability to accept spent fuel for disposal at a rate sufficient to reduce the need for additional at-reactor storage capacity.

2.3.3 Spent Fuel Transportation Operations

Most of the spent fuel requiring shipment for disposal would originate in the eastern one-third of the country. The MRS facility's central location to those current and projected spent-fuel inventories would improve the operation of the spent-fuel transportation system.

Figure 2.3 shows that including the proposed MRS facility in the waste management system would divide the shipment of spent fuel from eastern reactors into two segments: the shipment from eastern reactors to the centrally located MRS facility, and a longer leg from the MRS facility to a first repository located in the west. Spent fuel from the western reactors most likely would be shipped directly to the repository to avoid shipping the fuel across country

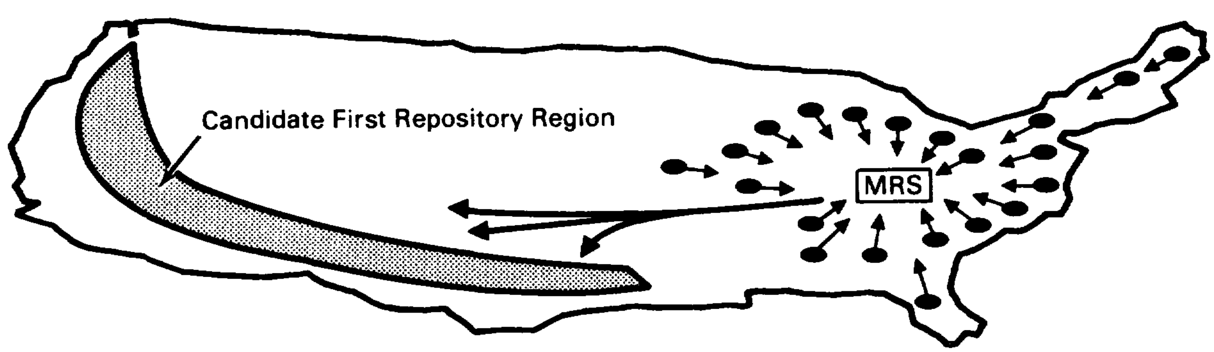


FIGURE 2.3. Movement of Spent Fuel from Eastern Reactors with an MRS Facility

for consolidation and canistering, and then back again for disposal. In the first segment, the spent-fuel shipments from eastern reactors to the MRS facility (and from western reactors to the first repository) would primarily consist of intact spent-fuel assemblies shipped in either truck or rail casks, depending on at-reactor cask-handling capabilities. This transportation segment would be similar to that of the no-MRS system, but the shipments from eastern reactors would be much shorter. The second segment, from the MRS facility to the repository, would consist of shipments of consolidated fuel (and associated fuel-assembly hardware) in large rail casks and would likely be by dedicated trains consisting of five or more spent-fuel casks.

Appendix F describes the analytical assumptions, calculation methods, and results used for the transportation system evaluations described in this volume. The key logistics assumptions for calculations reported in this section are described below. These assumptions apply to all of the figures or tables in this section, unless otherwise noted. Appendix F discusses the impacts of variations in these assumptions.

1. Three potential first-repository locations represent the variation in transportation requirements for the nine locations that DOE is considering for the first repository. These three locations are Yucca Mountain, Nevada (tuff geologic medium), Hanford, Washington (basalt geologic medium), and the Deaf Smith site in Western Texas (salt geologic medium).

2. The MRS facility would be located at the DOE's preferred site--the Clinch River site, near Oak Ridge, Tennessee.

3. Transportation results are for shipping a total of 62,000 MTU of spent fuel to the first repository. For the no-MRS system, all of this fuel would be shipped directly to the first repository. For the MRS system, 53,000 MTU of spent fuel from eastern reactors would be shipped to the MRS facility for consolidation and canistering before being shipped to the repository. The remaining 9,000 MTU of spent fuel, from western reactors, would be shipped directly to the repository.

4. For fuel shipments from reactor sites, 70% would be by rail cask and 30% by truck cask. These percentages correspond to the approximate proportion of reactors that can currently accommodate rail casks. Rail casks would hold 14 PWR or 36 BWR assemblies. Truck casks would hold 2 PWR or 5 BWR assemblies.

5. Consolidated spent fuel and associated fuel hardware would be shipped from the MRS facility to the repository site by.dedicated train. Each train would consist of 5 large casks containing canisters of consolidated spent fuel, and additional casks as required for the associated spent-fuel hardware. Canister dimensions, and therefore cask capacity, would vary for the 3 repository geologic media. The capacities assumed are 48 PWR or 98 BWR assemblies for tuff, 84 PWR or 171 BWR assemblies for basalt, and 72 PWR or 150 BWR assemblies for salt.

The changes in transportation system operation with an MRS facility in the waste management system would primarily affect the management and control of the transportation operations, and the potential for radiological exposure from transportation system operations. These effects are discussed in the following sections.

Transportation System Management and Control

Table 2.6 shows the average annual number of spent-fuel casks that would be shipped from the eastern reactors either to the proposed MRS facility or to the first repository. Approximately 250 rail and 725 truck shipments would be received annually from eastern reactors at either an MRS facility or the first repository. The table shows that spent fuel from incoming shipments from eastern reactors would be combined into fewer casks and shipments at the MRS facility for the subsequent, longer shipment to the repository for disposal.

The number of shipments that the fuel from eastern reactors could be combined into for cross-country shipment would vary among the three repository sites according to the physical characteristics of each repository's disposal container. Table 2.6 shows that the spent fuel from eastern reactors could be combined into 13 to 22 rail shipments per year (depending on the geologic medium assumed of the first repository) for the long cross-country transport segment in the MRS facility. In the no-MRS system, 250 rail and 725 truck shipments are required. Including an MRS facility therefore reduces cross-country shipments by 95%.

Combining spent fuel from eastern reactors into fewer cross-country rail shipments, which would originate and terminate at facilities controlled by the DOE, would improve the management and control of these shipments. Planning would be simplified because fewer cross-country route alternatives would be involved, with a single source and destination. With fewer routes to consider, greater focus would be provided for developing emergency preparedness plans, for training local officials to respond to potential radiological accidents,

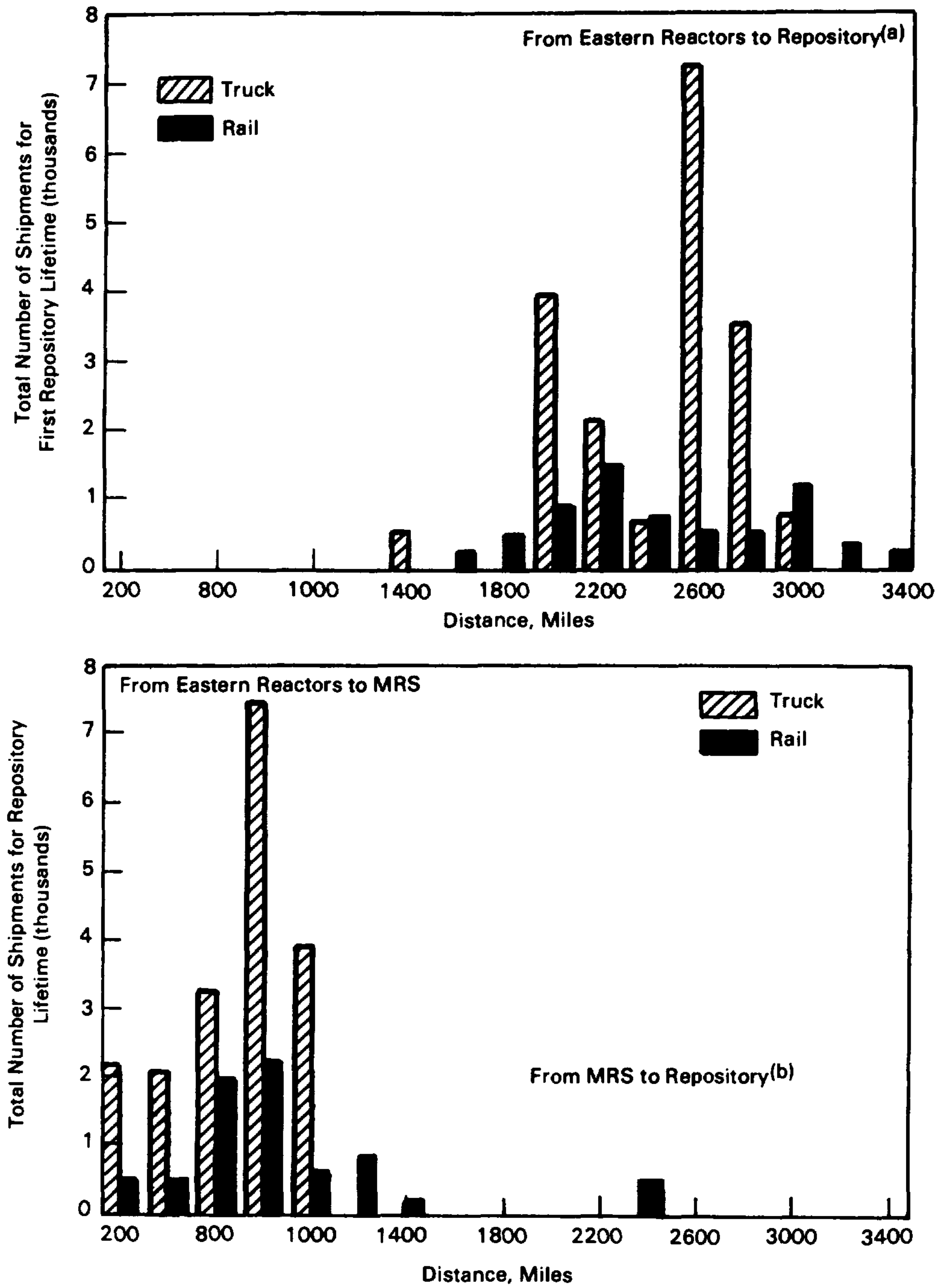
TABLE 2.6. Average Annual Shipments of Spent Fuel From Eastern Reactors

	First Repository		
	Tuff	Salt	Basalt
Reactors to MRS facility or to Repository			
Truck Casks	725	725	725
Rail Casks	250	250	250
Shipments	975	975	975
MRS Facility to Repository			
Spent-Fuel Casks	109	72	63
Hardware Casks	57	57	57
Shipments	22	15	13

for monitoring shipments, and for responding to operational interruptions or emergencies. Reductions in total cross-country shipments would proportionately decrease state and local preparations.

Figure 2.4 shows the average distribution of truck and rail shipment distances from eastern reactors, with and without an MRS facility. The figure is based on a tuff repository (located at Yucca Mountain, Nevada), which for the MRS facility would be the intermediate location of the three first repository locations used for these calculations. As the figure shows, the distances of both truck and rail shipments originating at reactors would be reduced substantially with an MRS system. The average shipment distance for shipments originating at the reactor sites would be reduced from about 2400 miles to about 700 miles.

An MRS facility would also simplify transportation operations from the reactor sites. An MRS facility would significantly shorten these trips. Because the decrease in the average distance for the more frequent, routine shipments originating at reactor sites would decrease the shipments' durations, fewer trips would be in progress at any one time. Table 2.7 compares the average number of days per year that truck or rail casks would be in transit from eastern reactors with and without an MRS facility. The data are also based on disposing of spent fuel in a tuff repository, which would be intermediate in terms of distance from eastern reactors. The table shows a decrease of about 50% in transportation activity (as measured by the average number of days in transit) from these reactors.



(a) Repository assumed to be at Yucca Mountain, Nevada.

(b) For rail shipments from an MRS facility to the repository, the capacity of outgoing casks is assumed to be 1.5 times the capacity of incoming casks, and each shipment is assumed to consist of 5 casks.

FIGURE 2.4. Truck and Rail Shipping Distances

TABLE 2.7. Comparison of Cask-Days for Shipping Fuel From Eastern Reactors With and Without an MRS Facility (annual cask-days for 2500 MTU)

	MRS Facility	No-MRS Facility
Truck Shipments	1000	3465
Rail Shipments	3400	6600

Reducing the average time for each shipment and the number of shipments in progress at any one time would simplify the monitoring and control aspects of managing transportation system operations. A particular shipment's location would be known with more certainty at any time, so monitoring functions and coordination with state and local transportation authorities would be simplified. Also, having fewer shipments in progress at any time would decrease resource requirements for monitoring shipments and responding to operational interruptions or emergencies.

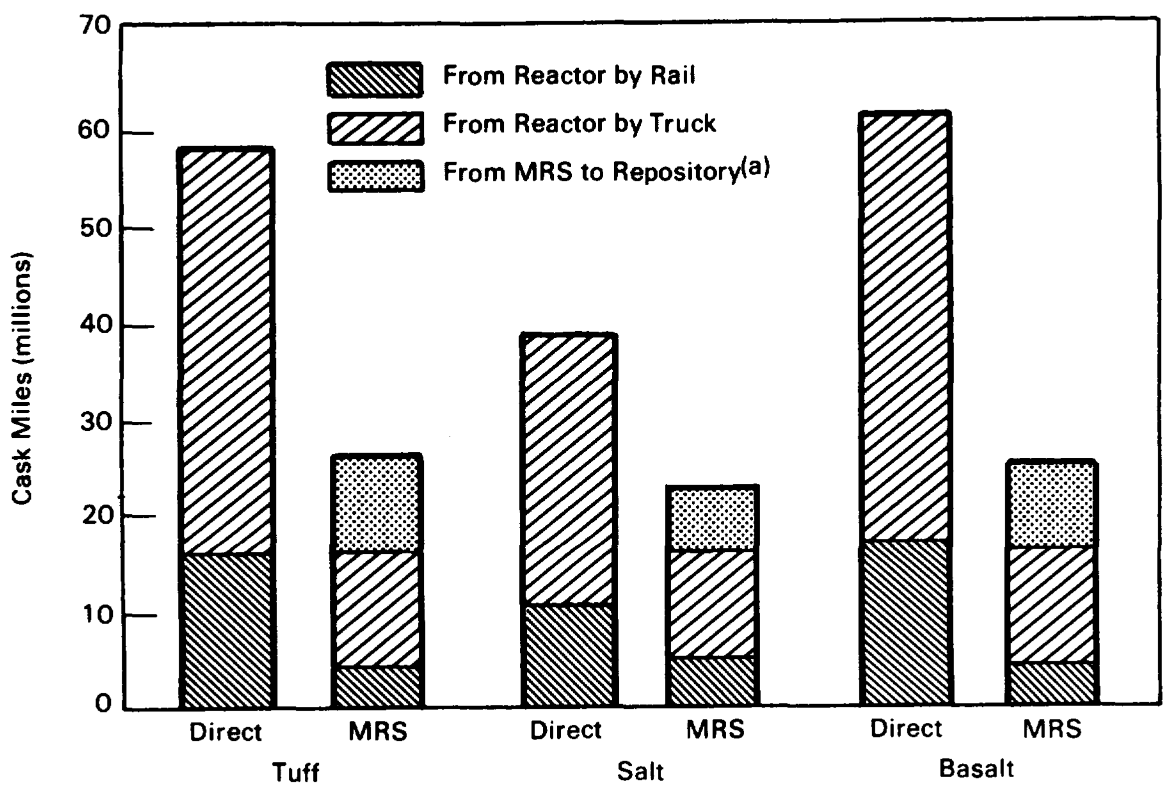
Radiological Exposure from Transportation Operations

The risks from transporting spent fuel to the first repository for disposal would be very low with or without an MRS facility in the waste management system. However, adding an MRS facility would slightly alter both the magnitude and distribution of these risks. The effect of the MRS facility on the magnitude of the public radiological exposure from transportation operations is discussed in this section. In Section 2.5, radiological exposure from transportation of spent fuel is further discussed in context of its contribution to the total public and occupational radiological exposure for operating the waste management system with and without an MRS facility.

The risk effects from spent-fuel transportation would be from both nonradiological and radiological factors. Nonradiological risks are measured in terms of fatalities and injuries from transportation accidents that would occur regardless of the nature of the commodity being shipped. With or without an MRS facility in the waste management system, truck and rail shipment of spent fuel would constitute a very small fraction of the normal commercial-freight shipping mileage and would not appreciably change the number of transportation-related fatalities or injuries.

Radiological risks are due to routine exposure to radiation from shipping the spent-fuel casks and potential releases from severe accident situations. This type of risk is unique to the shipment of nuclear material and is the reason that spent-fuel shipments are subject to more stringent regulations and control than normal commercial freight. Including an MRS facility in the waste management system would affect both routine exposure and the likelihood of an accident occurring involving radiological release.

Routine radiological exposure from shipping spent fuel in either truck or rail casks would be primarily a function of the number of miles that the individual cask travels (known as cask-miles) and the population density through which it travels. An MRS facility would reduce the mileage that truck and rail casks containing intact spent fuel from reactor sites would travel, but would increase mileage for large-capacity rail casks containing consolidated spent fuel or assembly hardware. Figure 2.5 illustrates this tradeoff for moving 62,000 MTU of spent fuel to each of three assumed locations for the first repository. As the figure shows, an MRS facility would reduce total cask-miles for each of these repository locations.



(a) Shipments from the MRS facility to the repository are assumed to be in 150-ton rail casks.

FIGURE 2.5. Cask-Mile Comparisons

Another factor to consider in comparing routine radiological exposure in the MRS and no-MRS systems is the variation in radiological exposure per cask-mile between the truck and rail shipping modes and any changes in the population densities along the routes. In general, the radiological exposure per cask-mile would be less for rail transport of spent fuel than for truck transport. In addition, the routine radiological exposure per cask-mile for rail shipments from the MRS facility to the repository would be less than for rail shipments from the reactors to the repository because dedicated trains are assumed to have fewer delays than normal commercial traffic. Therefore, for shipments originating at reactors, routine radiological exposure would be reduced by using the fewer number of cask-miles from dedicated train transport rather than the truck and rail cask-miles. Exposure would be reduced because both total cask-miles and the exposure per cask-mile for part of the transit to the repository would be reduced.

Table 2.8 summarizes the routine radiological exposures calculated for moving 62,000 MTU of spent fuel to each of the candidate repository locations with or without an MRS facility. The table shows that including an MRS facility would reduce routine radiological exposure. The bases for these results are discussed in Appendix F.

The other aspect of radiological risk that the MRS facility would affect is risk from accidents involving radiological release. These risks would be very slight with or without an MRS system because the design specifications for spent-fuel casks and licensing requirements make any radiological release from a spent-fuel cask involved in a transportation accident very unlikely (Wilmot et al. 1983). In general, the likelihood that spent-fuel casks would be involved in accidents would be related to the number and the distance of the trips. Averaged over a broad range of routes and conditions, the probability that a train or truck will have an accident is proportional to the distance it travels.

TABLE 2.8. Comparison of Routine Radiological Dose With and Without an MRS Facility (person-rems)

	Repository		
	Tuff	Salt	Basalt
MRS Facility	5,250	5,650	5,400
No-MRS Facility	14,600	10,000	15,800

Table 2.9 compares the number of shipment-miles (the number of miles traveled by trucks or trains transporting spent-fuel casks) for shipping 62,000 MTU of spent fuel to each of the potential first repository sites with or without an MRS facility. Shipment-miles would be the same as cask-miles (shown on Figure 2.4) for truck shipments and rail shipments into the MRS facility. However, shipment-miles would be lower than cask-miles for the shipments from the MRS facility to the repository because multiple casks (5 casks containing spent-fuel rods and additional casks for the associated assembly hardware from consolidation) would be shipped with each train. The table shows that both truck and rail shipment-miles would be reduced by including an MRS facility in the waste management system.

The reduction in shipment-miles in Table 2.9 would correspondingly reduce the opportunity for and likelihood of accidents involving a truck or train carrying spent-fuel casks. With an MRS system, the probability of an accident per shipment-mile for the dedicated train portion of the rail shipments could also be reduced because of preferred routing, decreased stops and other operational considerations for dedicated trains.

Including an MRS facility in the waste management system would also redistribute the radiological and accident risks to different populations. Spent-fuel shipments would be more heavily concentrated near the MRS facility compared with the no-MRS system. However, far fewer shipments would be made to

TABLE 2.9. Comparison of Shipment-Miles With and Without An MRS Facility (millions)[(a)]

	Tuff		Salt		Basalt	
	Truck	Rail	Truck	Rail	Truck	Rail
No-MRS	42.5	16.2	28.3	10.8	44.9	17.2
MRS						
From Reactors	11.9	4.6	13.8	5.3	12.5	4.8
From MRS Facility	--	1.3	--	0.5	--	0.8
Total MRS	11.9	5.9	13.8	5.8	12.5	5.6
% Reduction from MRS to no-MRS	72	64	51	46	72	67

(a) 70% rail/30% truck, with single-cask rail shipments from reactors and 5 spent-fuel rail casks per shipment from MRS to repository.

the repository. Corridor states into the first repository would face significantly fewer shipments with the MRS facility. This study has not attempted to place a value on this redistribution of transportation radiological risk. Some locations would face an increase in such risk, whereas the overall total system radiological risk from spent-fuel transportation would be reduced by including an MRS facility in the waste management system.

2.3.4 Effect of an MRS Facility on Packaging Operations

With an MRS facility in the waste management system, the initial packaging operations for spent fuel from eastern reactors will be performed at the MRS facility rather than at the repository. Fuel from eastern reactors would be consolidated and placed in a canister for either immediate shipment to the repository or for onsite storage until it could be shipped to the repository. Any additional packaging required prior to emplacement would be performed at the repository. Fuel from western reactors would be shipped directly to the repository, and all packaging operations performed there prior to emplacement.

The primary effects on system operations of fuel consolidation at an MRS facility for emplacement at the first repository relate more to the location rather than the way this operation is performed. The consolidation operation would be essentially the same whether it is performed at the MRS facility or at the repository. The major difference in performing it at the MRS facility is that a canister is provided for storing fuel rods or for containing them for shipment to the repository. Even if additional packaging is required before the canisters are emplaced in the repository, the canister would likely provide additional containment for disposal of the fuel, and additional structural integrity for the disposal package.

Consolidating the spent fuel at a separate site from the repository decouples the pre-emplacement and emplacement functions both in location and timing. The location aspect of this decoupling is the primary source of the changes in transportation system operations, previously discussed in Section 2.3.3. The timing of the decoupling relationship is the source of the operational flexibility, previously discussed in Section 2.3.1.

2.3.5 Effect of an MRS Facility on Repository Operations

Surface facility and underground operations at the first repository would change with an MRS facility in the waste management system. While the nature of the initial cask receiving and handling operation would be the same in the MRS and no-MRS systems, the repository receiving and handling operations would be much simpler in the MRS system. In the no-MRS system, the repository receiving and handling facility would handle a mixed stream of truck and rail casks. Because many origins and routes would be involved in shipping the fuel, the casks would arrive at varying rates. Therefore, in the no-MRS system, the repository receiving and handling facility would have to frequently change equipment to accommodate different types of casks and fuel and would have to be available most of the time because of varying arrival rates.

In addition to the flexibility to accept more spent fuel than could be emplaced in the early years of repository operation, the MRS facility could be used to sort or select fuel for disposal based on considerations appropriate for optimizing repository operations. As discussed earlier, the MRS facility could sort or select the spent fuel for emplacement from its storage backlog resulting from startup operations. The MRS system, operating in the storage-retrieval mode, could store all or part of the input stream at any time and could select the optimum set of fuel for shipment to the repository. However, in the no-MRS system, all fuel accepted would have to pass through all waste-preparation steps, including emplacement, regardless of whether it is the preferred fuel for emplacement.

The MRS system could be operated in the storage/retrieval mode to select spent fuel with the lowest heat output for emplacement in the repository. Generally, the ideal repository input stream would be cool and of homogeneous age. Cooler fuel would require fewer waste packages or allow closer spacing of waste packages in the repository.

Figure 2.6 illustrates the change in heat load for fuel arriving at the first repository if the MRS facility were to select fuel for emplacement. The figure shows the average heat generation per MTU of spent fuel delivered to the repository as a function of time. The data in the figure were calculated using the maximum waste-acceptance rates described in Section 1.4 for the MRS and no-MRS systems. For both systems, acceptance rights were assumed to be reallocated among utilities in a way that fuel would be accepted from reactor sites that would otherwise have to expand their at-reactor storage capacity to maintain an FCR storage capacity. Any additional acceptance capacity was then assumed allocated on the bases described in the standard utility contract (10 CFR 961). The contract specifies that waste acceptance will be on the basis of fuel age, with the exception that priority may be given to fuel from decommissioned reactors.

The detailed logistics analyses for the figure were performed using the Energy Information Administration (EIA) mid-case forecast (Heeb, Libby, and Holter 1985; Gielecki et al. 1984) for spent-fuel inventory and characteristics data, and reactor-pool-capacity data collected by the DOE from each utility (DOE 1984). The WASTES computer model (Shay and Buxbaum 1986) was used to identify which fuel would be accepted each year, based on the acceptance rates and priorities described above. The model was also used to calculate the average heat generation for fuel shipped to the repository, based on its age

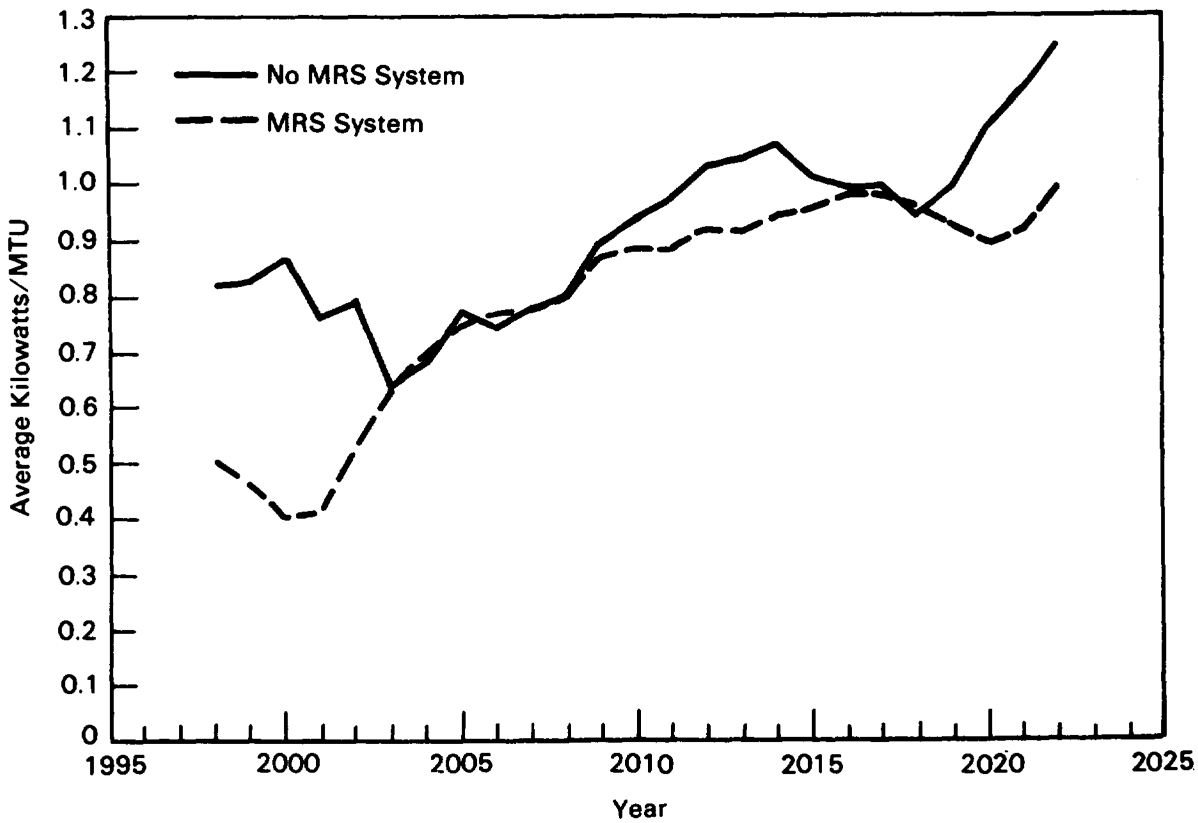


FIGURE 2.6. Average kW/MTU for Receipts at Repository 1 (no-MRS versus MRS systems)

and burnup. For the no-MRS system, the fuel accepted would be the fuel that would be emplaced in the repository. For the MRS system, the WASTES model identified the fuel with the lowest heat generation rate for emplacement in the repository from the fuel accepted in a given year or in inventory at the MRS facility.

The figure shows that if the MRS facility were operated in this mode, heat generation for fuel shipped to the first repository would average about 15% less than for the no-MRS system. This selection of fuel for the first repository would leave relatively hotter fuel in the inventory at the MRS facility to continue cooling until its heat generation decreased. The 15% decrease in the average heat-generation rate for fuel emplaced in the first repository would either reduce the underground area at the repository (lower cost) or reduce areal heat loading (more conservative licensing basis). As repository designs and operating strategies are further developed, the incentives for various sorting strategies will be further examined.

2.4 SYSTEM COST EFFECTS

The DOE is responsible for implementing the safe and environmentally acceptable operation of the federal waste management system in a cost-effective manner. The NWPA requires that the generators of the waste pay all disposal costs. In addition to the federal portions of the system, which are covered by the Nuclear Waste Fund (NWF), the total waste management system includes the storage and handling of spent fuel at reactors. These costs are typically paid by utilities and are in addition to their payment of NWF assessments. The DOE is responsible for executing and managing technically sound and cost-effective programs within the revenue constraints of the NWF and for considering the total effect of its programs on utility costs. Consequently, the following discussion of the cost effects of deploying an MRS facility considers the costs for both the federal and utility portions of the system. All facility costs in this section are from DOE (1986). The cost effects of adding an MRS facility to the waste management system are summarized in Table 2.10. Capital and operating costs were examined for utility spent-fuel storage, spent-fuel transportation, the MRS facility, and the repository's surface facilities. Each is discussed in the following sections. Development and evaluation (D&E) costs were not estimated. The D&E costs for the MRS Program are discussed in Volume 3 of this submission.

2.4.1 Facility Cost Effects

Adding an MRS facility to the waste management system would effectively transfer the facility for receiving, handling, and packaging spent fuel to a site separate from the first repository. The repository in the MRS system would require a smaller surface facility for receiving a reduced number of large rail casks containing canisters of consolidated spent fuel from the MRS facility. The repository would also have facilities for placing both these canisters and the DHLW canisters received from defense facilities into disposal containers. The repository would be able to receive and package the spent fuel directly from western reactors. These changes in the waste management system would increase total facility costs because of the additional site for waste-handling operations and some duplication in the receiving and handling facilities from adding an MRS facility.

Appendix C describes in detail the effects of various waste management system configurations on total capital and operating costs of the surface facilities. The following paragraphs summarize the major effects and results of that analysis.

TABLE 2.10. System Cost Effects of the MRS System

System Function	Cost Impact of the MRS System
Overall System	Increases cost for facilities and transportation in the federal portion of the waste management system by $1.4 to $2.0 billion. Would reduce costs in the utility portion of the system, depending upon the amount of additional storage that is avoided.
Waste Acceptance	Avoids utilities' storage costs from $150 to $450 million with the current repository emplacement schedule and could avoid as much as $0.6 to $1.7 billion if all 15,000 MTU of MRS capacity replaces more expensive at-reactor storage.
Transportation	Decreases transportation costs by as much as $0.2 billion compared to the no-MRS system.
Packaging	Increases facility capital and operating costs (of the MRS facility and the repository surface facilities) by about $1.6 to $2.0 billion, which includes $0.4 billion for an assumed storage inventory of 12,000 MTU.
Disposal	Information available is not sufficient to identify significant cost differences in the subsurface portion of the repository.

As part of an effort to provide a common basis for comparing MRS facility and repository costs under varying system configuration assumptions, the DOE commissioned the MRS/Repository Interface Task Force. The objectives of the task force were to analyze, on a consistent basis, capital and operating costs of the waste management system and to determine the redistribution of system costs that would result from adding an MRS facility. Prior to that effort, consistent cost comparisons were not possible because MRS facility and the existing repository surface facility designs were based on different assumptions concerning waste-handling technology and had not been developed to a consistent level of detail.

The task force effort (DOE 1986) produced cost data that were based on the assumption that surface facilities similar to the MRS facility design would be used for equivalent functions at the repository. This effort has improved the comparability of the MRS facility and the three repository cost estimates.

While these estimates are preliminary, they provide a reasonable basis for evaluating the cost implications of including an MRS facility in the waste management system.

The task force estimated costs for five waste management system scenarios (DOE 1986). Two of the scenarios, corresponding to the the no-MRS and MRS systems, are briefly defined in Table 2.11, and more extensively described in Appendix C. Cask storage for up to 12,000 MTU of spent-fuel inventory at the MRS facility is included in the assumed MRS scenario.[a]

The estimated facility costs for each of the three candidate media (basalt, salt, and tuff) for the first repository and the associated MRS facility that would serve that repository are shown in Table 2.12. These cost estimates are detailed in Appendix C and in the final report of the MRS/Repository Interface Task Force (DOE 1986). These estimates result in a cost of approximately $2.7 billion for the MRS facility. However, because functions would be transferred to the MRS facility, repository costs would be reduced. The effect of the MRS facility on the waste system, in terms of net system facility capital and operating costs, would be an increase of $1.6 to $2.0 billion, depending on the selected medium for the first repository. Estimates for scenarios where the MRS facility performs additional functions (such as receives western fuel) show that total facility costs would decrease as more functions are included in the MRS facility. These effects are discussed in Appendix C.

The MRS facility would add capabilities to the waste management system that are not present in the no-MRS system, including 1) the ability to receive spent fuel from reactors earlier than a repository and at accelerated rates; 2) the ability to decouple this receipt of spent fuel from reactors from the final packaging and disposal at the repository through its lag-storage capacity for canisters of consolidated fuel and some portion of its 15,000 MTU storage area; 3) the ability, through its 15,000 MTU storage capability, to provide a buffer against major disruptions or mismatches in fuel received from reactors and disposal capability at the repository, and 4) the ability to begin route-specific planning for transportation and detailed waste-acceptance planning several years earlier. The specific value of these incremental capabilities is very difficult to quantify, and no attempt has been made here to do so.

(a) The MRS conceptual design, which assumed that both eastern and western reactor fuel would be handled at the MRS facility, has storage capability for up to 15,000 MTU. Assuming the waste-acceptance schedules shown in Table 1.2, however, only about 12,000 MTU of storage would be used.

TABLE 2.11. Division of Waste-Packaging Functions for the No-MRS and MRS Systems[a]

		Waste Management System	
		No-MRS	MRS
First Repository	Receive:	All Fuel DHLW	Western Fuel DHLW Canistered Fuel from MRS
	Functions:[b]	Consolidate Canister Package	Consolidate and Canister Western Fuel, Package All Fuel
MRS	Receive:	None	Eastern Fuel
	Functions:	None	Consolidate Canister

(a) All scenarios assume disposal of 62,000 MTU spent fuel, including 9,000 MTU fuel from western reactors and 8,000 MTU equivalent of DHLW.

(b) Explanation of Functions:
Consolidate: Disassemble fuel assemblies and consolidate rods
Canister: Encase the consolidated fuel in canisters & seal
Package: Encase the waste (fuel assembly, fuel canister, DHLW canister) in the final disposal container

These added functions gained with an MRS facility have associated incremental costs. The facility would also add some duplicate facilities or operations to the system. In particular, the MRS system would add one shipping and one receiving step that would not be present in a no-MRS system--the canisters of consolidated spent fuel would have to be shipped from the MRS facility to the repository.

The additional MRS functions and their marginal costs are summarized in Table 2.13. As the table shows, the cost for the waste handling, site-support functions and utilities at the MRS facility would be approximately $2.3 billion. These added capabilities are required for early startup, accelerated

TABLE 2.12 Summary of Facility Capital and Operating Cost Comparisons for MRS and Repository Surface Facilities, Including Waste Packages (billions of mid-1985 dollars)[a]

System	Repository Costs	MRS Costs	Total Costs	Increment from Scenario 1
		Basalt Repository		
No-MRS	4.6	-	4.6	-
MRS	3.5	2.7	6.2	1.6
		Salt Repository		
No-MRS	4.3	-	4.3	-
MRS	3.3	2.7	6.0	1.7
		Tuff Repository		
No-MRS	3.5	-	3.5	-
MRS	2.8	2.7	5.5	2.0

(a) For additional details, refer to Appendix C.

receipt rate, and simultaneous receiving and shipping of fuel to the repository. Corresponding decreases in repository costs of $0.7 to $1.1 billion due to reduced waste-handling and support facilities produce a net cost of $1.2 to $1.6 billion. The cost of storing 12,000 MTU at the MRS facility adds about $0.4 billion.

Another cost incurred by the MRS facility would result from the use of a canister for holding consolidated spent fuel, either for storage at the MRS facility or for shipment to the repository for packaging in the final disposal container. In the no-MRS system, some design alternatives call for emplacing the consolidated spent fuel directly in the disposal container without an inner canister. Using a canister at an MRS facility would impose additional costs on the system, although these costs are estimated to be less than $50 million (DOE 1986). The canister would, however, provide an additional contamination barrier that would improve handling and testing at the MRS facility; similar benefits could also result during packaging and pre-emplacement operations at the repository.

TABLE 2.13. Facility Life-Cycle Cost Increments for Additional Functions Provided by the MRS Facility (billions of mid-1985 dollars)

	MRS	Net Cost at Repository: Basalt	Salt	Tuff	Total Net Cost
Waste Handling, Site-Support, and Utilities	2.3	(1.1)[a]	(1.0)	(0.7)	1.2 - 1.6
Waste Storage for 12,000 MTU	0.4	0	0	0	0.4
Waste Packages	0.0[b]	0.0	0.0	0.0	0.0
TOTAL	2.7	(1.1)	(1.0)	(0.7)	1.6 - 2.0

(a) Parentheses indicate net cost saving.
(b) Costs are less than $0.05 billion.

2.4.2 Effects of an MRS Facility on Utilities' Spent-Fuel Storage Costs

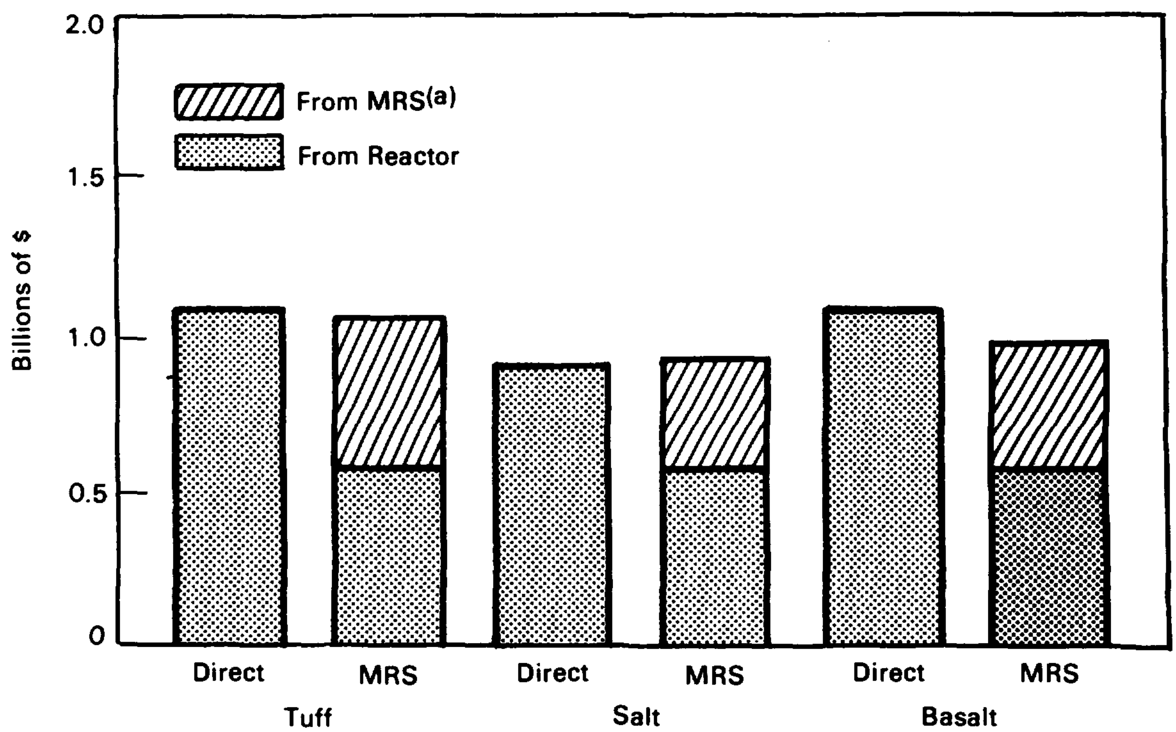
Adding an MRS facility could reduce the requirements for additional at-reactor storage capacity by about 4,000 MTU. The amount of reduction would depend on the amount of spent fuel generated by the utilities. The MRS facility could displace even greater quantities of at-reactor spent-fuel storage if the startup of the first repository were delayed and/or its initial rate of acceptance were reduced. These effects were discussed in detail in Section 2.3.

The avoided costs to the utilities are mentioned here only to place them in perspective with the other costs associated with adding an MRS facility. Because the cost of providing at-reactor storage is very sensitive to the storage method chosen and the length of time that storage is provided, a fairly broad range of $40 to $110/kg has been selected to estimate the costs to utilities. The lower end of the cost range represents the cost from in-pool consolidation, which may not be feasible or desirable at many sites, and the upper range represents storage of unconsolidated fuel in metal casks. Thus, the total utility costs that could be avoided by adding an MRS facility would be $150 to $450 million, assuming timely deployment of the repository. If the repository were delayed, the MRS facility could store up to a maximum of 15,000 MTU of spent fuel. If this entire quantity represented fuel that otherwise would require additional at-reactor storage beyond present pool capacity, the potential avoided costs to the utility could range from $0.6 to $1.7 billion.

2.4.3 Transportation Cost Effects

Transportation cost comparisons between waste management systems with and without an MRS facility are sensitive to assumptions about both cask technology and the location of the first repository. Depending upon the location of the first repository and the effective increase in cask payload for outbound casks compared to inbound casks, the MRS facility could result in either a net increase or decrease in system transportation costs.

Figure 2.7 shows the estimated costs for spent-fuel transportation for the MRS and no-MRS systems for three potential locations for the first repository. The figure shows that the transportation system cost for the fuel shipped to the first repository for disposal could decrease slightly ($200 million for basalt) or be unchanged (for salt and tuff). The cask and shipping cost data and assumptions for these estimates are discussed in Appendix F. For the MRS system, the estimates in the figure assume that spent fuel would be



(a) Shipments from the MRS facility to the repository are assumed to be in 150-ton rail casks.

FIGURE 2.7. System Transportation Costs (MRS and first repository)

consolidated at the MRS facility and that canistered fuel rods and spent-fuel hardware would be shipped in 150-ton casks to the repository, where the final disposal container would be provided. Spent fuel from western reactors is assumed to be shipped directly to the repository rather than to the MRS facility. Cost estimates for variations in these assumptions are contained in Appendix F.

2.4.4 Total System Capital and Operating Cost Effects

The net system capital and operating costs incurred by adding an MRS facility range from an estimated $1.4 to $2.0 billion in undiscounted costs. Figure 2.8 shows the components of this cost. As noted earlier, facility costs

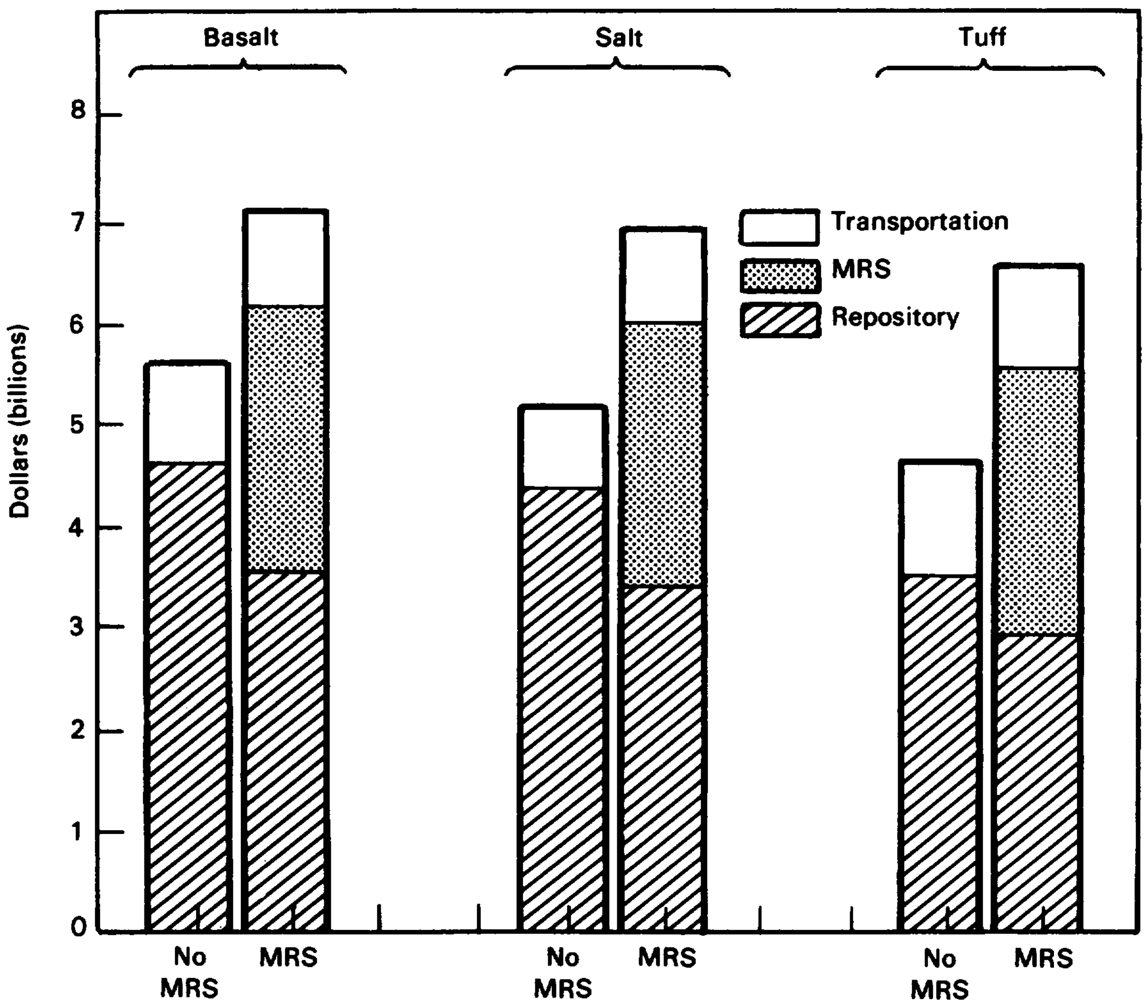


FIGURE 2.8. Costs for Repository Surface Facilities, MRS Facility and Transportation

would increase by $1.6 to $2.0 billion, and transportation costs would decline by as much as $0.2 billion. In addition, the spent-fuel storage provided by the MRS facility would accelerate spent-fuel acceptance and would provide a contingency in case of changes in the repository's emplacement schedule. These additions to the functions of the waste management system could offset utilities' substantial expenditures for additional at-reactor storage.

2.5 RADIOLOGICAL DOSE

This section discusses the relative changes in public and occupational radiological dose that would result from including the MRS facility in the waste management system and the bases for estimating the changes. Table 2.14 summarizes those changes. The exposure to radiation that would result from the spent-fuel-handling operations at the reactors, the MRS facility, surface facilities at the repository, and transportation between those facilities was examined.

2.5.1 Bases for Estimating the Effect of Radiological Dose

The radiological doses to the public and to workers in the waste management system from both routine activities and accidents are considered. The doses from accidents, multiplied by expected accident frequency, are found to be less than those from routine exposures, which are far below regulatory limits. Operation of all facilities and equipment in the waste management system must meet stringent Environmental Protection Agency (EPA) and NRC regulations that have been promulgated to ensure adequate protection of the health and safety of the public, workers and the environment.

TABLE 2.14. Radiological Dose Effects of the MRS System

Dose Category	Comparison of MRS and No-MRS System
Occupational Dose	Increases total occupational dose to workers because of the additional shipping step in the MRS system, although the dose received by any individual worker would be within regulated limits.
Public Dose	Decreases public dose in the MRS system because of the reduced dose from transportation.

The comparisons discussed in this section are based on preliminary generic analyses using available data. The results are useful for comparing alternatives, but are not intended to be absolute estimates for specific site facilities or transportation routes. Appendix E provides the bases for these results.

2.5.2 Comparison of MRS and No-MRS Systems

Adding an MRS facility to the waste management system would transfer the functions for receiving and consolidating spent fuel from the repository to the MRS facility and would add the extra spent-fuel shipping step as well as some interim storage. The transfer of functions and addition of activities, however, are not expected to increase the total radiological dose within the waste management system. An overview of the radiological doses in the waste management system with and without an MRS facility is shown in Figure 2.9. This figure shows the unit radiological dose to occupational workers and to the public from the spent-fuel activities at the reactor, at the repository, at the MRS facility, and during transportation of spent fuel.

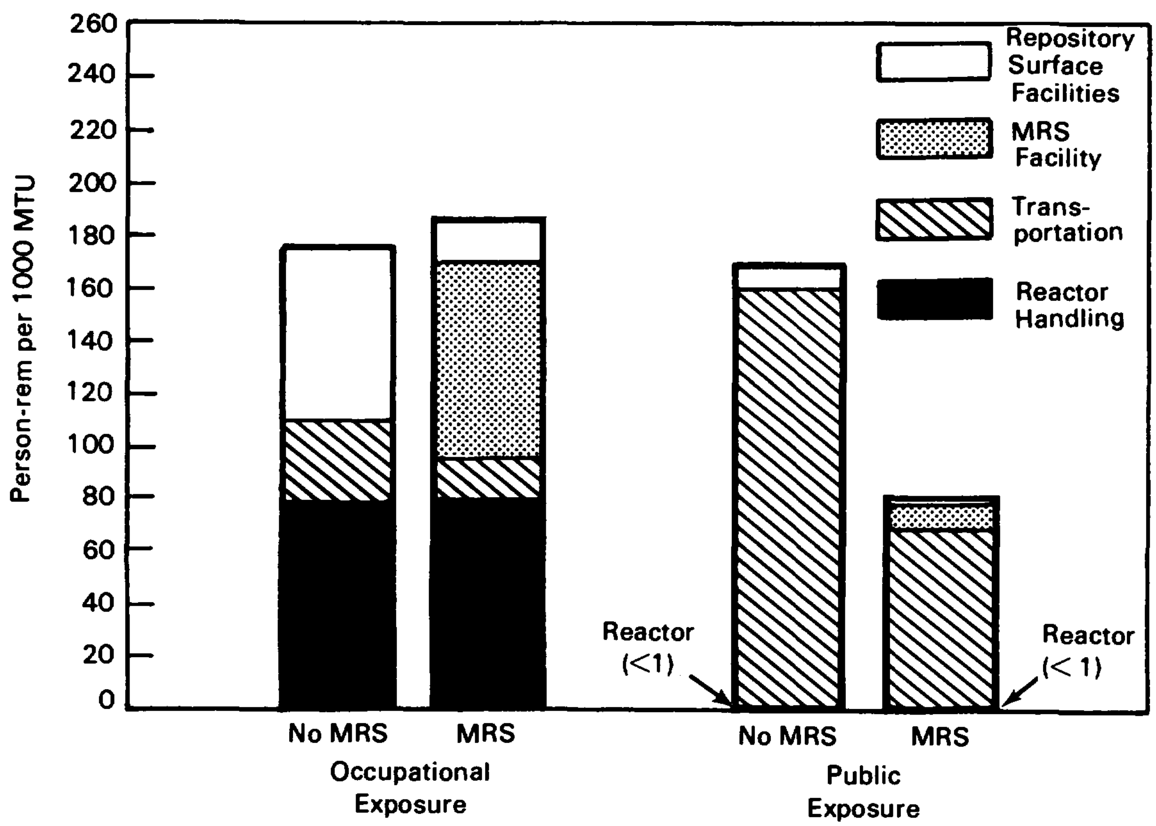


FIGURE 2.9. Comparison of Radiological Doses With and Without an MRS Facility

The data for the no-MRS system include spent-fuel handling operations at the reactor, spent-fuel transportation to the repository (70% by rail and 30% by truck), and repository operations (cask and spent-fuel assembly handling, consolidation, overpacking). The MRS system includes spent-fuel handling operations at the reactor, spent-fuel transportation to the MRS facility (70% by rail and 30% by truck), MRS operations (cask and spent-fuel assembly handling, consolidation), spent-fuel transportation to the repository (100% rail) and repository operations (cask and canister handling, placing the spent fuel into the final container).

As shown in Figure 2.9, the system occupational dose would increase slightly and the public dose would decrease by a factor of about two with an MRS facility. Adding an MRS facility to the system would slightly reduce the net radiological dose.

The public radiological dose from operating either the MRS facility or the surface facilities at the repository would be extremely low in all cases. The public dose would be dominated by the dose from transportation, although this dose would be low in an absolute sense. The public radiological dose would be decreased with an MRS facility because of the decrease in transportation dose because the overall number of cask miles would be decreased with an MRS facility. The transportation step from the MRS facility would contribute only a very small portion of the transportation dose because of the reduced volume of spent fuel after consolidation and the use of only large-capacity shipping casks in multicar trains.

In the no-MRS system, about one-fifth of the occupational dose would be from the transportation activity, with the remaining dose resulting from reactor and repository operations. Adding an MRS facility to the system would reduce the occupational transportation dose slightly. The MRS facility would increase the occupational dose from operations at the fixed facilities, primarily because of additional handling steps with an MRS facility in the system. An MRS facility should not significantly change occupational doses at the reactors (although some reduction would result from the reduced amount of spent fuel stored and/or consolidated at reactors because of earlier acceptance of spent fuel at the MRS facility).

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3.0 THE FEASIBILITY OF MONITORED RETRIEVABLE STORAGE

In this report, feasibility refers to the ability to carry out or accomplish all components of the MRS system as proposed. The components of the MRS facility were evaluated separately and as a system. Measures of feasibility include the technical maturity, level of certainty of cost and scheduling estimates, and the ability to obtain a license from the Nuclear Regulatory Commission (NRC).

This analysis concludes that the MRS system is feasible--that, with reasonable assurance the engineering requirements can be met with current technology, that the MRS facility can be constructed and operated for approximately the costs reported in Volume 3, that the facility can be licensed by the NRC, that it can meet applicable environmental and land-use requirements, and that it can be constructed and operated according to the schedule presented in Volume 3.

The measures of feasibility are discussed in this chapter. Section 3.1 discusses the technical feasibility of the major functions of the MRS facility. Section 3.2 discusses the DOE's basis for confidence in the cost projections and the funding analysis, which were largely based on conceptual designs and DOE-sponsored studies and annual reviews. Costs examined include equipment, staffing, operating, and decommissioning costs. In Section 3.3, the schedule for the MRS facility is analyzed, which includes the schedule for design, construction, and operational testing. Section 3.4 discusses both the DOE's confidence that the MRS facility would comply with NRC regulations and the efforts that have been and would be taken to ensure compliance.

3.1 TECHNICAL MATURITY

Because the conceptual design for the MRS facility is based on current technology, the DOE is confident that it is technically feasible. Each process and function of the facility has been performed in more than one application. Design verification and demonstrations (described in detail in Volume 3) would be required to optimize the design and demonstrate operability at the desired production rates. Field Investigation also would be conducted to obtain or confirm environmental and geophysical data at the site. The data would be used in the definitive design, in the safety analysis report, and in the environmental report for submittal to the NRC. After the MRS facility has been constructed, cold and hot testing of the MRS systems and components would be conducted to confirm operational and maintenance procedures. Cold testing of the fuel-handling equipment in the hot cells uses simulated assemblies not containing radioactive material. Hot testing uses radioactive spent fuel.

The following are the major functions to be performed in the MRS facility:

- receipt, handling, and shipping of casks containing radioactive material
- disassembly, consolidation and canistering of spent fuel
- storage and retrieval of canistered radioactive material.

The technical feasibility of each of these functions is discussed below.

3.1.1 Cask Receiving and Handling

Since the inception of the nuclear industry, shielded casks have been used for transporting radioactive material. For many years, the equipment for handling these large, heavy casks has been demonstrated regularly at locations throughout the world.

Techniques and procedures for examining casks for external radioactive contamination and for removing any contamination are well developed. Currently, the outer containment lid and the inner cover and shield plug are removed and replaced manually. Because of the number of casks expected to pass through an MRS facility, automated methods and equipment would be desirable for efficient operation and for minimizing occupational exposure to radiation. Such automated equipment would largely be adapted from existing demonstrated devices and techniques. No difficulties are expected in designing the equipment, and operational tests would be conducted for design verification.

3.1.2 Disassembly, Consolidation and Canistering of Spent Fuel

By 1981, over 51,000 fuel rods had been removed (Bailey 1985) from assemblies in reactor storage pools, largely because they had failed and were being replaced with new rods to allow continued use of the fuel.

As the need for storage in reactor pools has become more pressing, a few assemblies have been disassembled and the rods closely packed within canisters that fit into the storage racks. These consolidation procedures have been carried out as demonstrations; however, consolidation equipment has been developed by four U.S. companies. A recent in-pool demonstration showed the feasibility of extracting all the rods from assemblies with a single pull (Bassler 1984). The equipment was developed and repeatedly demonstrated in a dry environment using unirradiated fuel assemblies. Exposure (burnup) of the spent fuel does not appear to be a problem because the Germans have disassembled (dry) more than 80 tonnes of spent-fuel rods with burnups as high as 39,000 MWd/MTU (megawatt days per metric ton of uranium) with practically no breakage (Huppert 1978). The disassembly system currently designed for the MRS facility would extract the rods from several fuel assemblies simultaneously in a dry hot cell.

Further development of dry consolidation technology is planned. During the next year, in a cooperative program between the DOE and the nuclear industry, a significant number of irradiated fuel assemblies will be disassembled and consolidated into canisters for use in a dry-storage demonstration. This program will be conducted in a dry hot cell and will provide valuable design data. On a larger scale, the DOE initiated the Prototypical Consolidation Demonstration Project, which, over the next few years, will develop and demonstrate a system for irradiated fuel disassembly in a dry hot cell. The MRS Program will use this project for designing the MRS fuel-consolidation equipment. These activities will provide information on procedures for fuel-rod recovery if the rods were to fail.

Part of the disassembly and consolidation operation is the disposal of hardware remaining from the fuel assemblies after the fuel rods have been removed. In the current MRS design, these materials would be reduced in volume by passing them through a shredder and packing the shards into 55-gallon drums for shipment to a repository. Much of the nonfuel hardware is fabricated of Zircaloy. In any machining or cutting operations involving zirconium alloy, pyrophoricity (tendency toward spontaneous ignition) must be addressed. The pyrophoricity of zirconium is a well-known phenomenon in zirconium fabrication technology. The control of fires by smothering with an inert gas is typical in zirconium handling. Furthermore, actual tests of shredding nonirradiated Zircaloy have indicated that the shards produced are not pyrophoric. The Prototypical Consolidation Demonstration Project will add to the base of information on disassembly and volume reduction of hardware. If a shredder is adopted for the final design and if a fire suppression system is needed, such a system could be added to the design.

The remaining canistering operations, such as canister inerting and welding, canister decontamination, and leak testing, are thoroughly proven operations. The inerting to prevent cladding degradation would be performed by evacuating the canister and filling it with argon. This operation is common and does not present any significant design or operating problems. The resistance-upset method proposed for welding the canister uses the discharge of a large electric current through the interface between the canister and its cover. At the same time, a large compressive force is applied on the interface to produce a forged closure (Aanstoos and Weldon 1985) that can readily be tested for soundness by ultrasonic methods. The method has been demonstrated at the Savannah River Plant on the closure of smaller-diameter canisters of vitrified defense high-level waste. Other methods of welding also are available.

Following the closure welding operation, the exterior surface of the canister is decontaminated, as a preventive measure, using a high-pressure spray of liquid Freon. Freon as a decontaminant has been well demonstrated (Witt and Ewing 1982) and is in commercial service at many nuclear reactor stations. Freon's potential for radiolytic decomposition has not been fully analyzed for this application nor has the potential deposition of harmful (though nonradioactive) residuals on the canister surfaces, although past applications have not experienced such problems. However, if the Freon decontamination system should prove to be an inappropriate choice during definitive design, an alternative process would be substituted.

3.1.3 Storage and Retrieval of Canistered Radioactive Material

With the fuel rods contained within sealed canisters, storage and retrieval of the canisters would be a typical remote-handling operation. Remote grappling and handling of objects in highly radioactive locations have been routinely practiced since the beginning of the atomic energy program. For example, chemical separation facilities use similar techniques for remote maintenance and replacement of equipment. The grappling of irradiated fuel assemblies remotely, under water in reactors and reactor storage basins, has been successfully practiced for many years.

Irradiated fuel has also been handled dry since the beginning of nuclear reactor operation. Fuel has been inspected and stored dry in hot cells, and shipped dry in casks. Some Zircaloy-clad fuel rods have been stored dry for up to a decade in hot cells, although at relatively low temperatures (less than 100°C).

Demonstration tests involving the dry storage of spent fuel in metal casks are just beginning in the U.S. However, metal shipping casks have been used routinely since the mid-1940s. Worldwide, hundreds of Zircaloy-clad fuel-rod assemblies have been shipped dry in single-assembly and multiassembly casks. Such assemblies ordinarily remain in truck or rail casks for only a few days or weeks. However, spent fuel shipped by sea from Japan to Europe for reprocessing has resided in dry casks for two to three months (Sugier et al. 1982). The current generation of metal casks has successfully survived fire and drop and crash tests, and at least one design has been licensed for both shipment and storage in Europe.

The earliest extended dry-storage experience in the U.S. began in 1964 and involved liquid metal fast breeder reactor (LMFBR) fuel stored in vaults and drywells at the Idaho National Engineering Laboratory (INEL) (Anderson and Meyer 1980). INEL began operating additional dry-storage facilities in 1971, using drywells to store gas-cooled reactor (GCR) fuel; in 1974, using drywells to store LMFBR fuel; and in 1975, using drywells to store both GCR and LMFBR fuels (Anderson and Meyer 1980). The first dry-storage vault for British Magnox (GCR) fuel began operation in Wylfa, Wales, U.K., in 1971 (Maxwell and Deacon 1982). A dry-storage vault for high-temperature gas-cooled reactor fuel has been constructed at the Julich Experimental Power Plant in the Federal Republic of Germany, and a storage vault for test reactor fuel was completed in Japan in 1982. Although much of the early experience was with fuels other than light-water reactor (LWR) fuel, the experiences provide confidence that dry-storage facilities can be designed and operated safely.

Experience with dry storage of irradiated Zircaloy-clad fuel from water-cooled reactors dates from 1975 at the Whiteshell Nuclear Research Establishment in Canada, where fuel assemblies from the WR-1 reactor were stored in concrete surface casks (Tabe 1982; Ohta 1980). Fuel assemblies from a pressurized water reactor were stored in a vault and in concrete surface casks at the Nevada Test Site (NTS) starting in 1978 (Wright 1981; Hakl 1980), and in surface and tunnel drywells at the same site starting in 1979 and 1980, respectively. Storage of boiling water reactor assemblies (16) in a metal cask began in 1982 in Germany (Fleisch, Einfeld and Lührann 1982; Kaspar et al. 1982; Peehs, Kühnel and Kaspar 1982). This experience with dry storage and the various parameters of importance to dry storage have been clearly documented (Johnson et al. 1982). Johnson's review (1982) illustrates the depth and breadth of experience and the data base available on dry storage and associated handling of spent nuclear fuel.

Experience with vaults for the dry interim storage of vitrified high-level waste (HLW) from spent fuel reprocessing is also relevant to MRS technology. A vault facility began operation in 1969 in Marcoule, France. By 1973, 12 metric tons of vitrified HLW were in storage in metal canisters. A second vitrification campaign began in 1978. Currently, 680 stainless steel canisters filled with vitrified waste are being stored in air within the Marcoule vault, at about 100°C. A similar facility has been designed for construction at La Hague.

The experience identified above includes substantial demonstrations of the following:

- safe handling, emplacement, storage, and retrieval of irradiated fuel in drywells, vaults, and concrete casks

- storage in air, argon, carbon dioxide, and helium
- monitoring and maintenance of cover-gas purity
- adequacy of safety analyses associated with storage
- storage-system integrity.

These storage operations have been conducted for over 19 years with drywells and vaults and for over 7 years with concrete casks. In all cases, no significant operational difficulties have been experienced.

3.2 COST PROJECTIONS AND FUNDING ANALYSIS

Confidence in the accuracy of the estimated costs for the MRS facility is improved because conceptual design and project definition are in advanced stages and commercially proven technology is planned for most of the operations. In support of this MRS proposal, the DOE has prepared conceptual designs of the MRS facility. The designs encompass both the recommended sealed-storage-cask concept and the alternative drywell concept for the preferred site and both alternate sites. The present stage of the design of the building components and the essential equipment gives confidence in the facility's cost estimates. Except for the disassembly/consolidation equipment and the sealed storage casks, the components of the MRS system use commercially proven techniques that are routinely used in the nuclear industry.

Staffing needs and operating and decommissioning costs for the facility have also been analyzed. Related costs for transporting spent fuel and wastes to and from the MRS facility have been estimated as part of DOE's transportation program. The costs were based on current projected rates in commercial shipping practice and on cask cost estimates derived from DOE-sponsored studies (Neuhauser et al. 1984), including input from private manufacturers. While these costs may change because of inflation, institutional requirements, regulations or other natural marketplace variations, the DOE believes they are realistic descriptors of costs to be expected during subsequent phases of the MRS program.

The MRS funding analysis is based on an ongoing DOE effort, in response to requirements of NWPA. The effort consists of annual reviews of the adequacy of the Nuclear Waste Fund to accommodate foreseen costs of the waste management program. The last such annual assessment was submitted to Congress in January 1985; an updated assessment is to be submitted in the same time frame as, but separate from, the MRS Proposal. The 1985 analysis indicated that the costs for MRS would be a small fraction of the Nuclear Waste Fund; the updated analysis is expected to confirm that result. MRS cost estimates and funding analyses are discussed in Volume 3.

3.3 MRS SCHEDULE ANALYSIS

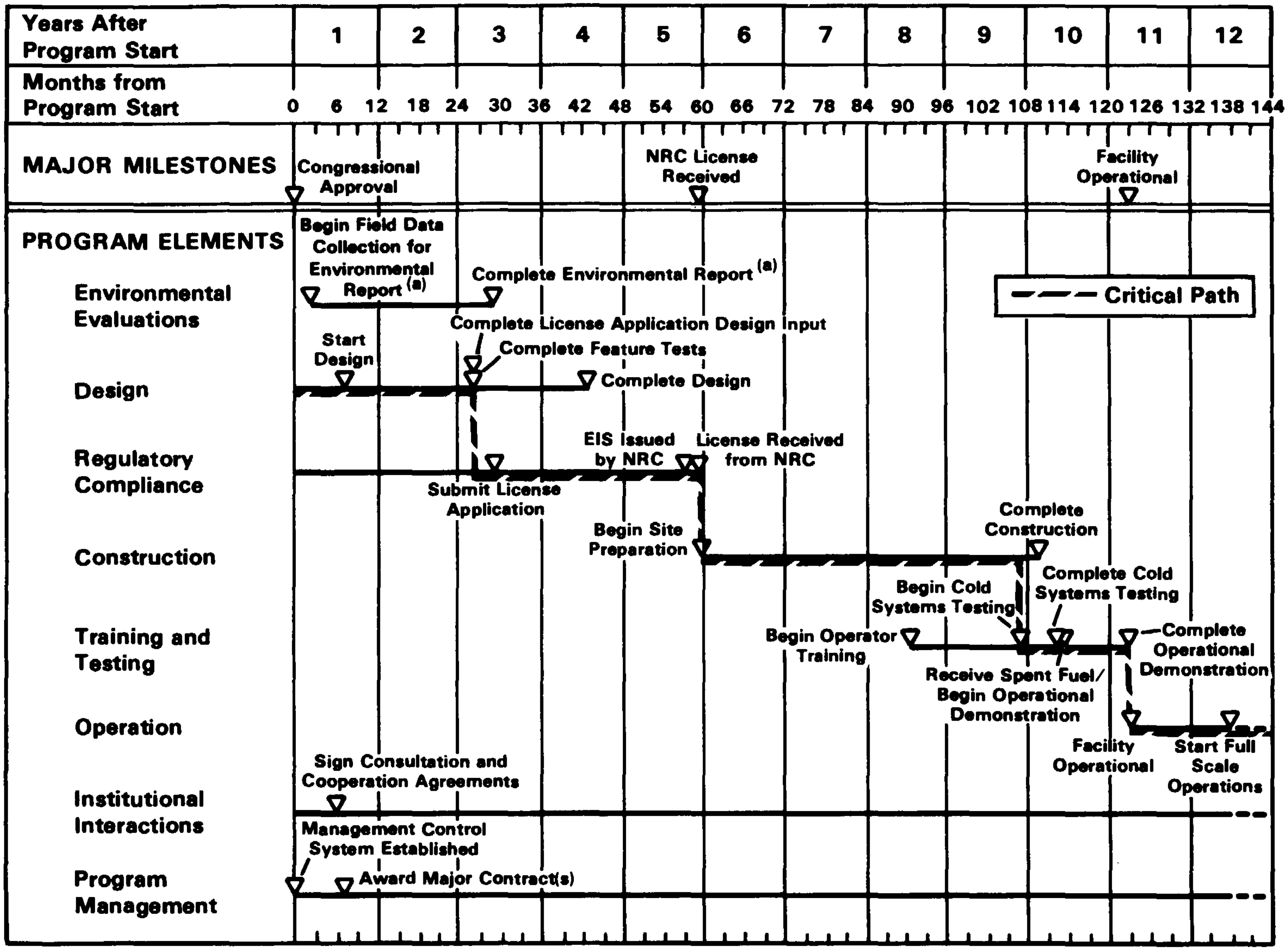
The DOE projects that the proposed MRS facility could begin operation approximately 10 years following approval to proceed and would reach full-scale operation within another 2 years. This schedule is shown in Figure 3.1 and discussed in Volume 3. The critical path for this schedule, related activities that could affect the critical path, and the potential for delay in various parts of this schedule have been analyzed and are discussed in Volume 3. The following sections discuss the schedule for design, construction and operational testing of the MRS facility.

3.3.1 Design of the MRS Facility

The DOE would begin the process of obtaining contractor(s) for the design, construction, and operation of the MRS facility as soon as notification of approval for the facility is received. Design would begin an estimated 7 months following approval and would be completed in an additional 36 months, or 43 months following approval. The design concepts, bases and parameters would be firm early enough in the design process that by the 22nd month of design (29 months after approval) a Safety Analysis Report and supporting documentation describing and analyzing the design would be completed and delivered to the NRC, along with the license application for an MRS facility. The results of design verification activities, conducted in parallel with the design, would be included in the license application.

The design schedule for an MRS facility and its interaction with other activities require close management control. However, because of the information obtained during the conceptual design phase and the existing knowledge of site characteristics collected during site selection, the DOE has confidence that the definitive design can be completed as scheduled.

Site-characterization studies and the collection of site data would also begin immediately upon approval of an MRS facility by Congress. This effort would provide both environmental data for the environmental report required by the NRC in support of a license application and data in support of the MRS facility's definitive design. The DOE intends to perform the site characterization and data collections cooperatively with state and local agencies, using data obtained by those agencies and sharing with them the data collected by the



[a] The precise nature of this document will be dependent on the provisions of any authorizing legislation.

FIGURE 3.1. MRS Deployment Schedule

DOE. The data collection effort in support of the license application would require a minimum of 12 months; data collection for design, performed concurrently, would require approximately 10 months.

3.3.2 Construction of the MRS Facility

Construction of the MRS facility is scheduled to begin as soon as the license is issued by the NRC, approximately 5 years following approval of the MRS proposal by Congress. Construction would require an estimated 4 to 5 years, with estimated completion 110 months following MRS approval. A comprehensive program of verification tests and demonstrations of critical facility components and systems would be conducted through the design and construction period to assist in final design, licensing, construction, and operation. These tests would involve fabrication and, when appropriate, operation of prototypic equipment under conditions closely approaching expected operating conditions. The test operation of the prototypic systems would also be used for early training of MRS operating staff. After the systems are installed, the tests would be repeated to verify operation of the facility as portions of the MRS facility are completed.

Protracted disruptions of work could result from strikes or similar labor situations, which would cause unrecoverable delays in the schedule. Less severe stoppages, however, could be compensated for through use of overtime or additional shifts.

Preconstruction activities (subcontractor selection, staffing and planning, etc.) would be completed early, thereby minimizing the time for construction startup after the NRC license is granted. Once physical construction started, site preparation and modification would require about 3 months. The remaining time would largely be devoted to constructing the facility itself. The acceptance testing and turnover of the facility to an operating contractor would be completed less than 10 years following congressional approval of MRS. Following acceptance tests, the program of operational verification testing would be completed.

Thirty days after the results of preoperational tests are sent to the NRC for review, tests using actual spent fuel would begin to verify system operation of the MRS facility and to exercise interfacing systems (e.g., transportation of spent fuel and receipt of the casks at the MRS facility) to verify their operational viability. The hot-system tests would continue for three months, followed by a nine-month period of operational demonstrations of the facility, which would exercise all portions of the MRS facility except the actual outloading of spent fuel for shipment to a repository. After the operational demonstration was completed, the facility would become operational.

A critical interface to operating the MRS facility as an integral component of the waste management system would be the timely availability of a fleet of spent-fuel shipping casks for shipping fuel from the utility reactors to the MRS facility and later from the MRS facility to a repository. The DOE is aware of the criticality of this timing, and in a program separate from the MRS Program, is developing the basis for the supply of a fleet of casks by private industry. The schedule for this program is being coordinated with the schedule for the MRS facility, as described in Chapter 3 of the Program Plan. Delays in obtaining a sufficient number of casks could delay operations at the MRS facility, although the technology for the shipping cask design and fabrication and for actual fuel shipments is well established, and no technical delays are expected. Some casks currently exist and could be used in the initial years of system operations if delays in cask availability were to occur. However, substantial additions to the present cask fleet are required for full-scale operations. The transportation program now in place is expected to provide enough casks when they are needed.

3.3.3 Operational Testing of the MRS Facility

For planning purposes, it is assumed that the MRS facility would become operational approximately 10 years following approval to proceed and would achieve its full planned throughput rate of 3000 MTU per year within about 15 months. The full throughput capacity of 3000 MTU per year could be maintained throughout the active life of the facility. The peak capability would be a throughput of 3600 MTU per year.

The planned time for increased throughput of the MRS facility to full operating capacity appears to be fully achievable. Normally, in the early phases of operation, capability is reduced by the need for equipment shakedown, and for the operating crew to become experienced in operations and maintenance. The 15 months allowed for attaining full-scale fuel throughput is expected to be adequate.

Full-scale operation of the MRS facility would also require coordination with the transportation networks involved in fuel shipments to and from the MRS facility. However, U.S. transportation systems have routinely supplied the needs of industry, both in frequent bulk shipments and in "specialty," one-of-a-kind shipments. With a sufficient fleet of casks available, as discussed above, the DOE is confident that the commercial transportation industry would rapidly adapt to the volume of waste shipments involved without delaying the MRS facility.

3.4 REGULATORY COMPLIANCE

The NWPA is explicit regarding compliance with the National Environmental Policy Act of 1969 (NEPA) in the event that Congress authorizes the MRS facility. In this case, it specifies that "the requirements of (NEPA) shall apply with respect to construction of such facility except that any environmental impact statement prepared ... shall not be required to consider the need for such facility or any alternative to the design cirteria ... set forth in subsection (b)(1)." The DOE recognizes that the specific actions which must be taken to fulfill its NEPA obligations will depend in large measure on the provisions of the congressional authorization. In anticipation of discharging its NEPA responsibilities, in the MRS Proposal the DOE is providing for the preparation of a comprehensive environmental document, which will be submitted to the NRC in support of the DOE license application. The procedures that will govern the preparation of this document will depend on the decisions that the DOE must make in implementing any authorizing legislation. The document could take the form of an environmental impact statement.

Compliance with NRC regulations has been a major consideration in the conceptual design effort and in related analyses. As part of this effort, the DOE has sought advice from NRC staff and from individual consultants and has performed many analyses in support of design. The MRS facility uses proven technology. Therefore, new licensing issues are unlikely to arise during license review. The DOE is confident that a license can be obtained in timely fashion. The DOE believes, and has been advised by NRC staff and private consultants, that the 30-month schedule proposed for the licensing review period would be adequate without prolonged hearings and litigation. However, if protracted hearings or unexpected litigation were encountered, the schedule would need to be extended. Also, an extensive program of cooperation with the State of Tennessee and with local governmental agencies has been established. The DOE proposes that this consultation and cooperation continue throughout the design, construction and operation of the MRS facility to assure an adequate level of understanding between DOE and the affected state and local organizations and to assure that adequate opportunity is given for state and local input to safety and environmental protection.

Supporting documents that would be required with the MRS license application include the following:

- Safety Analysis Report
- Decommissioning Plan
- Emergency Plan
- Environmental Report
- Quality Assurance Program
- Physical Security Plan
- Design for Physical Protection

- Safeguards Contingency Plan
- Personnel Training Program
- Proposed License Conditions and Technical Specifications.

This support documentation would be prepared in parallel with the facility design and would be submitted with the license application.

The MRS facility would be designed to keep exposures of operating personnel to radioactivity at or below one rem per year, that is, one-fifth of the level allowable under NRC regulations. Exposure to the public from facility operations would be kept well below allowable NRC limits. The primary methods of exposure control in the facility would be as follows:

- conservative use of shielding in the facility, augmented by use of remote-handling equipment

- designs to keep process-produced wastes to an appropriately low level

- use of multiple banks of high-efficiency (HEPA) filters in the ventilation exhaust system and additional HEPA filters in cells where radioactive materials are handled

- provision of appropriate shielding in the storage casks.

In the specific site-design environmental comparisons (Part 2 of this volume), the radiation exposure to the public resulting from MRS operation was evaluated and found to be far below NRC limits (Ralph M. Parsons Company 1985). Design-related studies have assessed occupational exposure to assure adequacy of shielding.

The environmental assessment of specific site-design alternatives indicates that MRS facility construction, operation and decommissioning would not adversely affect the environment. The assessment indicates that radiological impacts on the public from facility operation, either under normal or accident conditions, will be below normal background radiation exposure levels and well below regulatory limits. Similarly, both radiological and nonradiological effects from transporting spent fuel to and from an MRS facility would be small. These effects may be smaller in the MRS system than in the no-MRS system (see Appendix F).

Air and water quality assessments indicate that these effects from an MRS facility would be very small, except for the incidence of dust during construction, and would be acceptable. Impacts on the ecology from site construction and operation would be small at the Clinch River and Hartsville sites because of the prior disturbance from the construction activities at those sites.

The DOE has confidence that the facility can be constructed and operated in full compliance with applicable federal, state, and local requirements. This judgment will be reassessed as part of the environmental report submitted to the NRC as part of the license application. The NRC will prepare an Environmental Impact Statement in support of its license review.

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Part 2

Detailed Site-Design Evaluation

4.0 MRS FACILITY AND ACTIVITIES

According to the Nuclear Waste Policy Act, the MRS facility must be designed to:

- accommodate spent nuclear fuel and high-level radioactive waste resulting from civilian nuclear power activities
- permit continuous monitoring, management, and maintenance of such fuel and waste for the foreseeable future
- provide for the ready retrieval of such fuel and waste for further processing or disposal
- safely store such fuel and waste as long as may be necessary by maintaining the facility through appropriate means, including any facility replacements.

In accordance with these criteria, the MRS facility has been designed with a throughput that could accommodate current and projected inventories of commercial spent fuel. The integral MRS would serve primarily as a centralized receiving and packaging facility. The principal operations to be performed are receipt, disassembly, consolidation, and packaging of spent fuel, interim storage (as appropriate), and shipment of the spent fuel to a repository for disposal.

This chapter describes an integral MRS facility and its associated activities, which could generate impacts to the environment. The impacts are addressed in Chapter 6.

Two storage design concepts are analyzed in this document: the sealed storage cask concept, in which canisters of spent fuel and waste are stored above ground in sealed metal-lined concrete casks, and the field drywell concept, in which canisters of waste are stored in-ground in metal enclosures.

The basic assumptions used for both the MRS facility design concepts and for the impacts estimated in this EA are:

- operating lifetime: 26 years

- throughput rate: up to 3,600 metric tons of uranium (MTU) per year[a]

- storage capacity: up to 15,000 MTU (and 1,000 MTU lag storage capacity)

- type of waste: primarily spent fuel [(60% pressurized water reactor (PWR) and 40% boiling water reactor (BWR) by weight)] and a small amount (≈300 canisters) of commercial high-level waste

- age of waste: 90% is at least ten years old; 10% is five years old or is 10-year-old spent fuel with a high burnup (up to 55,000 megawatt days per MTU)

- shipments to the MRS facility are 70% by rail and 30% by truck. 100% rail shipments are also assessed in this document.

- shipments from the MRS facility to a repository are 100% by rail and include associated spent-fuel hardware.

Three sites have been identified by the DOE as candidate sites for an MRS facility. These sites are described in Chapter 5.

The design, construction, and operation of the MRS facility will comply with all applicable federal and state regulations and industry codes and standards. The MRS facility must be licensed by the Nuclear Regulatory Commission (NRC) to comply with 10 CFR 72 and other appropriate regulations. Appendix I gives a list of regulations that potentially apply to an MRS facility.

Construction of an MRS facility is dependent on congressional approval. If congressional approval is received, a definitive design, Environmental Report, and license application would be prepared and a license would be obtained before construction activities could begin. Physical activities would be as follows:

- preconstruction and construction
- transport of spent fuel from reactors to the MRS facility
- receipt, consolidation, and packaging of spent fuel
- interim storage (as appropriate)
- installation of a repository-specific overpack (if appropriate)

(a) The planned maximum throughput rate is ≤3,000 MTU per year (DOE 1985). However, the design capability of up to 3,600 MTU per year is used in Part 2 of this report to provide an upper bound for estimating impacts.

- transport of spent fuel and waste to a repository
- decommissioning of the MRS facility for unrestricted use.

A general schedule is given in Table 4.1.

TABLE 4.1. Projected Schedule for Deployment of an MRS Facility[a]

Year	Activity
1989	Submit license application to NRC
1990	Complete definitive design
1991	Begin construction
1996	Initiate operations
1998	Full-scale operations
2022	Decontaminate and decommission

(a) Schedule is based on the assumption that congressional approval is received by the summer of 1986.

4.1 PRECONSTRUCTION AND CONSTRUCTION

Preconstruction activities (site characterization) will be conducted to develop a final site-specific design for an MRS facility.[a] To investigate subsurface conditions, core samples will be taken. Some vegetation may have to be cleared to accommodate drilling equipment. The environment of the site will be studied, as required, to develop data for the Environmental Report and Safety Analysis Report. (Typically, for preconstruction activities, environmental monitoring equipment, such as meteorological instrumentation, is set up in a small temporary structure on or near the site.)

Construction will begin after the MRS facility is licensed by the NRC. Up to 800 workers will be employed in the peak year of the 51-month construction period. At each of the three sites, a portion of new rail line will be constructed that will extend 6.9 to 12.3 miles (11 to 20 km) beyond the site boundary to connect with an existing rail line (or rail bed at the Hartsville site). As necessary, roads will be reconstructed for heavy weight loads. Other construction activities will be similar to any large construction project.

(a) In the following discussion, the simple present and simple future verb tenses are used for ease in describing an MRS facility and do not imply that an MRS facility will be approved or built.

Temporary fencing will be installed around the construction site. The site will be cleared, and stumps and roots will be removed. At the Hartsville site, partially completed structures associated with the canceled Hartsville Nuclear Power Plants exist; most of the structures would remain. The amount of material to be excavated will be between 3.5 million and 6.8 million cubic yards (2.7 and 5.2 million m^3), depending on the site-design combination. Up to 465 acres (188 ha) of land will be required.

The site will be located and graded such that the final ground level is well above the probable maximum flood level at each site (Sections 5.1.3.2, 5.2.3.2, and 5.3.3.2). At the Clinch River site, where the probable maximum flood level is 800 feet (244 m) above mean sea level (MSL), the elevation of the buildings in the MRS facility would be 813 to 820 feet (248 to 250 m) above MSL, and the storage area would be up to 870 feet (265 m) above MSL. At the Oak Ridge site, where the probable maximum flood level is 826 feet (252 m), the elevation of the buildings would be from 860 to 870 feet (262 to 265 m), and the elevation of the storage area would be up to 890 feet (271 m). At the Hartsville site, where the highest probable maximum flood level[a] is 517 feet (158 m), the elevation of the buildings would be from 545 to 555 feet (166 to 169 m), and the storage area would be up to 548 feet (167 m) above MSL (Parsons 1985a). In all site-design combinations, basement floors of buildings will be above the probable maximum flood level.

Site utilities and temporary power will be installed. Power and transmission lines for the Clinch River or Oak Ridge sites would be built or relocated. At the Hartsville site, existing power lines can be tapped. A concrete batch plant will be constructed onsite. This plant will supply the concrete for constructing each of the onsite buildings.

The foundation for each building will be prepared, concrete will be poured, buildings will be constructed, and equipment will be installed. Permanent utilities will also be installed, including standby and emergency systems.

The three primary areas of an MRS facility are: 1) the support services area, 2) the packaging area, which contains the receiving and handling (R&H) building, and 3) the storage area. Actual layouts differ among the six site/concept combinations. For example, the layout of an MRS facility at the Clinch River site with the sealed storage cask concept is shown in Figure 4.1. General site layouts for each of the site-design combinations are shown in Sections 6.2, 6.3, and 6.4.

(a) At the Hartsville site, several potential flood sources exist. Probable maximum flood levels given here are the highest from all potential flood sources.

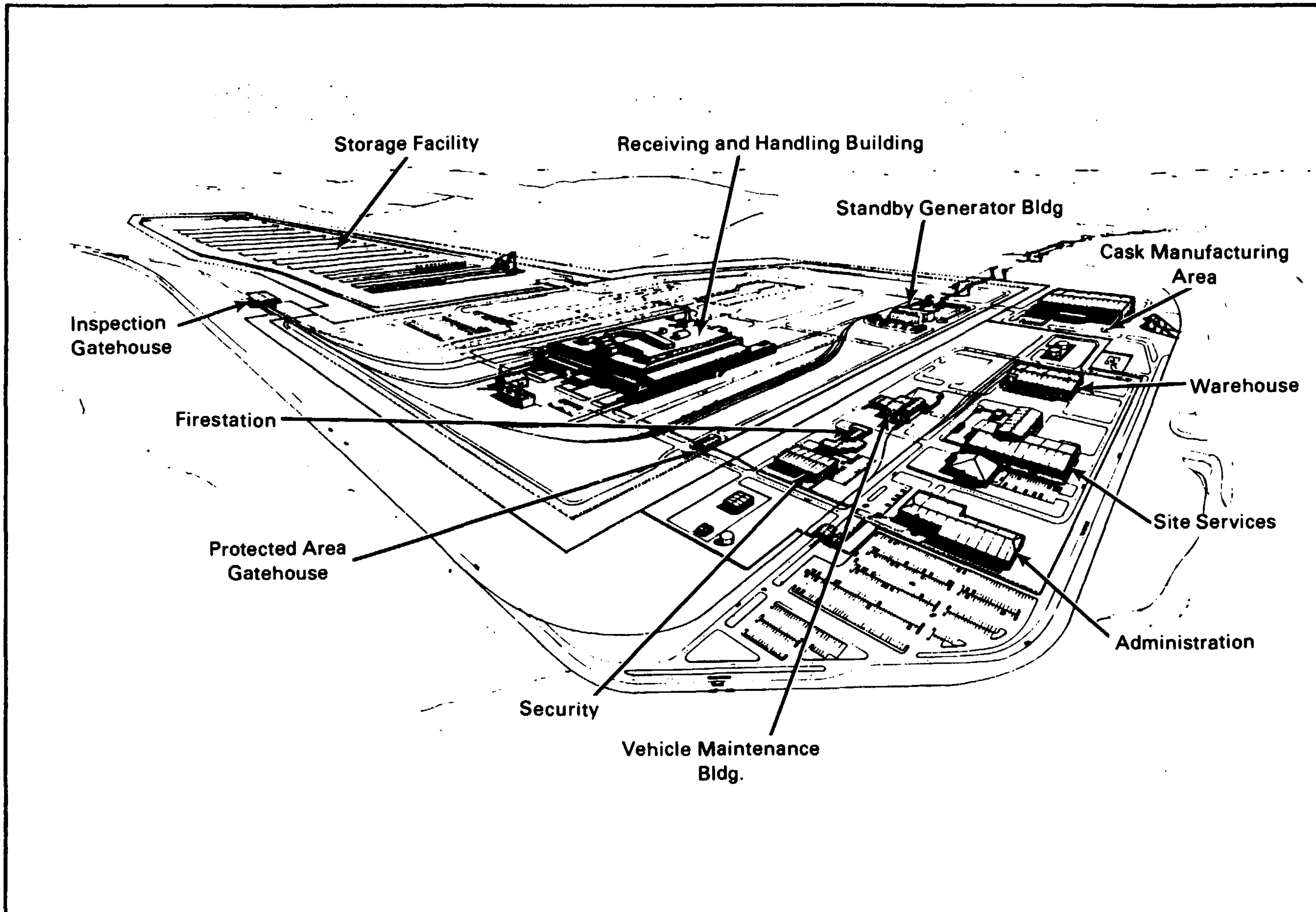

FIGURE 4.1. MRS Facility at the Clinch River Site (sealed storage cask concept)

The storage area will be developed to the extent necessary for 15,000 MTU of storage (i.e., all excavation, grading, drainage systems, etc. will be completed). For the sealed storage cask concept, a third of the concrete support pads would be poured during initial construction. For the field drywell concept, a third of the drywells would be drilled, lined, and equipped with monitoring instrumentation during initial construction.

After the MRS facility is constructed, it will be landscaped with trees, shrubs, and ground cover (usually gravel). Parking lots, walkways, and the area around some building entrances will be landscaped. Ongoing irrigation is not necessary at any of the three sites. All disturbed earth areas not covered by structures, paving or landscaping will be covered with crushed stone or grass to prevent soil erosion. A 100-foot (31 m) zone on either side of the protected area fence, designated as an "isolation zone," will be maintained clear. The facility is designed so that nuclear materials will be located at least 400 feet (100 m) away from the outermost fence. Distance between support buildings is determined by efficiency and convenience.

4.2 OPERATION

The MRS facility is scheduled to begin accepting waste in 1996.[a] The facility is designed to accept up to 3,600 MTU per year. The planned maximum acceptance rate is 2,500 to 3,000 MTU per year, with a total throughput of about 53,000 MTU to accommodate all spent fuel from eastern reactors destined for a first repository (DOE 1985). However, the design throughput rate of up to 3,600 MTU per year is assumed, for this analysis, in order to provide a bounding limit for estimating facility impacts. The primary operations will be to receive, disassemble, and consolidate spent fuel, to package it for disposal, and to store it onsite until it can be shipped to a repository.

At a 3,600 MTU per year receipt rate, the MRS will receive and handle spent fuel 24 hours per day, up to 7 days per week throughout the year.

A detailed description of the MRS facility follows. This description is based on the MRS conceptual design report described in Parsons (1985a,b).

4.2.1 Facility Description

The three primary areas composing the MRS facility are the support services, packaging, and storage areas.

(a) This schedule assumes congressional approval is received in the summer of 1986.

The support services and packaging areas of the facility are generally common to both storage concepts. These areas are described first, followed by a description of the two alternative storage area design concepts.

4.2.1.1 Support Services Area

The support services area will include: administration building, site services building, supplies warehouse, vehicle maintenance building, security building, inspection gatehouse, main gate badgehouse, fire station, heliport (for possible medical evacuations), water treatment facility, water storage, sewage treatment facility, fuel tanks, and pump station. These support services are common to many types of facilities and are not described in detail here.

4.2.1.2 Packaging Area

The packaging area will consist of:

- R&H building for receiving spent fuel and small quantities of high-level waste (HLW)
- Contact-handled transuranic waste (CHTRU) storage area
- main electrical substation
- standby-generator building
- gate house
- temporary holding area for shipments of radioactive waste materials (isolation area for railcars and trucks that arrive with insufficient paperwork, etc.).

The R&H building and the CHTRU storage area are described below.

Receiving and Handling Building. The R&H building will be the main packaging area at the MRS facility. It is essentially the same for both the sealed storage cask and the field drywell storage concepts, except for the canister discharge capabilities particular to the storage concept.

It is designed to receive rail- and truck-mounted shipping casks, unload and repackage their contents into canisters, transfer the canisters to interim storage as necessary, and load the canisters into rail shipping casks for shipment offsite. Details are given in Section 4.2.3.

The building is a multilevel structure with a ground floor area of about 290,000 square feet (27,000 m^2). Its major areas are the administration area, receiving and inspection areas, spent-fuel packaging areas, 1,000 MTU lag storage area for canistered fuel, transfer/discharge areas, radwaste treatment areas, and building services areas. Some of these areas are shown in Figure 4.2.

In several handling areas, operations will be performed remotely so that workers are protected from direct exposure to radioactive materials. The workers will observe the automated processes and will be able to operate or interrupt the handling machines from shielded operating galleries.

As an environmentally controlled structure, the R&H building is designed to prevent exposure of the public and of the operating personnel to radiation doses in excess of regulatory limits. Redundant filter systems will capture and contain airborne radioactive particulates. The building's ventilation system is designed to maintain a negative air pressure (with respect to atmospheric pressure) within the building.

Low-level waste (LLW) generated from MRS facility operation will be solidified and stored in the CHTRU storage area. High activity waste (HAW) generated at the MRS facility will be solidified (if liquid), packaged, and sent to onsite storage along with the spent-fuel canisters.

The waste treatment systems are described in Section 4.2.3.4.

CHTRU Storage Area. CHTRU will be stored in a separate area because of its low level of radioactivity, which requires less shielding than the other waste types stored at the MRS facility. The radiation dose rate at the surface of the container is used to designate whether a package is contact handled or remote handled. Generally, a container with a dose rate of over 200 mr/hour is designated as remote handled. The CHTRU storage area will be made up of near-surface vaults of reinforced concrete masonry units designed to withstand credible natural events. The compartmentalized vaults will contain stacks of waste drums and will be covered with thick concrete lids. When one vault is full, another will be prepared as needed. Each vault is equipped with drains to a common sump so that any moisture that might accumulate within the dry vaults can be monitored for radioactive contamination.

4.2.1.3 Storage Area

The storage area will be for storing spent fuel, nonfuel-bearing components, and any high activity waste (HAW) from the R&H building. The individual storage containers will be routinely monitored for possible loss of integrity.

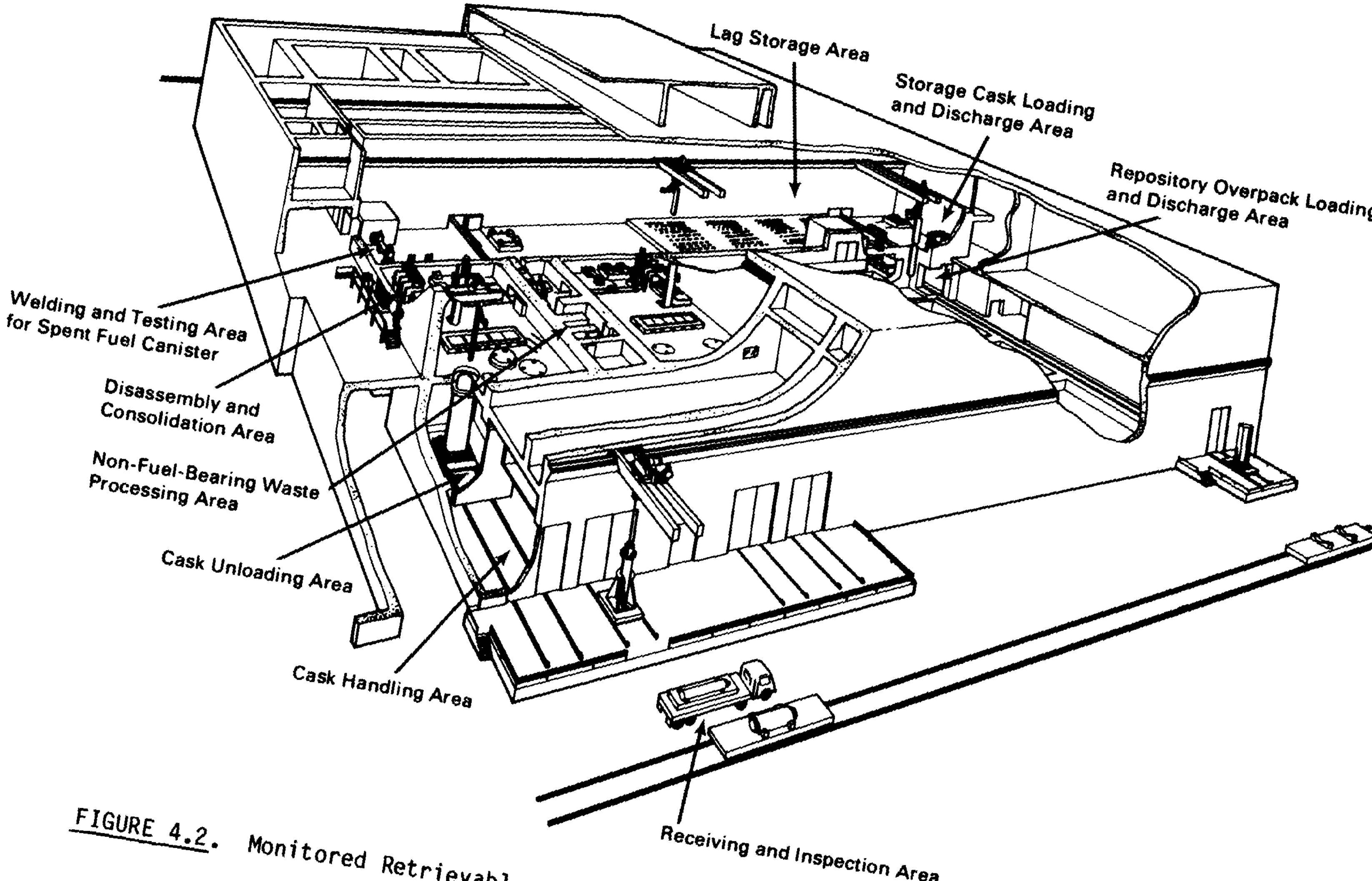

FIGURE 4.2. Monitored Retrievable Storage Facility Receiving and Handling Building

The exact configuration of the storage area and the type of containment will depend on the storage concept.

Sealed Storage Cask Concept. The sealed storage cask (Figure 4.3) would be a reinforced concrete cylinder with a steel inner lining. Heat from radioactive decay (waste heat) would be conducted through the concrete cylinder and removed at the surface by atmospheric convection and thermal radiation. The reinforced concrete cask would provide shielding to keep the surface radiation dose rate within acceptable limits. The concrete casks with their sealed steel liners and the metal canisters within the casks would provide double barrier containment of the wastes.

The storage area would be composed of a series of concrete support pads, as shown in Figure 4.3. These pads would be separated by roadways that would be used by an emplacement crane and a cask transporter. The cask support pads

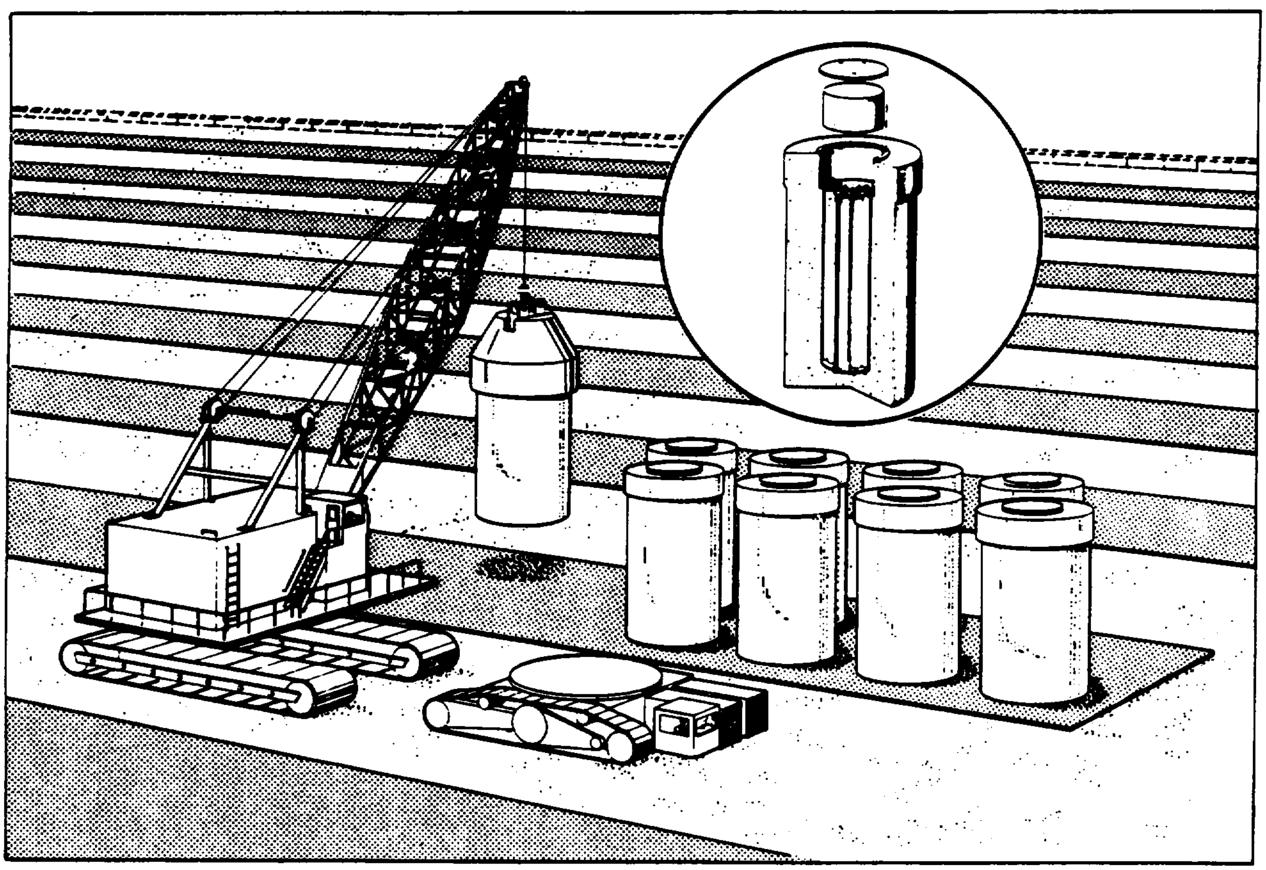

FIGURE 4.3. Sealed Storage Casks

would be about 40 feet (12 m) wide by 520 feet (159 m) long and include positions for 60 casks per pad. At the Clinch River site, some pads would be up to 830 feet (253 m) to accommodate up to 96 casks. Each cask would be approximately 12 feet (3.7 m) in diameter and 22-feet (6.7 m) high, weigh up to 220 tons (242 t), and stand upright on the support pad. The storage area could accommodate up to about 1,800 casks (15,000 MTU).

Field Drywell Concept. A field drywell storage area (Figure 4.4) would have stationary, in-ground, dry, sealed containers for storing canisters of spent fuel and waste. The storage area would consist of an array of these near-surface drywells where canisters of radioactive material would be placed for storage and retrieved for final disposition. The drywells could be sized

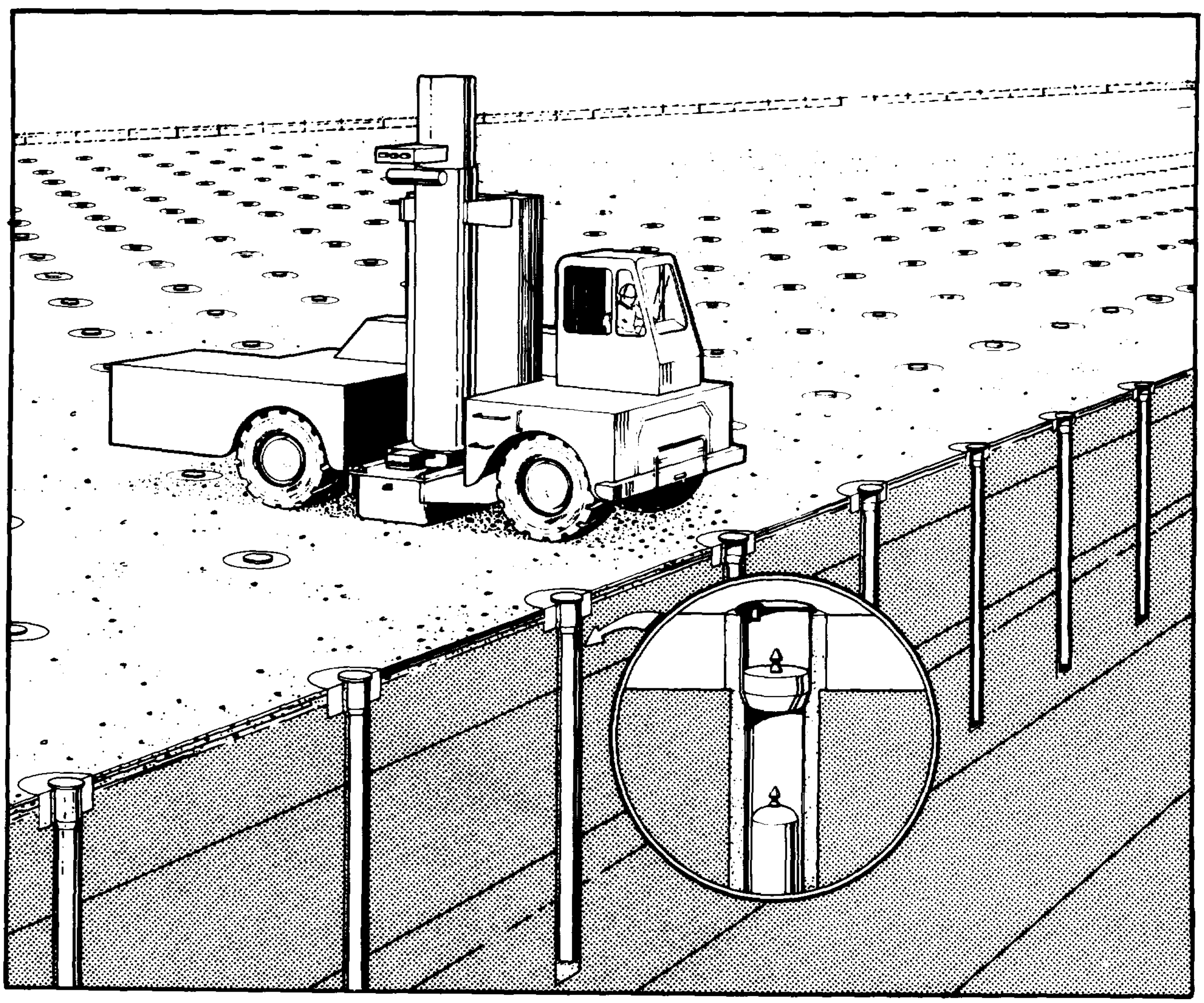

FIGURE 4.4. Field Drywells

to accommodate different sizes of canisters. Drywells could range from 16 to 36 inches (0.4 to 0.9 m) in diameter and 15.5 to 20.5 feet (4.7 to 6.2 m) in height. A 15,000-MTU storage area could accommodate up to about 16,500 canisters.

A drywell is a steel liner installed in a hole bored into the ground. This liner would usually be set into the bored hole along with a cement grout that would fill empty space. The drywell would use the surrounding soil as both a radiation shield and a conduction path to remove waste heat. The cement grout would enhance the transfer of waste heat away from the liner to the adjoining soils. Surrounding the top of the liner would be a concrete pad that would provide a working surface for transport machinery. After a canister and a shield plug are lowered into the drywell, a metal cover would be welded to the drywell liner to isolate the drywell contents from the environment. The canister and the sealed drywell together would provide double-barrier containment.

Transportable Metal Casks. Large metal casks are currently being considered by a number of utilities for the dry storage of spent fuel at reactor sites. Since those utilities may one day wish to ship such casks to an MRS facility, the facility is designed to receive, store, and retrieve these casks. (Both the sealed storage cask concept and the field drywell concept can accommodate these transportable metal casks.) The current design for storing these casks is illustrated in Figure 4.5, which shows the concrete "saddles" that would support the cask in a horizontal position.

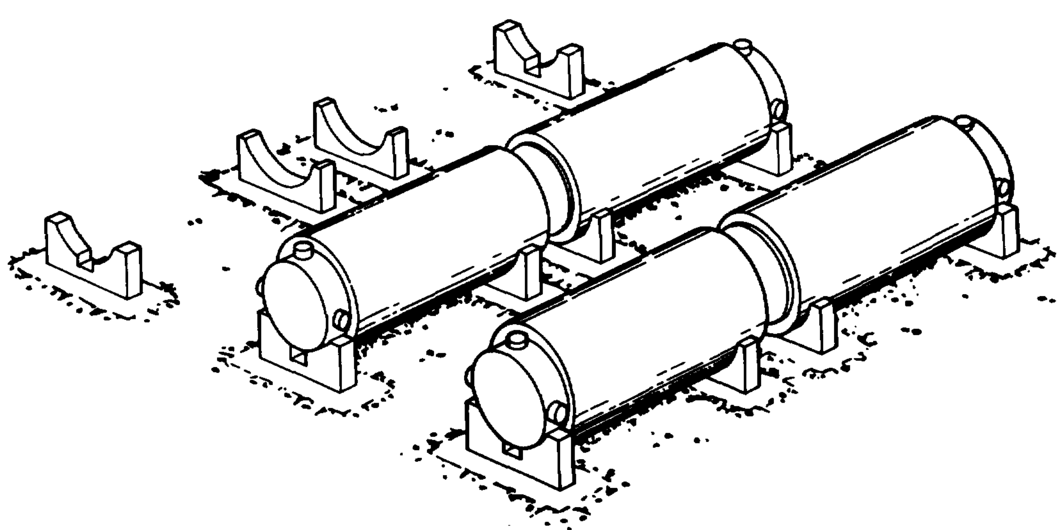

FIGURE 4.5. Transportable Metal Casks

4.2.1.4 Safeguards, Security, and Safety Features

The objective for taking safeguard and security measures is to protect the health and safety of the public and to monitor and control the movement of nuclear materials. The MRS facility design includes physical protection and access controls to deter, assess and respond to three types of threats: sabotage with intent to disperse, theft with intent to disperse, and theft with intent to retrieve special nuclear material. The primary means of achieving this protection in the MRS facility will be by surveillance and intrusion detection, and by controlling the movement of nuclear material within the facility.

The MRS site boundary will be designated by a chain-link or barbed wire fence. This is the boundary of the controlled area. In addition, the protected area of the facility will be entirely contained inside two 8-foot (2.4-m) high security fences. A 100-foot (31-m) alarm zone will exist between the fences. The facility will use independent alarm systems that are complementary but dissimilar.

All employees of the MRS facility must have a security clearance. Only qualified personnel may enter the protected area. All radioactive wastes will be handled and stored in the protected area. Access to the storage portion of the protected area will require a key card.

The storage area and all operations in the facility will be monitored for radiation to verify that conditions do not exist that could unnecessarily expose workers or the public to radioactive materials. The environment of the facility and the surrounding area, all personnel, and cask or drywell storage areas will be monitored. Environmental monitoring will include periodic sampling and analyzing of air, dust, water, and soil at fixed monitoring posts. Ground water will be monitored at the site, but details of the monitoring program have not been developed at this stage. Personnel monitoring will include personnel dosimetry and hand and foot monitoring.

The integrity of the sealed storage casks or field drywells and their contents will be monitored regularly. Cask or drywell integrity will be monitored by measuring internal pressure; canister integrity will be monitored by sampling for gases from the internal cavity of the casks or drywells. This monitoring will detect any leaks in the storage canisters, allowing prompt corrective action.

4.2.2 Transport to the MRS Facility

Spent nuclear fuel is currently being stored at individual nuclear power reactors. The fuel consists of rectangular bundles of slender rods typically

12 to 13 feet (3.7 to 4 m) long. When these bundles (assemblies) of spent fuel are removed from the reactor, they are placed in a pool of water for at least five years, where they cool and their radioactivity decreases. After "cooling," the fuel can be removed and transported to the MRS facility. For transport, fuel assemblies will be hoisted into a heavily shielded shipping cask, which will be closed, sealed, and inspected before shipment. The heavy shielding of the shipping cask will reduce radiation, thereby permitting transport as general commerce.

The shipping casks will then be loaded onto truck trailers or railcars for shipment to the MRS facility. About 70% of the spent fuel and waste is expected to be shipped by rail and about 30% by truck, using existing transportation routes.

4.2.3 Receipt and Packaging

All persons, vehicles, equipment, and materials entering and leaving the MRS-controlled area will be monitored, and only authorized persons and vehicles will be allowed to enter.

4.2.3.1 Receipt

A cutaway view of the receiving and handling (R&H) building and its principle operating areas was shown previously in Figure 4.2. When casks containing spent-fuel assemblies arrive at the MRS facility, they are inspected, washed down as necessary, lifted off the transport vehicle (truck or train), and mounted vertically on a cask transport cart. The cart is moved into the cask handling and decontamination room where gas samples are taken and the outer cask lid is removed.

The cask is moved into the cask unloading room where it is mated to the input port of an operating cell. Operations in the cell are performed remotely. When the cell's shield door is closed and sealed, fuel assemblies are removed from the cask one at a time. They are inspected and transferred either to a disassembly table or to an in-cell lag storage pit using a crane in the cell. After unloading is completed, the inner lid is replaced, and the empty cask is transferred back to the cask handling and decontamination room. There the cask surface is decontaminated as necessary and the outer lid is replaced. The cask is then loaded onto a transport vehicle and released from the facility.

4.2.3.2 Consolidation and Packaging

To reduce the volume occupied by spent-fuel assemblies, and, hence, reduce subsequent storage and transportation requirements, consolidation is performed.

Consolidation consists of disassembling fuel, bundling and inserting the loose rods into a canister, and compacting and packaging the residual hardware. These operations are performed remotely in heavily shielded cells. These cells are enclosed areas with a sophisticated ventilation system that captures and contains airborne radioactive particles.

Three fuel assemblies from a pressurized water reactor (PWR) or seven fuel assemblies from a boiling water reactor (BWR) are consolidated at once. With the assemblies clamped in place, the upper and lower structural components are cut off. A laser cutter is used in the conceptual design (Parsons 1985a). Mechanical grippers individually engage the ends of all rods and pull them horizontally through a system of supporting combs. The loose rods then drop a short distance vertically downward into a semicircular device. The close-packed bundle of rods is pushed through the cell's outlet part into an empty canister. The canister is filled with an inert gas, welded closed, decontaminated, and leak tested. It is then transferred to a vault for short-term storage (Section 4.2.3.3), to a loadout cell for emplacement in long-term storage, or to the transport cask loadout area for shipment to the repository.

Nonfuel-bearing hardware remaining after fuel disassembly is compacted and packaged into steel 55-gallon drums. The drums are then stored or shipped to a repository.

Up to 10% of spent-fuel assemblies received at the MRS are not consolidated. A small portion of the assemblies will contain fuel rods with cladding defects, for example. These rods could become further damaged during consolidation. Therefore, the defective assemblies are not consolidated; they are loaded directly into canisters.

4.2.3.3 Lag Storage

Lag storage vaults for temporary storage of fuel canisters occupy most of the central operating canyon cells. Lag storage capacity is 1000 MTU. The compartmentalized vaults are air-cooled by natural and forced convection. Fuel canisters are loaded into and unloaded from the vault through ports in the floor of the canyon cell. After lag storage, canisters are removed for long-term storage in sealed storage casks or field drywells (Section 4.2.4), or the canisters are shipped directly to a repository.

4.2.3.4 Onsite-Generated Radioactive Waste

Some radioactive waste (radwaste) will be generated and packaged within the R&H building as a result of consolidation and packaging and related support activities. Related support activities will include maintenance (including housekeeping), periodic decontamination, and analytical-laboratory operations.

The waste, depending on its level of radioactivity, will be treated in either the LLW/CHTRU radwaste system or in the HAW radwaste system. Waste origin, composition, and treatment steps are described below.

LLW/CHTRU Radwaste System. Some low-level waste (LLW) and contact-handled transuranic waste (CHTRU) will be generated each year at the MRS facility. Half of this waste is expected to be solids and half a liquid slurry. The solid portion will be composed mostly of cotton coveralls, caps, boots, gloves, shoe covers, paper, and disposable bags. About 25% of the solid waste will consist of failed equipment and contaminated small tools. The liquid slurry will be from the bottom of an evaporator that will be fed by various LLW/CHTRU drain systems (e.g., washdown sumps, contaminated laundry water, and analytical lab drains). A small portion of the liquid slurry generated each year is expected to be spent resin mixed with water. The resin is from ion exchangers, which are part of the filter system.

The solid LLW/CHTRU will be placed in 55-gallon drums and surrounded by a grout mixture. The liquid LLW slurry will be mixed with cement and sand, and solidified in drums. In addition to the solid and liquid waste, about 800 air filters will be compacted and packaged in drums. These high-efficiency particulate air (HEPA) filters will be used to collect and adequately remove airborne radioactive materials from the exhaust system. About 650 prefilters will also be used and disposed of annually. Filters from highly contaminated zones are classified as HAW and are treated accordingly (see discussion of HAW Radwaste System).

LLW and CHTRU will be stored onsite. Provision will be made for shipping LLW offsite to a LLW disposal site. At the end of MRS facility operations, all LLW/CHTRU at the site will be packaged and shipped offsite for disposal.

All drums of LLW/CHTRU are temporarily stored within the R&H building until the grout is cured and a "batch" is available for the drum interrogator. The TRU waste content of the drum is determined by gamma pulse height analysis as the drum is passed through the interrogator. Drums with TRU material (CHTRU) are sent to the onsite CHTRU storage facility. Drums without TRU material (LLW) are sent to a temporary storage facility before being shipped for offsite disposal.

The total volume of LLW/CHTRU produced at the MRS facility each year will be about 21,000 gallons (80 m^3). For comparison, 80 m^3 is approximately one-eighth the volume of LLW generated in United States medical facilities and less than 0.1% of all LLW generated each year in the United States (DOE 1981).

HAW Radwaste System. About 9,000 pounds (4,100 kg) of HAW will be generated at the MRS facility each year. Approximately one fifth of this will be spent resin, and the rest will be slurry from the HAW/RHTRU evaporator. The evaporator will be fed by liquids from the HAW drain system that were used for decontamination. Once these liquids are condensed in the evaporator, the resulting slurry will be solidified with cement in 55-gallon stainless steel drums. Spent resin will be solidified in the same manner, and all drums will then be shipped to an offsite disposal area or placed in drum storage cages for onsite storage.

HEPA filters and prefilters in highly contaminated zones are also classified as HAW. These filters will be remotely changed monthly or bimonthly, resulting in about 4,000 used filters per year. The filters will be compacted, packaged in 55-gallon drums, and shipped to an offsite disposal area (or to onsite storage and then to an offsite disposal area).

4.2.4 Interim Storage

If interim storage (greater than the 1,000 MTU lag storage capacity) is necessary, canisters will be loaded directly into a storage cask or shielded transporter (depending on the storage concept). For the sealed storage cask concept, the canisters will be loaded into a storage cask; the cask will then be closed with a shield plug and a metal lid will be welded to the liner. The cask will be moved into the storage area with a storage-cask transport vehicle (a slow-moving vehicle similar to the one that transports a space shuttle). A crane will then hoist the cask from the transporter and place it upright on a previously prepared concrete pad (see Figure 4.4).

For field drywell storage, the canisters of prepared spent fuel and waste will be loaded down from the hot cell directly into a shielded transporter for transfer to a drywell. The transporter will be positioned over the drywell, and the canister and drywell shield plug will then be lowered into the drywell. The transporter will be moved, and the top of the drywell liner will be closed with a metal lid welded to the drywell liner (see Figure 4.5).

4.2.5 Retrieval and Shipment to a Repository

Following interim storage, waste canisters will be retrieved and shipped to a repository by train. The emptied storage casks or field drywells will be decontaminated, as necessary, as they are emptied.

Although overpacking of canisters (placing them in an additional steel disposal container) is not part of the current design, space within the hot-cell facilities is allocated for this operation should it be decided to overpack at the MRS facility. Canisters will be loaded into rail casks and shipped to a repository by dedicated train. The train will consist of about five cask cars for spent fuel and three to five cask cars for other wastes (e.g., nonfuel-bearing components). These wastes, packaged in 55-gallon drums, will be loaded into shipping containers approved by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT) for rail transport to a repository.

4.3 DECONTAMINATION AND DECOMMISSIONING

After all spent fuel and waste has been shipped, the MRS facility will be decontaminated and decommissioned. Decontamination will consist of removing radioactive material from floors, walls, and equipment in the MRS facility. Decommissioning will consist of removing the facility from service after its useful life and taking the necessary steps to protect the public from residual radiation hazard.

Based on current operational assumptions (DOE 1985), all canisters at the MRS will have been shipped to a repository by the year 2022. As the canisters are retrieved from storage, the emptied storage casks or field drywells will be decontaminated, sealed, and left onsite. Final decommissioning of the MRS facility is assumed to begin in the year 2022, after all waste has been shipped offsite and the storage area has been decommissioned.

The MRS facility will be decommissioned such that all its areas and buildings are available for unrestricted use, as defined in Regulatory Guide 1.86 (AEC 1974). Capabilities of portions of the R&H building (i.e., analytical laboratory and radwaste treatment areas) will be used in decommissioning the rest of the MRS facility; these portions of the R&H building will be decommissioned last. Any equipment or facility components that retain unacceptable levels of contamination will be dismantled and shipped offsite for disposal.

Current decommissioning plans are outlined below. A detailed decommissioning plan for the MRS facility will accompany the license application.

4.3.1 Storage Area

Sealed storage casks and field drywells will be decommissioned similarly. Final monitoring measurements will be taken, using the cask or drywell's existing monitoring equipment. The empty cask or field drywell will be decontaminated, sealed, and stored permanently in the storage area. Any casks that cannot be decontaminated to acceptable levels will be demolished and disposed of offsite. The transporter will then be surveyed, decontaminated, and shipped offsite.

4.3.2 CHTRU Storage Area

Before the waste is removed from the vaults, a temporary structure with a self-contained ventilation system will be placed over the CHTRU storage area vault to be decommissioned. The interior compartments of the vault will be monitored, the waste packages and their pallets will be packaged for shipment, and the interior surfaces of the vault will be surveyed and then decontaminated as necessary. The decontamination fluids will be routed to the R&H building radwaste system by tank truck. Drain lines will then be flushed, decontaminated, and grouted.

4.3.3 Receiving and Handling Building

All components of the building and its equipment will be decontaminated as necessary. Some decontamination activities include: dry vacuuming, spraying with decontamination fluid or foam, wet vacuuming, and high-pressure rinsing. Effluents will be controlled by using the existing containment barriers, ventilation system, and radwaste treatment systems. Decontaminated equipment from the R&H building will then be surveyed and shipped offsite as either LLW or HAW.

Finally, piping and other components of the radwaste systems will be flushed with decontamination solution, removed, volume-reduced, surveyed, packaged, and shipped to offsite disposal.

4.4 REFERENCES

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5.0 POTENTIALLY AFFECTED ENVIRONMENT

This chapter describes the three sites the Department of Energy (DOE) has identified for evaluation in the MRS proposal and it describes the surrounding environment that could potentially be affected by the construction, operation, and decommissioning of an MRS facility. These sites (all in Tennessee) are the Clinch River Breeder Reactor Site, the DOE Oak Ridge Reservation and the Tennessee Valley Authority (TVA) Hartsville Nuclear Plant Site. The sites will hereafter be referred to as the Clinch River, Oak Ridge, and Hartsville sites (see Figure 5.1). These sites were selected through a site screening and evaluation process, which is described in the document, Screening and Identification of Sites for a Proposed Monitored Retrievable Storage Facility (DOE 1985a).

Each of the three sites is described in terms of the following environmental characteristics: background radiation; climate and air quality; land, water and natural resources and their uses; plant and animal life; socioeconomic conditions; transportation systems; and aesthetic characteristics. Endangered species and nearby historical sites are also identified.

For background radiation levels in Tennessee, considerable variation exists depending upon elevation, topography and local geology (Oakes et al. 1976). Several investigators have measured these levels over the past decade or two using different types of dosimeters - pressurized ion chambers, scintillation counters, and thermoluminescent dosimeters (TLDs). Most sets of measurements seem to be internally consistent, but measurements made by different investigators at different times at the same location are not always consistent. The differences arise because of the different instrument-response characteristics, the inclusion or exclusion of contributions from cosmic and fallout radiation, and the influence of local terrain and structures.

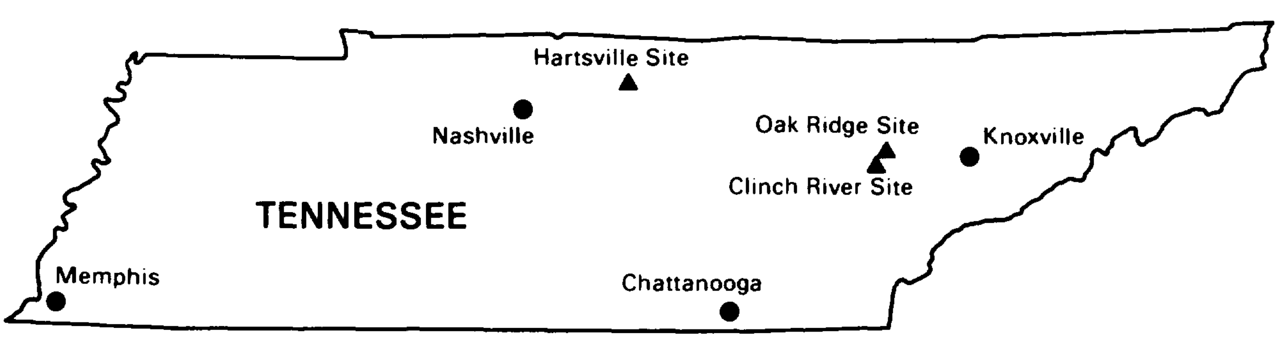

FIGURE 5.1. Location of the Three Candidate MRS Sites in Tennessee

Readings are variously reported as exposure rate (μR/hr), dose rate (μrad/hr), or dose equivalent rate (mrem per year). However, based on the assumption that

$$1 \text{ R} \sim 1 \text{ rad} \sim 1 \text{ rem},$$

radiation levels here are consistently reported in rem.

For socioeconomics, current conditions for local population, employment, and community services are described, and baseline conditions for 1991, the year construction of an MRS would begin, are projected. These projections are based on the existing socioeconomic structure and its current trends.

The accoustical environment is an important aesthetic consideration. The best descriptors of environmental noise are long-term equivalent A-weighted sound level (L_{eq}) and day/night sound level (L_{dn}), defined as follows:

- A-weighted sound level - the quantity measured by a sound-level meter with a frequency response that approximates human hearing, discriminating against sound pressures at frequencies below 500 Hz and above 10,000 Hz, known as the A-weighting scale

- L_{dn} - day/night average sound level; the 24-hour A-weighted equivalent sound level with a 10 dB penalty applied to nighttime levels (e.g., 40 dB at night is interpreted as 50 dB to determine the average sound level)

- $L_{eq}(24)$ - equivalent A-weighted sound level over 24 hours.

Figure 5.2 is a scale of noise levels typical of indoor and outdoor environments. The scale ranges from 0 to 120 dBa, the threshold of hearing to the threshold of physical discomfort. The Noise Control Act of 1972 specifies noise levels on the basis of protecting the public welfare within an adequate margin of safety. An L_{dn} level of 55 dB for outdoors level in residential areas has been identified as compatible with this intention (EPA 1974).

Two major sources of the environmental data presented in this EA are the Clinch River Breeder Reactor Plant Environmental Report (PMC 1975) and The Hartsville Nuclear Plant Environmental Reports (TVA 1974a). Portions of the Clinch River and Hartsville sites have since been disturbed by construction activities.

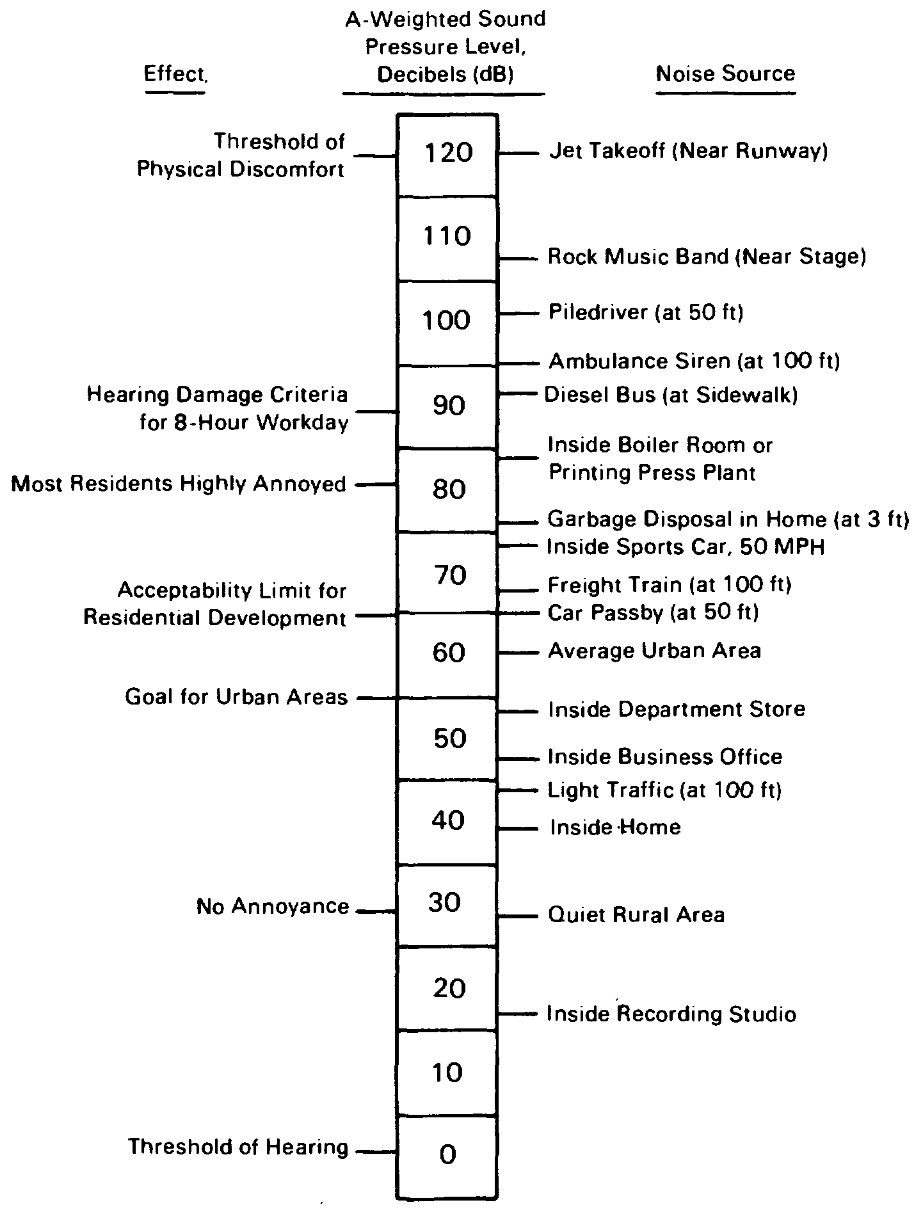

FIGURE 5.2. Noise Levels from Indoor and Outdoor Environments

5.1 CLINCH RIVER SITE

The Clinch River site is located in east-central Tennessee, in the eastern part of Roane County. The Clinch River site covers a portion of the site area for the canceled Clinch River Breeder Reactor (CRBR) Project (see Figure 5.3). It is located on the southeast flank of Chestnut Ridge on a peninsula formed by a meander of the Clinch River, 25 miles (40 km) west of Knoxville, Tennessee and 9 miles (15 km) southwest of the city center of Oak Ridge, Tennessee.

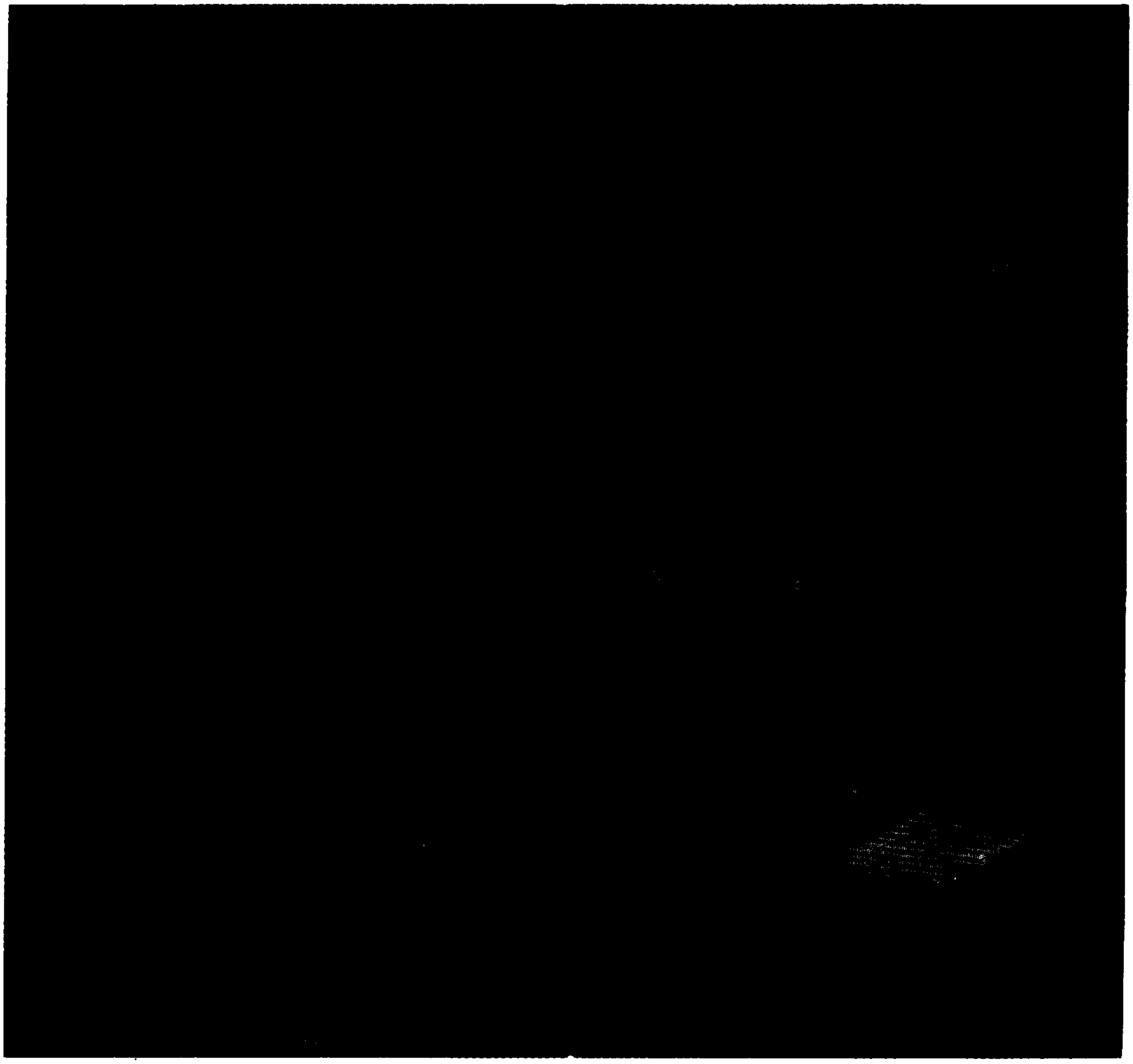

FIGURE 5.3. Aerial Photograph of the Clinch River Site

The Clinch River site is within the Roane County portion of the Oak Ridge city limits (see Figure 5.4). The site is adjacent to the DOE's Oak Ridge reservation, is owned by the federal government, and is in the custody of the Tennessee Valley Authority (TVA). Presently, the site is under the control of the DOE pursuant to an agreement between DOE and TVA for preliminary site

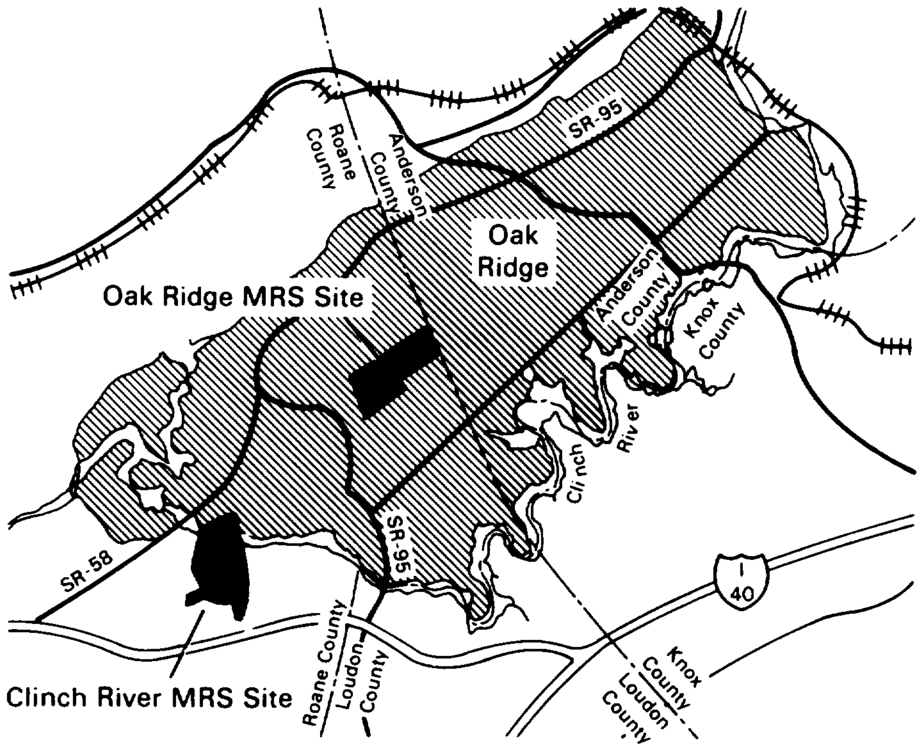

FIGURE 5.4. Oak Ridge City Limits

preparation at the Clinch River project. As a part of the CRBR project, major site modifications were made, including major excavations for the previously planned construction of portions of the nuclear reactor plant. Upon termination of that project, the DOE has proceeded with the redress and reclamation of the site. Following completion of site redress in mid-1986, control of the site will revert to the TVA.

The Clinch River site is located in the Appalachian Highland Physiographic Division of the eastern United States. This area is characterized by rugged terrain varying from rolling hills to mountains. Physiographic provinces within 200 miles (320 km) of the site include Interior Low plateaus, Appalachian plateaus, Valley Ridge, Blue Ridge, and Piedmont.

The present day topography which is characterized by subparallel ridges with intervening valleys (Figure 5.5). The major ridges are Chestnut Ridge to the northwest and Dug-Hood Ridge to the southeast. Ridge-crest elevations range from 900 to 1,200 feet (270 to 370 m). The valley separating these ridges is regionally referred to as Raccoon Valley. Locally it is referred to as either Poplar Springs Valley or Bethel Valley. This valley consists of rolling hills with elevations that range from 750 to 800 feet (230 to 240 m).

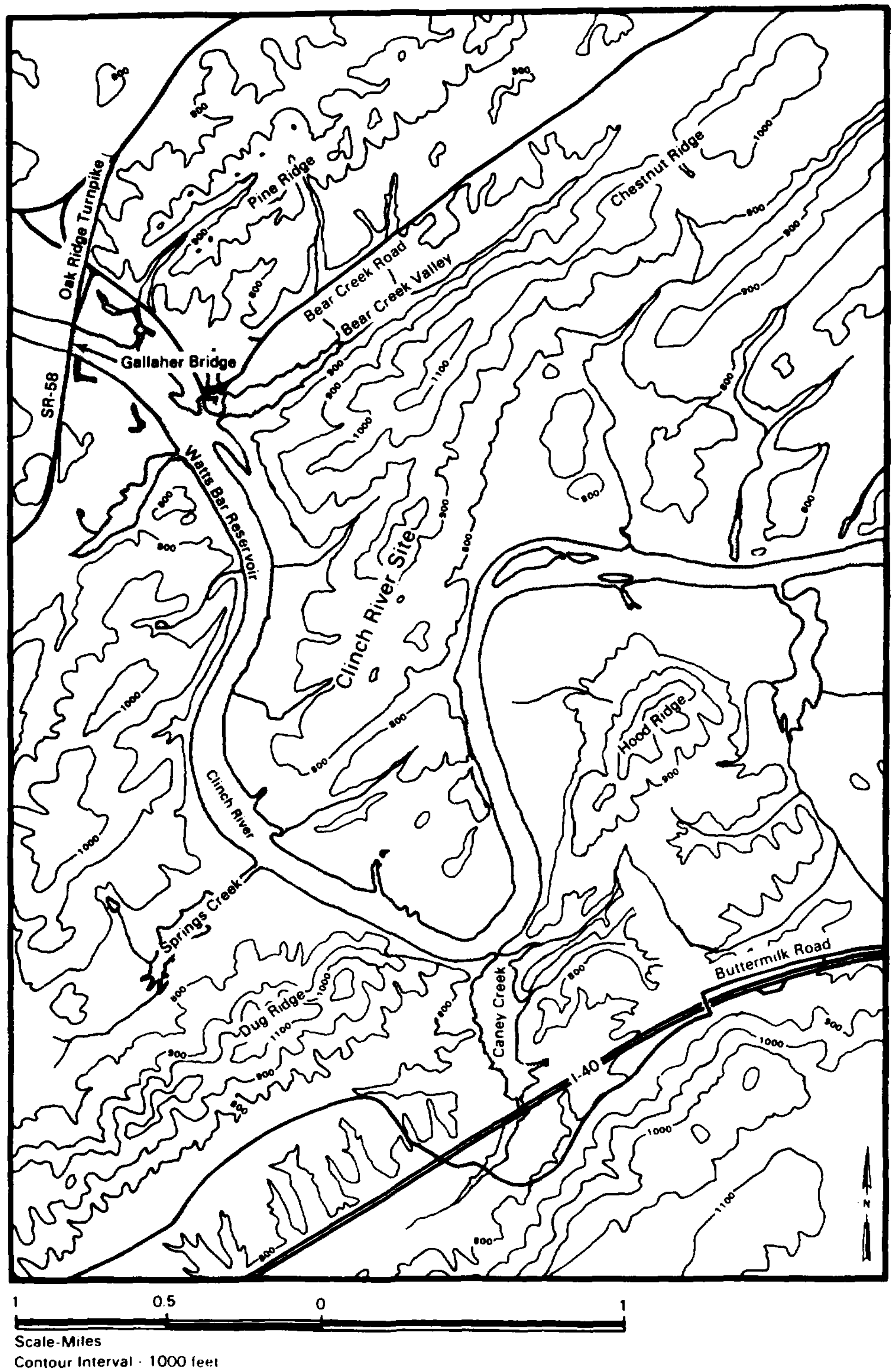

FIGURE 5.5. Topography of the Area Surrounding the Clinch River Site

The site is located on a peninsula formed by a U-shaped bend in the Clinch River between river miles (RM) 15 and 18.

5.1.1 Radiological Characteristics

Background radiation levels presented here are from measurements taken over the years 1962-1984. The radiation measured is from both naturally occurring and produced radionuclides present at and near Oak Ridge National Laboratory (ORNL), which is located 4.2 miles (6.8 km) northeast of the Clinch River site and 1.5 miles (2.4 km) southeast of the Oak Ridge site. Because of the proximity of the Clinch River site to the Oak Ridge site, the two sites have essentially the same radiological characteristics. Therefore, for radiation levels these two sites are considered together, with ORNL being the center of a 50-mile (80-km) radius.

Exxon Nuclear Company reported on a literature study of the existing radiation levels from both natural and produced radionuclides at the site of their previously proposed fuels reprocessing plant (Exxon 1977). Included in the report were background radiation levels along a north-south transect of U.S. Highway 27 (US-27), measured by Levin et al. (1968). In the Levin et al. study, 19 measurements were made between the Kentucky-Tennessee border and Chattanooga. All levels along US-27 were between 80 and 90 mrem per year, regardless of distance from ORNL. The lowest radiation level reported by Levin et al. was 74 mrem per year, 40 miles (64 km) southwest of ORNL at Spring City. The highest level was 93 mrem per year at both Graysville, approximately 60 miles (97 km) to the southwest and at Robbins, approximately 35 miles (56 km) to the northwest (Exxon 1977).

Some of the locations measured by Myrick et al. (1981) were within 50 miles (80 km) of ORNL. The results of those measurements, in relation to ORNL, were (Exxon 1977):

45 miles west along I-40	60 mrem/yr
50 miles north at Jellico	61 mrem/yr
30 miles northwest at Elgin	40 mrem/yr
10 miles northeast at Norris	76 mrem/yr
50 miles east at Dandridge	54 mrem/yr

A measurement of 84 mrem per year was made at Elgin in 1966 (Exxon 1977). This was somewhat higher than the 1981 measurement at the same location, which could be due in part to higher levels of fallout radioactivity present in 1966.

In 1973, the terrestrial component of the natural background in Knoxville was measured at 104 mrem per year (Auxier et al. 1973).

Measurements at 13 stations at the Clinch River site were made by the TVA in 1982 and 1983 (Pierre 1983, 1984). The average value across all 13 stations was 80 mrem per year.

During 1983, background radiation levels at remote locations and around the Oak Ridge site perimeter were measured by Martin Marietta (1984a). Radiation levels at remote locations within 50 miles (80 km) of ORNL were 62 mrem per year 23 miles (37 km) northeast at Norris Dam, 64 mrem per year 12 miles (19 km) south at Ft. Louden, 70 mrem per year 42 miles (68 km) east at Douglas Dam, and 46 mrem per year at Knoxville. Perimeter results included values of 87, 96, and 120 mrem per year along the south boundary of the city of Oak Ridge, 82 mrem per year along the Oak Ridge turnpike about 2 miles (3.2 km) west of town, and 86 mrem per year about 1 mile (1.6 km) northwest of Oak Ridge Gaseous Diffusion Plant (ORGDP). Measurements to the south of the project generally ranged from 80 to 90 mrem per year, with the exception of one value of 150 mrem per year near White Oak Lake, a location previously contaminated with ^{137}Cs from ORNL facilities.

Auxier et al. (1973) measured an area at ORNL that had never been used for contaminated work. Terrestrial radiation was calculated at 70 mrem per year. Cosmic radiation was stated to be 35 mrem per year (Auxier et al. 1973), although values of about 45 mrem per year have been reported (Oakley 1972; Klement et al. 1972; Oakes et al. 1976).

An aerial survey of the Oak Ridge area was performed by the U.S. Geological Survey. The values obtained ranged from 20 to 100 mrem per year with a mean of 53 mrem per year (Oakley 1972; NCRP 1975). These results are reported to be for terrestrial radiation only; i.e., corrections were applied for cosmic radiation and the influence of any effluents present from nuclear facilities (Oakley 1972).

From this data, it appears that the terrestrial component of background radiation varies between 60 and 90 mrem per year in the populated areas within 50 miles of the Clinch River/Oak Ridge sites. The higher values were generally found east of the sites, although no clear pattern was evident. For the present analysis, a value of 80 mrem per year is selected as a reasonable average. Table 5.1 summarizes the background radiation levels for the two sites. The internal radiation (25 mrem per year) is from naturally-occurring radionuclides taken into the body via air and food (NCRP 1975).

5.1.2 Meteorology

Climatological data for the Clinch River site are from Project Management Corporation (1975). The region surrounding the Clinch River site has a mild, humid climate. Air temperatures range from -9°F to 105°F (-22°C to 41°C).

TABLE 5.1. Summary of Background Radiation Levels at the Clinch River and Oak Ridge Sites

Item	Dose Rate (mrem/yr)
Terrestrial radiation	80
Cosmic radiation	45
Internal radiation	25
TOTAL	150[a]

(a) Fallout radiation adds another 4 mrem per year to this total.

Summer temperatures are normally in the high 80s °F (approximately 30°C), and winter temperatures are usually around 40°F (4.4°C). The average daily maximum is 69.4°F (21.8°C), and the minimum is 47.6°F (8.7°C). The average monthly mean temperature is 58.5°F (14.7°C).

Average annual precipitation measured at the Oak Ridge Area station over 21 years from 1944 to 1964 is 51.52 inches (130 cm). Winter is the wettest season, when 31% of the annual precipitation occurs. February and March are the wettest months, with precipitation averaging about 5.4 inches (14 cm) for each of these months. October is the driest month, averaging only 2.82 inches (7.2 cm) of precipitation. Maximum monthly rainfall (12.84 inches; 32.6 cm) and observed maximum 24-hour rainfall [7.75 inches (19.6 cm)] occur in September.

Annual snowfall averages about 10 inches (25.4 cm). Maximum recorded snowfall for one year was 41.4 inches (105 cm), more than four times the average. Heavy snows [when more than 6 inches (15 cm) are recorded in 24 hours] have occurred in each month from November through March.

Rain, snow, and fog occur approximately 127, 3, and 34 days per year, respectively.

Analysis of the one-year summary of onsite wind data (February 1977 to February 1978) shows an average annual wind speed of 3.5 miles (5.6 km) per hour at 33 feet (10 m) above ground level, and 5.6 miles (9 km) per hour at 200 feet (70 m). The wind is most frequent from the west-northwest at the 33-foot (10-m) level and from the west-southwest at 200 feet (70 m). Maximum wind speeds of about 52 miles (84 km) per hour have been recorded. Tropical storms occur about three times in 10 years.

An inversion layer generally covers the entire region at an elevation of 1,100 to 1,800 feet (350 to 550 m) in the mornings, and 3,300 to 4,900 feet (1,000 to 1,500 m) in the afternoons (Holzworth 1972).

An air pollution episode is forecast to occur whenever: 1) the mixing depth is less than 1,500 m, 2) the mean wind speed is less than 9 mph (4 m/sec), 3) no precipitation is expected to occur, and 4) these or worse conditions persist for two days. The Clinch River site is in an area where 17 episodes (a total of 40 days) of high air-pollution potential, by this definition, have occurred over a five-year period. This potential is high for the eastern United States but low compared with a large part of the western United States (Holzworth 1972).

Atmospheric dispersion characteristics for the site, developed from atmospheric stability and joint frequency data, are included in Appendix B.

The Tennessee Division of Air Pollution Control (TDAPC) has the responsibility for implementing air quality regulations and issuing air quality permits within the State.

Tennessee has adopted the national ambient air quality standards [NAAQS (40 CFR 50)] which limit the concentrations of six pollutants - total suspended particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), and lead (Pb) - in the outside air. Tennessee has also established ambient standards for gaseous fluorides (HF).

Additionally, the TDAPC has adopted regulations governing the prevention of significant deterioration (PSD) of air quality. These regulations apply to all areas in attainment of the NAAQS. The closest Class I[a] area is the Great Smoky Mountains National Park, about 30 miles (48 km) southeast of the Clinch River site.

Ambient pollutant concentrations at the DOE facilities at Oak Ridge are found in the Annual Environmental Monitoring Report (Martin Marietta 1984a). Monitoring for fluorides and suspended particles centers on the ORGDP, which is about five miles west of the Oak Ridge site. Monitoring of sulfur dioxide, fluoride, uranium, and suspended particulates is done at the Y-12 plant, which is about three miles northwest of the site. Figure 5.6 shows the location of air-monitoring stations at the Clinch River site.

(a) Areas are designated as Class I, II, or III (40 CFR 51) in order of decreasing allowable incremental concentration of pollutants. Class I areas, which have the most restrictive emissions limitations, include, for example, international parks and national monuments, parks, and wilderness areas that meet certain criteria. All three candidate sites are in Class II areas.

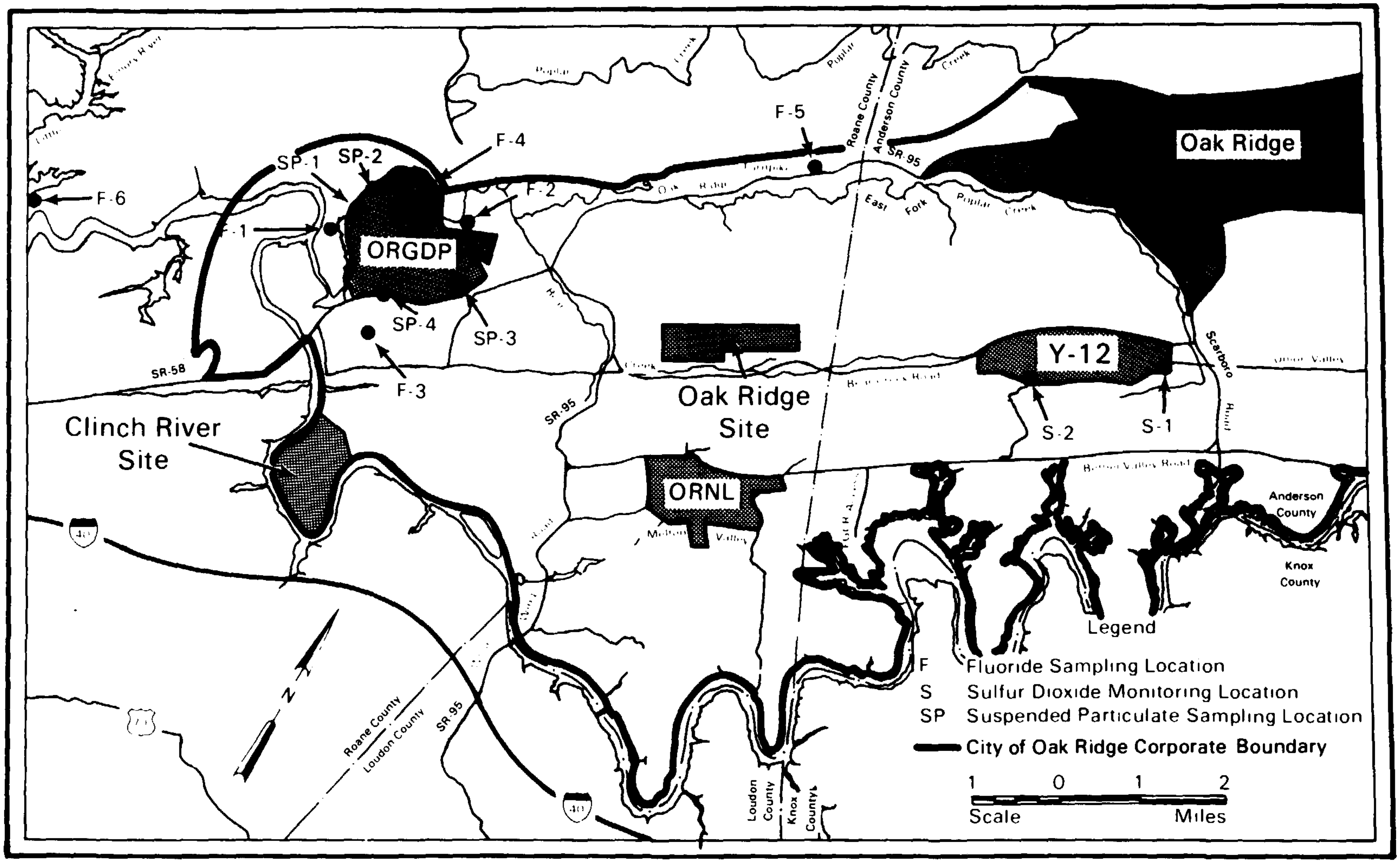

FIGURE 5.6. Air Monitoring Locations Near the Clinch River Site (Martin Marietta 1984)

The main source of suspended particulate is fly ash from burning of coal at the Y-12 steam plant. Concentrations of suspended particulates ranged from 29% to 88% of the annual standard at the six monitoring locations. (The Annual Environmental Monitoring Report for 1983 indicated that maximum 24-hour concentrations of particulate material at Y-12 exceeded the 24-hour standards. To reduce the particulate levels, baghouses[a] were being installed with an anticipated completion date of December 1985). This new pollution-control equipment should reduce emission of particles. In the past, the primary standard for ozone (O_3) has not been met; however, data showing attainment of the standard in Roane County have been submitted to EPA. Existing ambient concentrations of regulated pollutants in the Clinch River/Oak Ridge area are given in Table 5.2.

5.1.3 Geology and Hydrology

The geologic and hydrologic characteristics of the Clinch River site are discussed in this section.

5.1.3.1 Geology

The Clinch River site is bounded on the eastern, southern, and western sides by the Clinch River and on the northern side by the northern base of Chestnut Ridge, a major north-east-trending ridge. The Clinch River floodplain lies along the western side and the southern tip of the peninsula. This floodplain is flat to gently sloping and extends to about 752 feet (229 m) elevation. The maximum width of the floodplain is about 500 feet (153 m). Steep bluffs occur along the eastern border of the site.

Chestnut Ridge has a crest elevation of about 1,100 feet (340 m) and slopes down to the river floodplain at an average slope of 13°. The orientation of Chestnut Ridge is controlled by the strike of bedding in the underlying rocks.

The Knox Group and the Chickamauga Group are the two major rock units that underlie the site (PMC 1982). The Knox Group consists of cherty dolomite, with limestone and shale interbeds. The Chickamauga Group consists of thin- to medium-bedded siltstone, limestone, and shale.

The depth of soil overburden is variable across the site, ranging from 0 to greater than 70 feet (21 m). The soil is predominantly in-place, weathered-rock residuum consisting of plastic, clay-like silt material with chert gravel layers. In addition to the residual soil, scattered alluvial terrace deposits and floodplain deposits of sandy silt also occur at the site (PMC 1982).

(a) Baghouses are arrays of fabric bag filters that trap particulate matter when dust-laden gases pass through them.

TABLE 5.2. Concentrations of Pollutants Monitored in the Clinch River/ Oak Ridge Area (Martin Marietta 1984a)

Pollutant	Maximum 24-hr Concentration ($\mu g/m^3$)	Annual Average Concentration ($\mu g/m^3$)	TDAPC Standard ($\mu g/m^3$)	% of Standard
Fluoride	0.2[(a)]	<0.1 ± 0.02[(b)]	1.2[(c)]	8
Suspended particles	95[(d)]	22 ± 50%[(d)]	75[(e)]	29
SO_2[(f)]				
S-1	94	18	80[(g)]	23
S-2	94	13		17

(a) Maximum concentration for fluoride based on seven-day averaging interval.
(b) Data from nine monitoring stations in the vicinity of ORGDP and Y-12 areas.
(c) Tennessee Division of Air Pollution Control regulations for gaseous fluorides has a sliding scale of concentration vs averaging time. 1.2 $\mu g/m^3$ is for a 30-day averaging interval; 1.6 $\mu g/m^3$ for 7-day averaging.
(d) Data from nearest monitoring station, SP-4 at ORGDP (Figure 5.6).
(e) Tennessee Ambient Air Quality Primary Standard for total suspended particulates 75 $\mu g/m^3$ annual geometric mean, 260 $\mu g/m^3$ maximum 24-hour average.
(f) Data from monitoring stations S-1 and S-2, respectively, located in Y-12 area, east of the Clinch River site (Figure 5.6).
(g) Tennessee Ambient Air Quality Standards for SO_2:
maximum 24-hour average 365 $\mu g/m^3$ = 0.14 ppm
annual arithmetic mean 80 $\mu g/m^3$ = 0.03 ppm.

The Knox Group dolomite is susceptible to solutioning (PMC 1982). Northwest of the CRBR site, a band of closed depressions are interpreted to be sinkholes that formed due to solutioning of the underlying Knox Group dolomite. In contrast, only small solution cavities and solution-widened joints are known to occur within the Chickamauga Group (PMC 1982).

The seismicity of the Clinch River site is characterized by a small number of events with a Modified Mercalli intensity (MMI) (Wood and Neumann 1931) of generally VI or less (see Table 5.3). Major earthquakes affecting the site have included the New Madrid earthquakes of 1811 and 1812, the Charleston,

TABLE 5.3. Abridged Modified Mercalli Intensity Scale (Wood and Neumann 1931)

Intensity	Description/Reaction
I	Not felt except by a few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, and so on, broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.
VIII	Damage slight in specially designed structures, considerable in ordinary substantial buildings with partial collapse, great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water levels. Persons driving cars disturbed.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipelines broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

South Carolina, earthquake of 1886, and the Giles County, Virginia, earthquake of 1897. These resulted in estimated MMIs of VI-VII, VI, and V, respectively, at the Clinch River site (Parsons 1985). The Giles County earthquake, with a reported epicentral MMI of VII-VIII, was the largest in the same tectonic province as the site. (Giles County, Virginia, is located 220 miles (354 km) northeast of the Clinch River site.)

The safe shutdown earthquake determined for the Clinch River Breeder Reactor (CRBR) would result in ground accelerations (G) of 0.25 G at the site. The ground acceleration values are based on the postulated occurrence of an earthquake of MMI VIII adjacent to the site (PMC 1982). (An MMI VIII earthquake is equal to the largest historic earthquake in the southern Appalachians). A number of faults have been mapped at or near the site. However, none of the faults are considered capable of generating earthquakes (Parsons 1985).

5.1.3.2 Hydrology

The Clinch River site is located on a peninsula formed by a meander of the Clinch River. The river provides a boundary for the site on the eastern, southern, and western sides and, therefore, must be considered when evaluating environmental effects. This section discusses the characteristics and use of the Clinch River and other existing surface waters and ground waters.

Surface Water. The Clinch River is the main surface water body at the Clinch River site. From the site, the river flows in a southwesterly direction to its confluence with the Tennessee River at Tennessee River RM 567.8, near Kingston, Tennessee (PMC 1975).

Based on stream gage records from three locations, the average flow of the Clinch River is 4,561 cfs (130 m^3/sec). The maximum recorded flow was 42,900 cfs on February 9, 1937, before the closing of Melton Hill Dam. Based on discharge records from Melton Hill Dam since the closing in 1963, the average annual flow is about 5,380 cfs (150 m^3/sec) at the site (PMC 1975). The maximum hourly average release was 54,960 cfs (1,500 m^3/sec) on April 5, 1977, and the maximum daily average release was 34,966 cfs (980 m^3/sec) on January 11, 1974, at Melton Hill Dam (PMC 1975).

Normal maximum water level of the Clinch River at the site is approximately 741 feet above mean sea level (MSL). The elevation of the 100-year flood at the site is approximately 749 feet above MSL, and the elevation of the probable maximum flood, which includes dam failure, is 800 feet above MSL (Parsons 1985). The elevation of the river at Melton Hill Dam on May 7, 1984, during the recent flood, was 795.6 feet (242.6 m) above MSL. Melton Hill dam is 6.5 miles (10.5 km) upstream from the site.

Major tributaries of the Clinch River are the Powell and Emory Rivers. The Powell River, which parallels the Clinch River about 10 miles (16 km) to the north throughout most of its length, joins the Clinch River at RM 88.8. Drainage area at the mouth of the Powell River is 938 square miles (2,430 km^2). The Powell River enters the Clinch River above Norris Dam. The Emory River, with a drainage area of 865 square miles (2,240 km^2), enters the Clinch River southeast of Harriman, Tennessee, at Clinch River RM 4.4. Annual average flow of the Emory River is 1,670 cfs (47 m^3/sec), and the peak flow, occurring on March 23, 1929, was estimated at 207,500 cfs (5,800 m^3/sec) at the mouth.

No perennial streams exist on the site; however, after a heavy rain, surface water flows from the ridges into valleys and gullies that drain into the river. The site is on an arm of the Watts Bar Reservoir, which extends up the Clinch River. The Watts Bar Reservoir is a multipurpose reservoir providing power generation, navigation aid, flood control, and recreation facilities (PMC 1975).

Surface-Water Use. Twelve public water supplies and 15 industrial water supplies using water from surface sources are located within a 20-mile (32-km) radius of the Clinch River site. Four of the 12 public water supplies and five industrial supplies are located where they could be influenced by discharges from the site.

A water pumping and filtration facility is located at Clinch River RM 14.4, near the ORGDP. This facility, sized to handle 5 million gallons (18,900 m^3) per day, supplies potable water to the ORGDP and the Clinch River Industrial Park. The average daily use rate for this facility is about half of the rated capacity (PMC 1975). The DOE's ORGDP recirculating pump facility at Clinch River RM 11.5 withdraws water for cooling systems only (Exxon 1977).

Surface-Water Quality. Surface water quality is monitored in several locations near the Clinch River site, as shown in Figure 5.7. Monitoring Station C-3 is at the ORGDP pumping station, just downstream from the site. The concentration of chemical contaminants in the Clinch River at C-3 is given in Table 5.4. The accuracy of the analytical tests for cadmium, lead, and mercury are not sufficient to determine compliance with regulations. The concentrations of other pollutants are below levels set by Tennessee Water Quality Criteria.

The velocity of the Clinch River at the site is highly variable and depends on turbine operations at Melton Hill, Fort Loudon, and Watts Bar dams. Water velocity at Clinch River RM 17 may vary from about 3 feet (1 m) per second after water discharge from the Melton Hill dam upstream to near zero velocity (PMC 1982).

The temperature of the Clinch River generally ranges from 33 to 78°F (1 to 25°C).

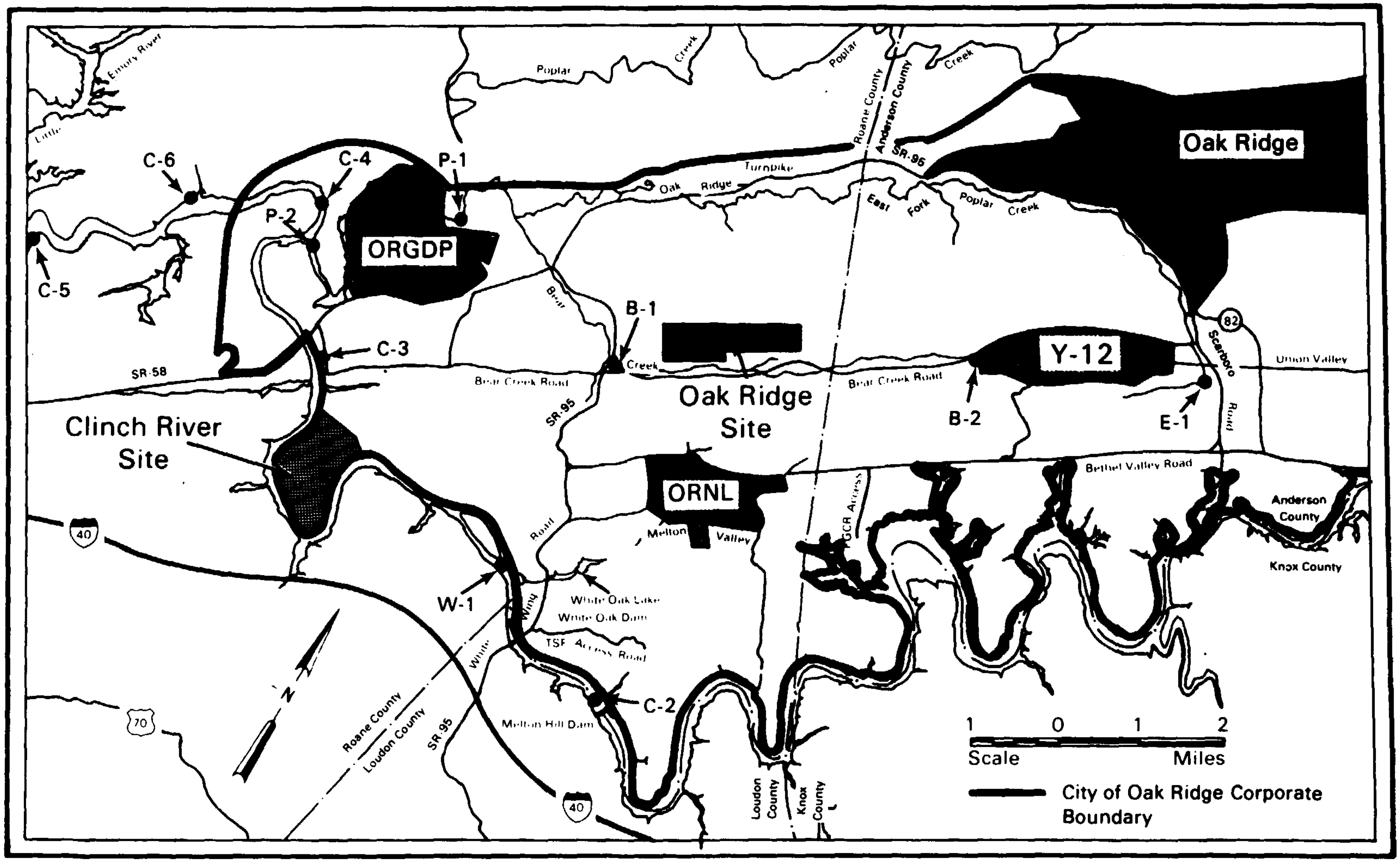

FIGURE 5.7. Surface-Water Monitoring Locations Near the Clinch River and Oak Ridge Sites

TABLE 5.4. Water Quality Data for the ORGDP Sanitary Water Pumping Station (Martin Marietta 1984b)

Substance	Number of Samples	Concentration (mg/L) Maximum	Minimum	Average	Standard[a]	% of Standard
Cd	12	<0.002	<0.002	<0.002	0.000025[b]	<8000[c]
Cr	12	0.037	<0.010	<0.012 ± 0.005	0.05	<24
CN	12	<0.002	<0.002	<0.002	0.0035[d]	<57
NO_3(N)	12	1.8	0.19	0.55 ± 0.26	10	6
Pb	12	<0.010	<0.010	<0.010	0.0038[b]	<263[c]
$SO_4^=$	11	30	13	20 ± 3	250	8
T.D.S.	11	169	135	151 ± 8	500	30
Zn	12	0.13	<0.020	<0.050 ± 0.023	0.05[b]	<100
F^-	12	0.30	<0.10	<0.14 ± 0.04	1	<14
Hg	12	<0.001	<0.001	<0.001	0.00005[e]	<2000[c]
Ni	12	0.030	<0.010	<0.015 ± 0.005	0.1	<15

(a) Tennessee Stream Water Quality Criteria for Fish and Aquatic Life. Assumed Hardness = 100 mg/L as $CaCO_3$.
(b) Monthly Average (Daily Maximum is Cd 0.003 mg/L, Pb 0.17 mg/L, Zn 0.32 mg.L).
(c) Analytical tests are not sufficiently accurate to determine compliance with the standard.
(d) From Martin Marietta (1985).
(e) Current EPA Water Quality Criteria for Fish and Aquatic Life is 0.0002 mg/L 24-hour average and 0.0041 mg/L maximum.

Ground Water. Ground water in the vicinity of the Clinch River site, as elsewhere in east Tennessee, generally occurs in fractures in the underlying rocks. This water supplies drilled wells, dug wells, and springs. Dug wells are most common in the thick residuum overlying the dolomite of the Knox Group, but some have been dug in shale and along valley bottoms in alluvial material. Dug wells often go dry during periods of drought.

The Knox Group and the lower and middle parts of the Chickamauga Group compose an aquifer system in the vicinity of the Clinch River site. The Clinch River, which bounds the ground-water system on three sides, is a ground-water sink; discharge from the aquifer system goes directly into the river or into streams that flow into the river. Because the incised meander of the river is a major topographic feature set down in bedrock, it is unlikely that ground-water flow could pass beneath the river (PMC 1975).

Ground water occurs at the Clinch River site primarily in weathered joints and fractures in subsurface rocks. Movement of ground water is largely restricted to the upper, more weathered zones of the rock underlying the area.

Generally, ground water at the site occurs under water table conditions, but local and transient semiconfined conditions have been observed during periods of high water levels, especially in the low regions of the site. Ground-water recharge is primarily derived from precipitation, although it is possible that in some restricted areas recharge may occur from the Clinch River during periods of rapid increase of river stage.

Ground-water levels follow an annual cycle, with maximum levels occurring during January and February, decreasing to low values recorded during October and November. Generally, ground water is at a depth of less than 30 feet (9.1 m), except in areas of high topographic relief.

The ground-water table responds rapidly to precipitation; it rises several feet in one day during and after periods of heavy precipitation (PMC 1975). Normal seasonal water level fluctuations are from 5 to 20 feet (1.5 to 6.1 m), and are generally largest in areas of topographic highs and smallest in areas of topographic lows. Local and transient semi-confined conditions have been observed during periods of high water levels, especially in the low areas of the site. The large fluctuations in the ground-water table in the topographic highs and the quick response to precipitation are likely due to smaller permeabilities in these areas and to the closer proximity of these areas to recharge areas. The smaller fluctuations in the ground-water table in the area of the groundwater flow are a result of a combination of higher permeability in this area and the regulating effect of the Clinch River, which affords a relatively constant downstream boundary condition.

Permeabilities of the underlying rocks at the Clinch River site have been measured by means of packer permeability tests (PMC 1975). Permeability is the rate of water flow through a cross-section of unit area under a unit hydraulic gradient and may be expressed in terms of cubic feet per year per square foot or, equivalently, feet per year. Permeability and porosity, along with the water table gradient, determine the rate of water movement in the soil and in the weathered and fractured zones in the rock.

Values of permeability were measured in 1973. Almost one-third of the permeability values ranged from 0 to 10 feet (0 to 3 m) per year. More than 90% of the values were less than or equal to 800 feet (240 m) per year. Permeabilities clearly tend to decrease with depth. The maximum measured values of permeability in the limestones and siltstones at the Clinch River site were not significantly different.

Due to the difficulty in maintaining open holes in the residual soils and more weathered portions of the underlying rocks, few tests were made in the more weathered zones. Thus, the permeabilities measured are representative of the less weathered materials on the site and do not constitute a representative sample of permeabilities of the more weathered zones of the aquifer. Had it been possible to distribute the packer tests more uniformly among the zones of various degrees of weathering, it is likely that a higher median value of permeabilities would have been found.

In general, movement of ground-water occurs in a direction normal to the ground-water contours. At the site, movement is generally from topographically high areas to topographic lows; however, this pattern is modulated by the extent of weathering of the bedrock aquifers.

Ground-Water Use. A 1973 survey showed that 110 wells and springs are located within 2 miles (3.2 km) of the Clinch River site (PMC 1975). However, all of these wells are located south of the Clinch River, the ground-water sink for the system. Only environmental sampling wells exist at the site, and most of the wells near the site are small domestic wells of limited capacity (PMC 1975).

Within a 20-mile (32-km) radius of the site, 17 public water supplies and seven industrial water supplies withdraw water from wells and springs (PMC 1975). Other ground-water use in the region is primarily limited to agricultural and single-family wells. Because of the abundance of surface water and the relatively low yield of aquifers in the area, future ground-water use is not expected to differ significantly from present use (PMC 1975).

Ground-Water Quality. Extensive ground-water sampling has been conducted from over 30 monitoring wells on the Clinch River site. Analyses show that the levels mandated by the Primary Standards for Drinking Water (40 CFR 141) have not been exceeded. The range of sample values exceeded secondary standards (40 CFR 143) for pH, iron, and total dissolved solids (TDS). A summary of measured parameters and drinking water standards is given in Table 5.5.

5.1.4 Ecology

The Clinch River site is similar to its surrounding area in geology, soil composition, and overstory vegetation, mostly consisting of forested land on shallow infertile soil overlying shale and dolomitic rock formations. The ecology of the site and a detailed description of existing flora, fauna and aquatic life of the site and its surrounding area are presented in this section. Data are from Project Management Corporation (1975).

TABLE 5.5. Results of Chemical and Physical Tests of Ground-Water Quality at the Clinch River Site (PMC 1975)

Parameter	Concentration (mg/L) Maximum	Mean	Standard[a]	% of Standard
Cadmium	0.003	0.001	0.01	10
Chloride	18	8.4	250	3
Chromium	0.017	0.007	0.05	15
Fluoride	1.7	0.3	1.4 - 2.4[b]	21
Iron	1.5	1.1	0.3	360
Lead	<0.01	<0.01	0.05	20
Nitrate	9	2.1	10	21
Sulfate	9	7.1	250	3
Total dissolved solids (TDS)	560	445	500	89
pH (pH units)	8.7	7.7	6 - 9	--
Total hardness as $CaCO_3$	314	150	--[c]	--

(a) Tennessee Water Quality Criteria for Domestic Water Supplies except where noted. Tennessee values generally adopted from 40 CFR 141 and 40 CFR 143.

(b) From Martin Marietta (1984a). Temperature dependent - Below 12°C maximum, fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

(c) Does not impair usefulness.

5.1.4.1 Flora

The Clinch River site is located in the southwestern portion of the Ridge and Valley Section of the Oak-Chestnut Forest Region and is less than 10 miles (16 km) southeast of the Cumberland Mountain Section of the Mixed Mesophytic Forest Region, as defined in Deciduous Forests of Eastern North America (Braun 1950). In the area adjacent to the Cumberland Mountains, some evidence exists of segregation into communities comparable to the association-segregates of the Cumberland Mountains: beech/maple/basswood/buckeye; white oak/beech/ maple; white oak/chestnut; and higher slope chestnut. The dominant community on low shale and limestone ridges of the Valley Ridge physiographic province is white oak/black oak/hickory. The low-ridge forest may contain scarlet oak, chestnut oak, tulip poplar, and a number of other species suggestive of the mixed-oak forest of the mountain slopes. Southern pines are common in young secondary stands.

An inventory for the five-county area (Anderson, Knox, Roane, Morgan, and Loudon counties) shows the occurrence of 1,370 species of vascular plants. Nearly 600 species have been observed on the site, including 93 new records for Roane County and 55 for the five-county area.

The Clinch River site consists mostly of moderate to heavily wooded areas. Estimated vegetation cover of the site is presented in Table 5.6. As shown previously in Figure 5.3, some of the site has since been cleared for the now-canceled CRBR.

Between 1948 and 1954, 411 acres (166 ha) of the site were planted with various pine species. This land has been maintained as a plantation, with little or no hardwood growing there. Elsewhere on the site, where the forest land has remained undisturbed, succession has occurred from a Virginia pine (Pinus virginiana) and eastern red cedar (Juniperus virginiana) covering to hardwood/pine/cedar forests. Even when hardwood becomes predominant, some pine remains.

TABLE 5.6. Estimated Vegetation Cover for the Clinch River Site[a]

Community Type	Number of Acres	% of Site
Hardwood	498	37
Pine Plantation	436	32
Successional Pine	95	7
Cedar/Pine	107	8
Hardwood/Cedar	75	5
Hardwood/Pine	52	4
Hardwood/Cedar/Pine	26	2
Non-forest	75	5
TOTAL	1,364	100

(a) Prior to CRBR construction activities.

Three rare species have been observed and/or collected in the vicinity of the site. The rare species include: black snakeroot (Cimicifuga rubifolia Kearney), ginseng (Panax quinquifolius Linnaeus), and Carey's saxifrage (Saxifraga careyana Gray). These three species were preliminarily listed as rare or threatened. A complete list of the plants considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.1.4.2 Fauna

A variety of vegetative communities on the Clinch River site (primarily woodland) provide varied habitat for many wildlife species. Many communities found on the site are typical of eastern Tennessee, an area rich in flora and fauna.

White-tailed deer (Odocoileus virginianus) are the only big game animals commonly occurring on the site (Project Management Corporation 1975a). Ten to 12 white-tailed deer are estimated to be at the site (Project Management Corporation 1975a). Two of the most important small game species occurring on the site are the eastern cottontail rabbit (Sylvilagus floridanus) and the eastern gray squirrel (Sciurus carolinensis). Of the two species, the squirrel is more abundant. Cottontails occur throughout the site, but primarily near old fields, open areas (transmission lines), and edge areas. Foods of the cottontail include green vegetation in summer and bark and twigs in the winter. Gray squirrels are found in more mature deciduous woodland areas where they feed on nuts, acorns, and seeds.

The red and the gray fox (Vulpes fulva and Urocyon cinereoargenteus, respectively) are the most common predators on the site. Based on data from nearby areas, it is expected that the red fox population density is larger than that of the gray fox. Both species occur throughout the site. Bobcats (Lynx rufus) occur on the nearby Oak Ridge Reservation.

Opossum (Didelphis marsupialis), raccoon (Procyon lotor), and striped skunk (Mephitis mephitis) are omnivores common to the site. They are often found near water but may also roam throughout the wooded areas. Spotted skunks (Spilogale putorius) may also occur in habitats similar to those on the site. They prefer brush habitat and edge areas along stream banks and rivers. Aquatic species such as muskrat (Ondatra zibethica) and mink (Mustela vison) occur along the Clinch River.

The white-tailed deer, cottontail rabbit, gray squirrel, oppossum, raccoon, striped skunk, and mink are important fur-bearing animals at the site.

The short-tailed shrew (Blarina brevicauda) is the most common insectivorous mammal occurring throughout the major habitat types. The smoky shrew (Sorex funeus), southeastern shrew (Sorex longirostris), and eastern mole (Scalopus aquaticus) are other insectivores that may occur on the site.

Mist netting was carried out at several locations on the site near the Clinch River and its associated lagoons. The only species captured were the red bat (Lasiurus borealis) and the big brown bat (Eptesicus fuscus). Red bats are relatively common and occur as year-round residents. These bats most often roost in trees. The big brown bat is much less common. These bats form maternity colonies in buildings, but move to caves for winter hibernation.

Four species of upland game birds have been found on the Clinch River site. The habitat most heavily utilized by these birds appears to be mixed oak woods and borders of old fields and woodlots. Bobwhite quail (Colinus virginianus), a popular game bird in the southeast, is the most abundant upland game species throughout the site. Bobwhite prefer brushy fields, abandoned farms, and open pine woods. Ruffed grouse (Bonasa umbellus), a woodland gamebird, has been found throughout the site. Grouse prefer hardwood and brushy cover, using conifers in winter and abandoned fields and orchards through the remainder of the year. Mourning doves (Zenaida macroura) have also been observed on the site. This migratory bird is especially important as a game bird in the southern United States. The American woodcock (Philohela minor) is a common upland game bird in the eastern United States. It prefers wooded swamps, alder thickets, and moist bottomlands.

Few waterfowl species have been found on the Clinch River site. All species encountered were observed along the Clinch River. Black duck (Anas rubripes), mallard (Anas platyrhychos), and blue-winged teal (Anas discors) are known to occur in the area. The Wood duck (Aix sponsa), a common resident of the eastern United States, is the most abundant waterfowl species on the site. It nests in tree cavities near wooded river bottoms or forested stream banks. The Canada goose (Branta candensis), the most widely distributed of North American waterfowl, is a winter visitor throughout much of the United States. Migrating birds rest and feed on marsh vegetation, or graze on young plants and waste grain in nearby fields.

Among the raptorial birds, two commonly observed species are the black and the turkey vulture (Coragyps atratus and Cathartes aura, respectively). Both species are proficient in catching thermal updrafts and soaring for miles in search of carrion, their primary food source. Although common on the Clinch River site, the black vulture is generally restricted to more southern areas of the United States. Other raptors occurring on the site include: the red-shouldered hawk (Buteo lineatus), the red-tailed hawk (Buteo jamaicensis), the broad-winged hawk (Buteo platypterus), the American osprey (Pandion haliaetus), the marsh hawk (Circus cyaneus), Cooper's hawk (Accipiter cooperii), sharp-shinned hawk (Accipiter striatus), bald eagle (Haliaetus leucocephalus) the great horned owl (Buba virgianus), the barred owl (Strix varia), and the screech owl (Otus asio).

The Clinch River site provides a rich and varied habitat for many reptiles and amphibians occurring throughout the Oak Ridge area. Rocky ledges, honeysuckle thickets, small ponds, and intermittent streams on the site are preferred habitats for such animals. A majority of reptile species show a home range preference of mixed oak forest associations. Here, stratification of vegetation and diversity of plant species provide a variety of habitats. Ponds, streams, and creek banks contain the greatest variety and density of frogs (Rana spp. and Hyla crucifer), while moist ravines are preferred by salamanders (Plethodon glutinosus).

Other habitats for reptiles and amphibians are roadsides and old fields. The most abundant species in these habitats is the eastern fence lizard (Sceloporus undulatus). Predominantly pine or pine/cedar habitats contain the fewest reptiles and amphibians. The only reptile collected or observed here was the black racer (Coluber constrictor).

No rare or endangered animal species are indigenous, although three endangered mammals are known to occur in the general site area. They are the gray bat (Myotis grisencens), the Indiana bat (Myotis sodalis), and the eastern cougar (Felis concolor cougar). Five species of threatened or endangered birds have also been observed at the Clinch River site but do not have resident populations. These are the bald eagle, sharp-shinned hawk, Cooper's hawk, marsh hawk, and American osprey. A complete list of the animals considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.1.4.3 Aquatic Life

Eighty-one zooplankton species have been identified at the Clinch River site. Twenty-four of these and other organisms present could not be identified to the species level. Rotifera, as is the case in most flowing systems, was the most abundant and diverse group. Members of the orders Cladocera and Copepoda compose nearly the entire arthropod population.

Of the 425 species of phytoplankton and protozoa identified during a 1956 study, 279 were phytoplankton and 146 were protozoa (PMC 1975). Chlorophyta (green algae) were the dominant group based on number of genera and species, followed by Chrysophyta (yellow-green algae, golden algae, and diatoms). Blue-green algae, dinoflagellates, and euglenoids were also found, but to a lesser extent.

Diatoms were the most abundant species present in May 1974, but by mid-summer, blue-green algae had replaced them in dominance. In November 1974, and in January and April 1975, diatoms were again the dominant species. Differences in dominant species were not observed between sampling transects during a particular sampling time.

Fifty-eight genera and 153 species (149 species plus four varieties of periphyton) were collected during the period March 26, 1974, through May 14, 1975. Five phyla are represented in the 153 species and varieties collected. The greatest number of these (85 species and four varieties) belonged to the phylum Chrysophyta and were mainly diatoms. Other phyla were represented by 28 species of Chlorophyta (green algae), 31 species of Cyanophyta (blue-green algae), one species of Euglenophyta (euglenoids), and four species of Pyrrophyta (dinoflagellates).

Macroinvertebrates at the Clinch River site include mollusks, annelids, flatworms, and insects. Arthropoda, including many abundant species of chironomids in each sampling period, are the most diverse group. Seasonal variation in populations is demonstrated by the low count in the March 1974 samples and in the high count in the summer and fall 1974 samples. Diptera, Annelida, and Mollusca were present as dominants in all the samples.

Several studies have been conducted of fish populations in the Clinch River near the site. Forage fish, mostly gizzard shad (Dorosoma cepidianum) and threadfin shad (Dorosoma petenense), accounted for 74% of the samples while rough and game fish accounted for 18.7% and 6.9%, respectively. Skipjack herring (Alosa chrysochloris), spotted bass (Micropterus punctulatus), large-mouth bass (M. salmoides), sauger (Stizostedion canadense), and white bass (Morone chrysops) are important species of piscivores, which feed primarily on fish but also consume insects, crustaceans, and other invertebrates.

One specimen of the endangered pink mucket pearly mussel (Lampsilis orbiculata) was found in the Clinch River near the proposed site in 1982, but no other record of its occurrence in this area has been found. No other federal or state threatened or endangered species have been collected recently in this area. A complete list of the aquatic species considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.1.5 Land Use

Both the Clinch River and the Oak Ridge sites are located in east central Tennessee, in the eastern part of Roane County. The Clinch River site is on a peninsula, bounded on the east, south, and west by the Clinch River and on the north by DOE's Oak Ridge Reservation (ORR) (see Figure 5.4). The Oak Ridge site is located 3.5 miles (5.6 km) northeast of the Clinch River site in Bear Creek Valley, entirely within the ORR. Because of their geographic proximity, land use for these two sites is discussed together.

5.1.5.1 Commercial, Industrial, and Residential Sites

Urbanization in this section of eastern Tennessee, and specifically in Anderson and Knox counties, is increasing. This expansion is typified by the growth of Knoxville, which serves as a major center for entertainment, and commercial and industrial activity. Urban centers within 10 miles (16 km) of the sites include the cities of Oak Ridge, Lenoir City, Kingston, and Harriman.

The paramount objective in selecting a site for the Manhattan Engineering District in 1942 was that of security. The resulting 58,000-acre site chosen by the United States Army was isolated, sparsely populated, and hilly - ideal in terms of protection from threats of espionage, sabotage, or nuclear accidents, but not well suited to residential, commercial, and private-sector industrial development. The urban center of Oak Ridge is now 10 miles from the nearest interstate highway, and a minimum 45-minute drive from the closest commercial airport. Its corporate boundaries encompass sharply limited developable land by reasons of terrain and restricted ownership.

The terrain problems that have acted as a deterrent to further industrial development have also adversely affected residential construction. Site preparation costs in Oak Ridge are significantly higher than those in neighboring communities characterized by more gentle terrain. The location of the original townsite in a long, narrow valley has effectively precluded annexation, a growth technique long employed by other Tennessee municipalities. Extension of water and sewage services into adjacent valleys would be be prohibitively expensive (city of Oak Ridge 1983).

Much of the employment in the five counties surrounding the sites (Anderson, Roane, Knox, Morgan, and Loudon) is due to the presence of the DOE and DOE-related nuclear industries. The largest of DOE-sponsored activities include the Oak Ridge Gaseous Diffusion Plant (ORGDP, or K-25), which produces enriched uranium, the Oak Ridge National Laboratory (ORNL), which functions as a research and development facility, and the Y-12 Plant, which provides research and production facilities for DOE's military program (PMC 1975). The ORGDP, ORNL, and Y-12 Plant are located, respectively, 1.5 miles (2.4 km) north, 5.56 miles (8.9 km) northeast, and 4 miles (6.4 km) northeast of the Clinch River site and, respectively, 3 miles (4.8 km) northwest, 4 miles (6.4 km) east, and 2 miles (3.2 km) south of the Oak Ridge site. The city of Oak Ridge has three industrial parks. The 95-acre (38-ha) Clinch River Industrial Park is located in the western part of town, and the 210-acre (85 ha) Valley Industrial Park is located in the southern part of town. The 86-acre

(35 ha) Municipal Industrial Part is located in the central portion of town. The companies that occupy these sites are involved in metal fabrication and casting, machinery, and tool production, and various facets of the nuclear industry (Tennessee Division of Community Development 1983).

Even though urbanization is increasing in this area, its presence is still a localized phenomenon confined to the larger cities. Much of the area, especially Loudon County (which borders Roane County to the east), is still predominantly rural.

Within 5 miles (8 km) of the Clinch River site, no significant concentration of residential population exists. About one-third of the land within this 5-mile (8-km) radius is owned by the United States Government (PMC 1975).

Residential development within the immediate vicinity of the two sites is characterized primarily as rural, even though both of the sites are located within the Oak Ridge city limits. The majority of the Oak Ridge population resides outside of the 10-mile (16-km) radius that extends from the Clinch River site. Historically, the residential population close to the site has been very stable and is expected to remain relatively constant. Most future growth is projected to be confined to the urban centers (PMC 1975).

Because the Oak Ridge site is 3.5 miles (5.6 km) closer to the Oak Ridge city center than the Clinch River site, residential development around it is slightly more dense. A development of approximately 100-plus residential units is sited just north of ORR, about three-fourths mile (1.2 km) from the Oak Ridge site's northern exclusion boundary.

5.1.5.2 Agricultural Activity

Because the land that constitutes the Clinch River site was prepared to receive a breeder reactor, it does not support agricultural crops at present. Most of its soil is not well-suited for agricultural purposes. Similarly, because it is located on the federal reservation, the Oak Ridge site is not currently used for agricultural purposes (Golder 1985). A survey of ORR lands classified only 15% of the soil as belonging to Classes I, II, or III (DOE 1980). Land falling under this classification is considered productive to moderately productive. The remaining 85% is either useful only for pasture land, or completely unsuited for any agricultural endeavors (DOE 1980). Almost all of the land immediately adjacent to these two MRS sites is ORR land and is not used for agriculture. Only the area across the river from the Clinch River site is privately owned and used for agricultural purposes.

Some of the outlying area surrounding the Clinch River site, however, is productive agricultural land. Primary crops grown within a 10-mile (16-km) radius of the site include corn, hay, soybeans, tobacco, and wheat. Most of these are on scattered plots and small family farms. The primary cash crops grown within a 10-mile (16-km) radius of the Oak Ridge site are tobacco, corn, soybeans, and wheat. Most farms in the Oak Ridge site region are small, and plots are scattered.

Eastern Tennessee has a long agricultural tradition. Although farming activity has gradually declined in recent years, it still constitutes a significant portion of total land use. In Anderson County, 20.3% of the total land area is devoted to agriculture. The percentage of land used for agriculture increases to 27.8% for Roane County, 32.4% for Knox County, and 52.9% for Loudon, the mostly rural county (Department of Commerce 1983).

5.1.5.3 Grazing Areas

Pasture and grazing account for a significant portion of land use in the region. In 1980 there were 37,200 head of cattle in the five-county area surrounding the two sites. This activity is particularly important in Knox and Loudon counties. These counties account for most of the five-county region's production.

The number of beef cattle within 5 miles (8 km) of the Clinch River site in 1974 numbered 475 (PMC 1975). These consisted of scattered herds ranging in size from 20 to 30 head. The herds were located primarily in the southeast, southwest, and northwest quadrants.

The number of beef cattle within 10 miles (16 km) of the Oak Ridge site is about 240. The herds tend to be relatively small (less than 30 head), yet beef production has been gradually increasing over the years.

Dairy farms are also prevalent in the region. However, the presence of these farms is not strongly felt in the immediate vicinity of the sites. No commercial dairy farms are located within a 10-mile (16-km) radius of the Clinch River site in either Morgan, Anderson, or Knox counties. However, four commercial dairy farms are located within 10 miles (16 km) of the Clinch River site in Roane County, and one in Loudon County (PMC 1975).

Five commercial dairy farms are located within a 10-mile (16-km) radius of the Oak Ridge site, with a total of 175 cattle (ORNL 1982). Four of these farms are in Roane County, and one is in Loudon County. No commercial dairy farms exist in the other three adjacent counties.

5.1.5.4 Mineral, Forests, and Natural Resources

No mineral extraction occurs within a 10-mile (16-km) radius of the Clinch River site (PMC 1975). In the surrounding area, however, various natural resources are extracted. Coal mining, in particular, is very important to the region, especially in Morgan County. Other minerals and resources mined from the area include limestone, crushed stone, marble, granite, zinc, and manganese (Tennessee Division of Community Development 1983).

No mining occurs within 5 miles (8 km) of the Oak Ridge site. The closest ongoing mining is strip mining for coal in Morgan County. There are two natural gas wells about 20 miles (32 km) northeast of Norris Dam in Hancock County. No natural gas is known to exist closer to the site.

Timber resources are very extensive. In many of the counties in eastern Tennessee, commercial forests account for more than one-half of all land. Both sites are in heavily forested areas. Forest suitability at the Clinch River site is characterized as excellent. Some sections of the site's forest have a net present value of $2,000 per acre. There have also been investments in forest plantations at Clinch River (TVA 1985). Forest suitability at the Oak Ridge site is similar to the Clinch River site. More than one-half of the land in surrounding counties is commercial forest land (much of it oak and hickory). As the hardwood forest is harvested, the area is replanted with fast-growing pines. Timber on the federally-owned Oak Ridge Reservation is under the forest management plan administered by the Environmental Science Division at ORNL (ORNL 1982).

5.1.5.5 Utilities

Existing utilities at the Clinch River site include a 161 kV electric power transmission line (Fort Loudon to K-31) that runs north/south through the Clinch River site, and a 500 kV line (Bull Run/Watts Bar Nuclear) that runs east-west through the north end of the site. A 161 kV line also runs through the Oak Ridge site. These transmission lines and others in the vicinity of the Clinch River and Oak Ridge sites are shown in Figure 5.8.

Natural gas is supplied to the Oak Ridge Reservation (ORR) by the East Tennessee Natural Gas Company. Natural gas pipelines are located near the east boundary of the Clinch River site and to the south and west of the Oak Ridge site (ORNL 1984) (see Figure 5.9).

Existing water supply systems for the Clinch River and Oak Ridge DOE facilities are also shown in Figure 5.9. Approximately 4,000 feet (1,200 m) from the boundary of the Oak Ridge site is a 24-inch (61-cm) sanitary water line that serves the facilities at ORNL. This line is about 2 miles (3.2 km) from the proposed location of the facility's buildings. Water treatment for ORGDP is located at Clinch River RM 14.5, near the northwest boundary the Clinch River site. Existing facilities include a pumping station, a treatment facility, storage tanks, and distribution lines.

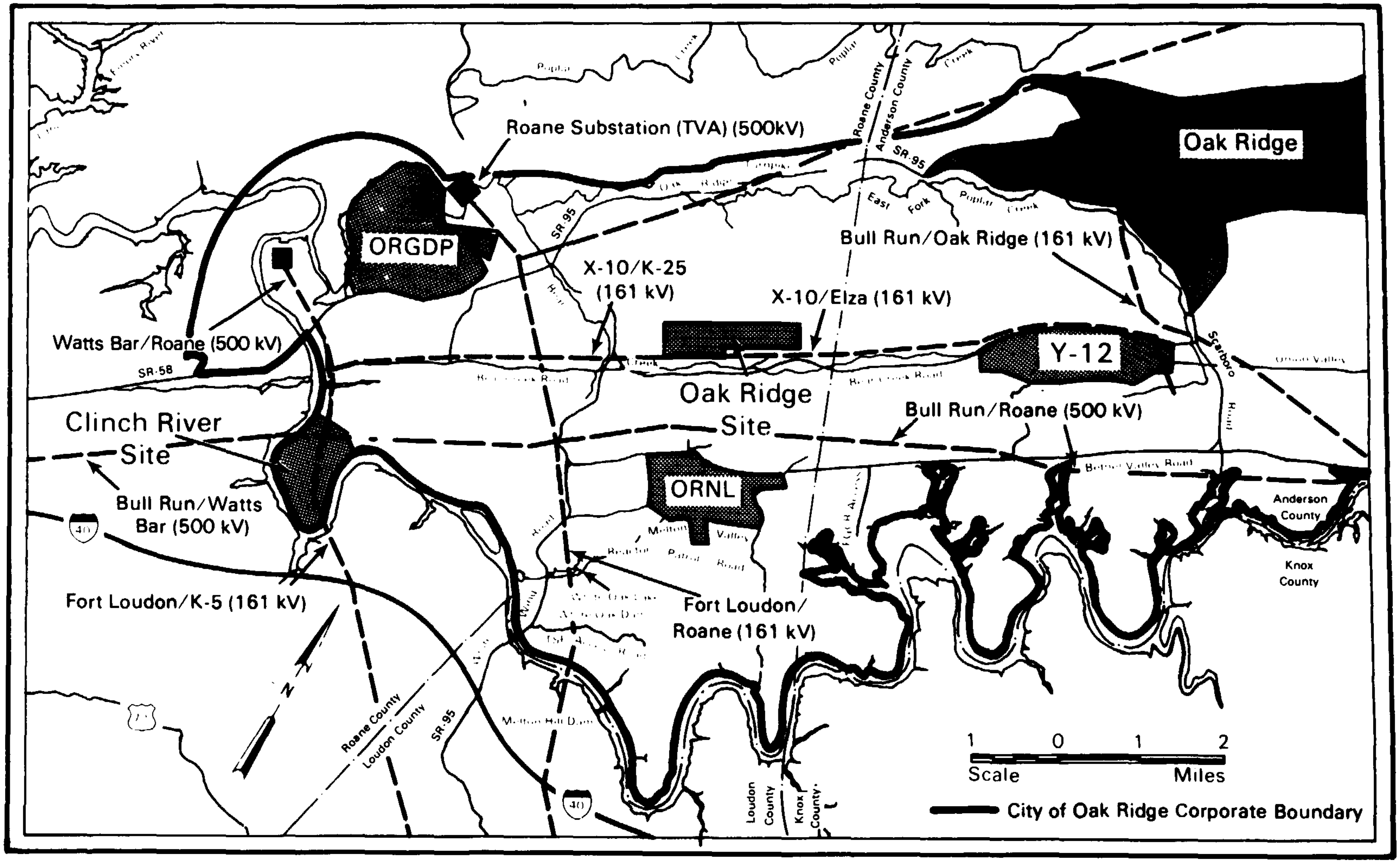

FIGURE 5.8. Transmission Lines at the Clinch River and Oak Ridge Sites

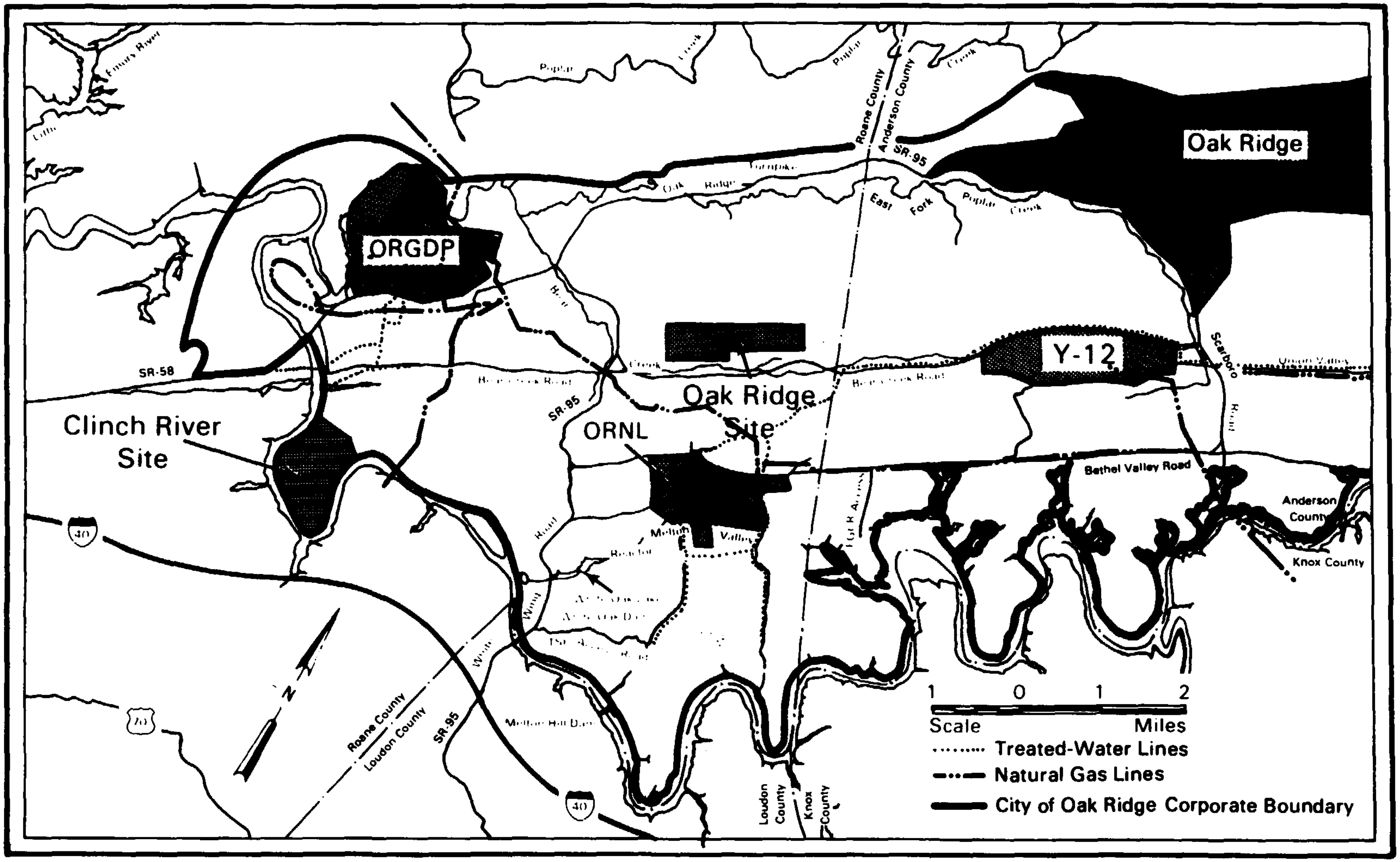

FIGURE 5.9. Water Supply and Natural Gas Lines for the Clinch River and Oak Ridge Sites

5.1.5.6 Outdoor Recreation

The Clinch River and associated waterways forming the Tennessee Valley Lakes have become an increasingly desirable recreational resource and attract many visitors. The area affords the opportunity to engage in numerous outdoor activities such as fishing, swimming, and boating. Commercial camping units and state parks with camping facilities are located throughout the eastern Tennessee region.

In 1984, a portion of the Oak Ridge site was designated as a wildlife management area.[a] Within 10 miles (16 km) of the Clinch River site, three additional wildlife preserves, sanctuaries, or hunting areas exist. These include parts of the Long Island Wildlife Management area, the Paint Rock Management area, and a third wildlife management area located at Kingston. The major such area within 10 miles (16 km) of the Oak Ridge site is the wildlife management area at Kingston.

Numerous parks and recreational facilities exist within 5 miles (8 km) of the two sites. These include both public and commercial camp grounds, day-use parks, boat launches, lake access areas, and a stock-car race track (PMC 1975). These facilities could substantially increase the transient population in the immediate vicinity of the sites.

5.1.6 Socioeconomics

Constructing, operating, and decommissioning an MRS facility requires labor, materials, and services that must be either supplied by the existing resource base of the impact area or imported into the area. The effects of these actions on the impact area are partly determined by the existing resources of the area and changes in the availability of these resources. The baseline forecast described in this section will provide a benchmark from which to assess economic impacts associated with an MRS facility throughout its planned life. The Clinch River and Oak Ridge sites are treated synonymously in this discussion because of their geographic proximity and similar socioeconomic characteristics.

Most socioeconomic effects of the MRS facility can be expected within 50 miles (80 km) of the MRS site. In most cases, workers who expect to be at a given worksite for only a short period of time may be willing to live 50 to 75 miles (80 to 120 km) away, especially where commuting distances may be greater for a given commuting time (Leholm et al. 1976; Gilmore

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(a) Cooperative Agreement Between the Department of Energy and the Tennessee Wildlife Resources Agency for the Establishment of a Wildlife Management Area, November 1984.

et al. 1982); however, empirical analyses have shown that most workers (and hence, most secondary economic and population effects) will be within 30 miles (48 km) of the site in places of at least 1,000 people. (Murdock and Hamm 1983; Gilmore et al. 1982). Fifty miles is thus a reasonable estimate.[a] Because one Kentucky county (Bell) and one Tennessee county (Hamblen) just outside the 50-mile (80-km) radius appear to be economically linked through transportation and communications as well as trade to counties within 50 miles (80 km), these two counties were also included. Figure 5.10 shows the socioeconomic impact area for the Clinch River and Oak Ridge sites, while Figure 5.11 shows the principal cities of interest in the primary impact area. For the Clinch River and Oak Ridge sites, the 50-mile impact area includes 28 counties in Tennessee, Kentucky, and North Carolina (see Figure 5.10). Due to historical commuting patterns dictated by transportation access, housing, and job location, five of these counties have a relatively high potential for conventional socioeconomic effects. The five counties are: Anderson, Roane, Morgan, Loudon, and Knox. Due to a relatively large population, socioeconomic impacts may not be noticeable in Knox County (which contains Knoxville); therefore Knox County will be treated separately. Because the Clinch River flows into the reservoir system of the Tennessee River, there is a potential for perceived environmental problems at the MRS site to result in recreational avoidance of some downstream reservoirs and, thus, loss of recreation-related income. Rhea and Meigs Counties may also be affected because they are the next closest downstream counties. The primary impact area for the Clinch River and Oak Ridge sites, then, is designated as the four counties of Anderson, Roane, Morgan, Loudon, plus Knox, Rhea, and Meigs Counties for some assessments.

Since social and economic variables are dependent on time and stage of MRS activity, this section requires a different treatment of the subject matter than other sections of this report. Accordingly, forecasts and impacts will be presented by year and stage of construction and operation.

5.1.6.1 Historical and Sociocultural Background

The Clinch River/Oak Ridge area is located in the Appalachian region of eastern Tennessee. The first Europeans (English) settled in the region in the late 1700s, displacing Cherokee Indian inhabitants. The Cherokee were the last

(a) Fifty miles was selected as a maximum distance. The western U.S. actually sees commuting distances as great as 100 miles. During Hartsville Nuclear Plant construction, construction employees at the plant regularly commuted distances over 50 miles one way. Nashville, the center of which is about 39 miles from the Hartsville site, supplied over 12 percent of the plant's workforce when the employment level was similar to that at peak construction for MRS. When the effects of indirect employment are added, 50 miles appears reasonable. The logic is cited in Appendix H.

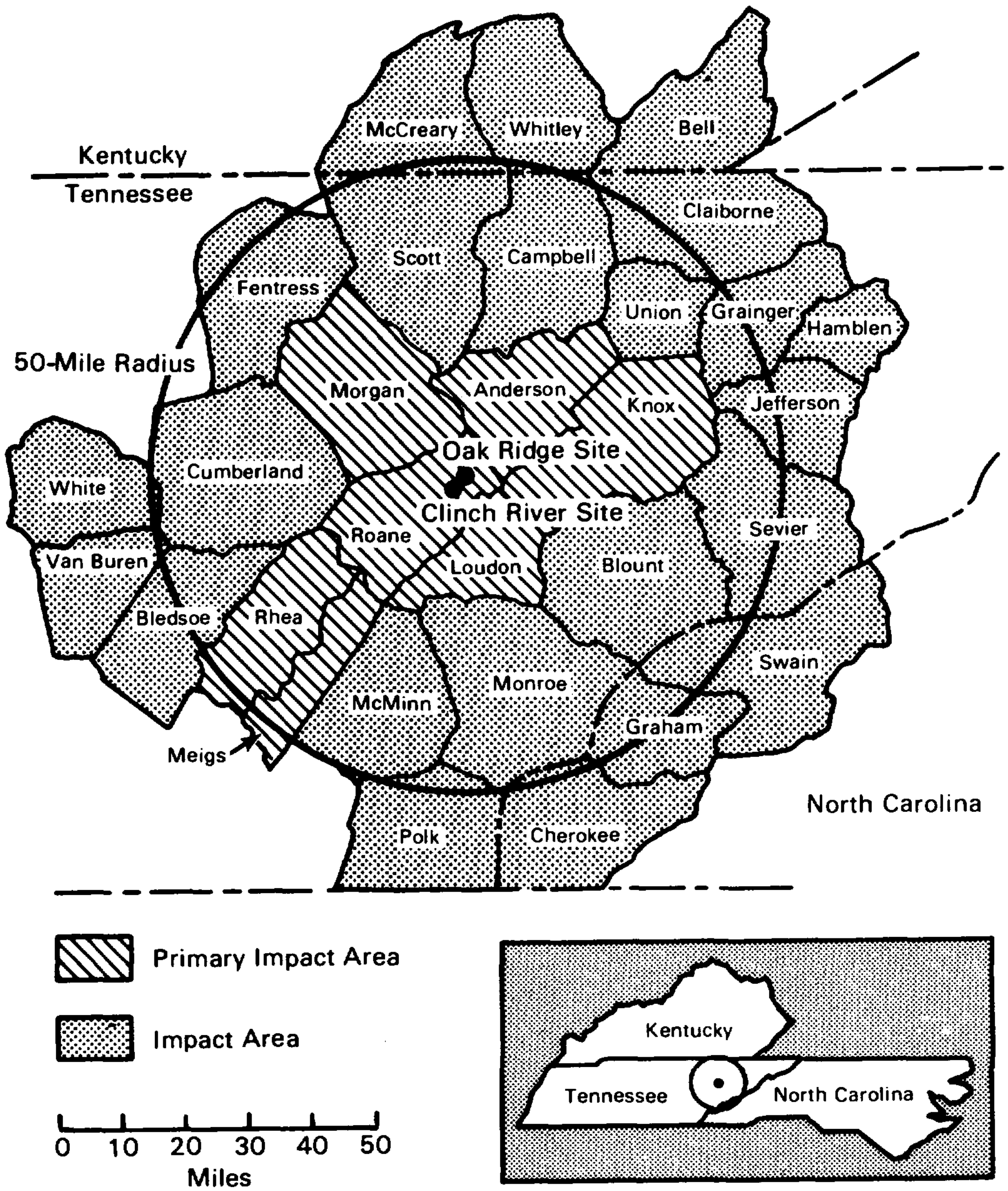

FIGURE 5.10. Socioeconomic Impact Area for the Clinch River and Oak Ridge Sites

in a series of aboriginal inhabitants who had occupied the area for at least 10,000 years (Fielder 1974). During the 1800s, Germans interested in mining and industry in nearby communities also moved into the area.

Major construction projects were undertaken in east Tennessee during the 1930s by the Tennessee Valley Authority, inducing a major influx of people from

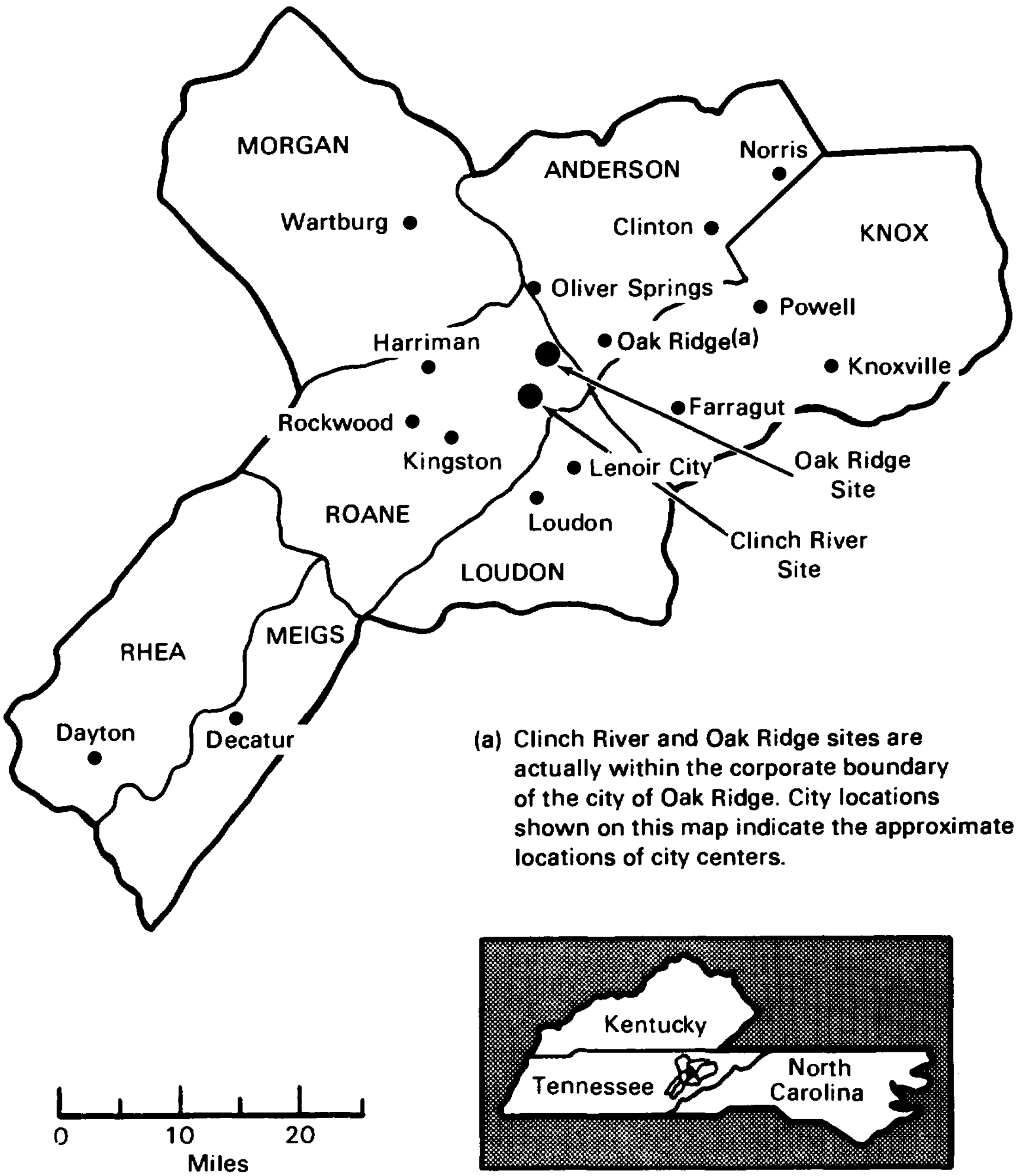

FIGURE 5.11. Principal Cities Within the Primary Impact Area for the Clinch River/Oak Ridge Sites

all over the United States. The area that was to later become Oak Ridge was a relatively slow-growing agricultural area prior to 1942 when the United States Army established the Manhattan Engineering District there. This brought on a second wave of migration into the region, increasing the population in the immediate area and surrounding communities. The Oak Ridge townsite, established as part of the Manhattan District reservation, grew to house 75,000 during the peak of war-related activities. Following the war, the resident population quickly dropped to approximately 28,000. It has remained at that level until today.[a]

During the 1940s and 1950s, the United States Army and the Atomic Energy Commission (AEC) maintained full ownership and control of what was then the Oak Ridge townsite. Little was done to encourage the development of urban private sector facilities such as churches, shopping centers, private industries, and recreation establishments. All commercial activity was strictly regulated, as were most other aspects of life in preincorporated Oak Ridge. Although the community has been diligent in its pursuit of an expanded commercial and industrial base since the City's incorporation, the early planners of Oak Ridge did not envision much more than a bedroom community to house project related personnel. According to the 1948 Master Plan prepared for the AEC by Skidmore, Owings, and Merrill, private sector heavy industry was not to be part of an incorporated Oak Ridge. Consequently, at the time of Oak Ridge's incorporation, the city's industrial base lacked any semblance of an industrial service industry necessary to support further growth and development.

Until implementation of the Atomic Energy Communities Act of 1955, the AEC ran the plants in Oak Ridge, managed the land, provided housing, and assumed total responsibility for providing services to the population. Unrestricted access to the area outside the plants came in 1949. Four years later, land owned by the federal government was made available on a lease basis for residential construction. By 1955 there was a town in place, still operated by the AEC. From that point, sales to private interests of property outside of the 35,000 acre (14,200 ha) reservation began. Benefiting from the transfer of federally owned utilities and public facilities, the City of Oak Ridge was incorporated in 1959.

Twenty-five years later, despite significant strides, the DOE and its contractors remain the dominant force in the local economy. The DOE accounts for 77% of total employment in Oak Ridge and owns 63% of total land area within the city limits, including most of the relatively easily developed land. Only a small portion of the remaining land can be developed for industrial uses because of the topography of the area (Freeman et al. 1984, pp. 11-12, 20, 30).

Today the social and economic interactions of Anderson, Roane, Morgan, and Loudon Counties are closely tied to the DOE-related activities in the area. Cities outside the immediate surrounding area are more diversified, including

(a) City of Oak Ridge Comprehensive Plan (Draft), April 8, 1985, p. 1.

non-DOE supported manufacturing, transportation, agricultural and natural resource industries. Knoxville, in Knox County, is the major population center for the area.

5.1.6.2 Demographics

Table 5.7 gives a breakdown of population and population density by county for the primary impact area and remaining counties of the 50-mile impact area.

The central counties that contain the Clinch River/Oak Ridge sites and the city of Oak Ridge (Anderson and Roane) had a combined 1980 population of 115,771, while the primary impact counties had a combined 1980 population of 192,594. The total 50-mile impact area had a population of 1,076,248 in 1980. The 1984 estimated populations were 118,400 for Anderson and Roane Counties, 198,300 for the primary impact area, and 1,123,500 for the 50-mile impact area.

The primary impact counties had a combined 1980 population of 115,826 in the 18- to 64-year-old age bracket, supplemented by 203,325 in Knox County for a total of 319,151 persons in the 18- to 64-year-old age bracket. This figure is important because it represents the potential labor force of the area. The larger the area's potential labor force, the fewer migrants will be needed to fill new job openings.[a]

The next largest population group is the 5- to 17-year-old age bracket, which had 42,007 persons in the primary impact area counties. The 5- to 17-year-old age bracket in the primary impact area represents the potential demand for primary and secondary education services.

The primary impact counties had 21,645 persons in the over-65 age group. This group represents the principal source of potential demand for medical and nursing home care.

The populations of these age groups are in the same approximate proportions as the United States as a whole, so the region is not unique in this regard.

Baseline Forecasts. A baseline forecast of area population, etc., assumes that the MRS facility has not been constructed. This forecast has been developed for comparing population growth with the facility during construction, operation, and decommissioning. Table 5.8 presents the baseline forecasts for the years 1991, 2010, and 2030 for the age groups described for the total area.

(a) Labor force participation rates and the mix of skills among workers also influence the size of the available labor force.

TABLE 5.7. 1980 Population and 1984 Estimated Population for the Clinch River/Oak Ridge Impact Area (University of Tennessee 1985; U.S. Department of Commerce 1985b; U.S. Department of Commerce 1983)

Counties	Population		Land Area	1980 Average Population	1980 Population by Age Group			
	1980	1984	(mi^2)	Density	<5	5-17	18-64	>65
Primary Impact Area								
Anderson County	67,346	69,200	339	199	4,377	14,210	41,351	7,408
Loudon County	28,553	30,300	235	122	1,827	5,849	17,111	3,766
Meigs County	7,431	7,700	189	39	572	1,761	4,414	684
Morgan County	16,604	17,200	523	32	1,229	3,935	9,597	1,843
Rhea County	24,235	24,700	309	78	1,818	5,550	14,153	2,714
Roane County	48,425	49,200	357	136	3,293	10,702	29,200	5,230
Subtotal	192,594	198,300	1,952	99	13,116	42,007	115,826	21,645
Knox County (Knoxville)	319,694	329,400	506	632	19,501	61,062	203,325	35,806
Other Tennessee Counties[(a)]	444,167	472,400	6,601	67	31,042	98,798	263,801	50,525
Kentucky and North Carolina Counties[(b)]	119,793	123,400	2,498	48	9,623	28,402	66,786	14,983
Total Impact Area	1,076,248	1,123,500	11,557	93	73,282	230,269	649,738	122,959

(a) Bledsoe, Blount, Campbell, Clairborne, Cumberland, Fentress, Grainger, Hamblen, Jefferson, McMinn, Monroe, Polk, Scott, Sevier, and Union Counties.
(b) Bell, McCreary, and Whitley Counties in Kentucky; Cherokee, Graham, and Swain Counties in North Carolina.

TABLE 5.8. Baseline Population Forecasts by Age Group for the 50-Mile Clinch River/Oak Ridge Impact Area[a]

Age Group	Year 1980	1991	2010	2030
Combined age groups (total population)	1,076,000	1,295,000 (1.7)	1,545,000 (0.9)	1,605,000 (0.2) (0.8)
<5	73,000	85,000 (1.4)	85,000 (0.0)	80,000 (-0.3) (0.2)
5-17	230,000	220,000 (-0.4)	235,000 (0.6)	225,000 (-0.2) (0.0)
18-64	650,000	835,000 (2.3)	1,035,000 (1.1)	995,000 (-0.2) (0.9)
>65	123,000	155,000 (2.1)	190,000 (1.1)	305,000 (2.4) (1.8)

(a) From MASTER model. Number in parentheses is annual average percent growth over previous period. Second number in parentheses in the last column is annual average percent growth over the entire period.

The year 1991 is selected because it would be the first year of construction if the MRS proposal is approved in 1986. The year 2010 is selected because it would be a typical impact year for the facility operation. The year 2030 is included because it would occur after MRS decommissioning and is the most distant year available in the forecast. For all age groups taken together, the population for the Clinch River/Oak Ridge area is forecast by PNL's MASTER model (Adams et al. 1983; see Appendix H) to grow at an annual rate of 1.7% between 1980 and 1991. Between 1991 and 2010, population grows at 0.9% per year; after 2010, the growth rate decreases further. When the population forecast is broken down into age category, more revealing results are found. For example, the rate of growth of the 5- to 17-age group, the relevant group to examine for forecasting primary and secondary education demand, is -0.4% annually before 1991, reflecting the low birth rate of the baby boom generation. Due to migration, the potential labor force population (18 to 64) grows at a slightly faster rate than total population before 1991. A major increase in this segment could be significant when compared with baseline employment increases because it may indicate whether or not additional workers would need to migrate into the Clinch River/Oak Ridge area to take jobs at the MRS site. The 65 and older age group increases in the near term and after the year 2010. After 2010, the demand for health care would increase due to growth in this group.

Using PNL's MASTER Model to compare the Clinch River/Oak Ridge population forecasts to population forecasts from Data Resources, Inc. for the entire United States (Data Resources 1985), it is apparent that the general Oak Ridge/Clinch River area will grow at a rate (0.8% per year) similar to the nation as a whole (0.9% per year).

Geographic Distribution. The major population center of the Clinch River/Oak Ridge area is Knoxville, 22 miles (35 km) due east of the MRS site. Knoxville had a 1980 population of 179,030. The total population of Knox County numbered 319,694. The largest county in the primary impact area (excluding Knox County) is Anderson (containing the city of Oak Ridge) with 67,346 people. The rest of the population is scattered fairly evenly around the primary impact counties in small towns and communities.

5.1.6.3 Employment

Creating an accurate portrait of an area's baseline employment characteristics is vital to any analysis of socioeconomic change. The extent of any stresses upon a community will depend partly on the community's original employment base and growth rate. Socioeconomic stresses may occur if the quantity and mix of the local labor force were not sufficient to satisfy the increased demand for labor brought about by an MRS site. This section presents the Clinch River/Oak Ridge area's 1984 civilian labor force and total employment. Baseline forecasts for future relevant years are also provided.

Information on the 1984 total civilian labor force, total employment, total unemployment, and the unemployment rate by county for the impact area is presented in Table 5.9. The total civilian labor force in 1984 for the primary impact counties, based on Bureau of Labor Statistics (BLS) data, was 87,480 workers. This can be broken down into 30,630 workers in Anderson County and 56,850 workers in the remainder of the primary impact area. The total civilian labor force for the 50-mile (80-km) impact area was 473,112 people. Knox County, which includes the city of Knoxville, has a total civilian labor force of 146,690 workers. This is particularly relevant because the western part of Knoxville is within easy commuting distance of the site--about 20 miles (32 km) to the east.

TABLE 5.9. Employment and Labor Force Data by County for the Clinch River/Oak Ridge Impact Area, Compared with Tennessee and the United States in 1984 (University of Tennessee 1985; U.S. Department of Labor 1985)

Counties	Total Labor Force	Total Employment	Total Unemployment	Unemployment Rate
Primary Impact Areas				
Anderson County	30,630	28,200	2,430	7.9
Loudon County	13,120	11,710	1,410	10.7
Meigs County	3,310	2,790	520	15.7
Morgan County	5,590	4,720	870	15.6
Rhea County	12,270	11,010	1,260	10.3
Roane County	22,560	20,440	2,120	9.4
Subtotal	87,480	78,870	8,610	9.8
Knox County	146,690	135,410	11,280	7.7
Other Tennessee Counties	194,660	169,980	24,680	12.7
Kentucky and North Carolina Counties	44,282	38,866	7,416	16.7
Total Impact Area	473,112	421,126	51,986	11.0
Tennessee	2,223,000	2,033,000	190,000	8.5
United States	113,544,000	106,702,000	8,539,000	7.5

The unemployment rate varies widely throughout the Clinch River/Oak Ridge primary impact area. Based on 1984 BLS figures, it ranged from a high of 15.7% in Meigs County to a low of 7.7% in Knox County. The unemployment rate in Anderson County was 7.9% but it was substantially higher in the neighboring central county of Roane, where it reached 9.4%. Because of the large population in Anderson County, the unemployment rate for the primary impact area (excluding Knox County) was 9.8%. This was below the average for the 50-mile impact area but above that in either Tennessee as a whole or the nation.

The large difference in the unemployment rates of the two central counties illustrates that while they are geographically close, there are substantial economic differences between the two counties. Anderson has had a stronger economic and industrial base. Anderson County is included in the Knoxville metropolitan statistical area (MSA) while Roane County is not. However, most of the growth in the area during the last 10 years has been in Knox County. (DOE 1985b).

These unemployment figures are important because they identify the size of the current idle work force and provide an idea of how much additional economic activity the region can currently absorb. In some regards, however, these figures can be misleading. The unemployment rate only identifies the total quantity of workers without jobs. It reveals nothing about their skills and abilities.[a]

Examining the various sectors that constitute the region's total employment provides a better understanding of these statistics. Data on employment by sector and county for the year 1983 is presented in Table 5.10. According to the Tennessee Department of Employment Security, in 1983 18% of the total Roane County labor force worked in manufacturing, 8% in wholesale and retail trade, 8% in service jobs, and 19% in government. In Anderson County, 22% of the labor force worked in manufacturing, 16% worked in wholesale and retail trade, 33% in professional or service jobs, and 25% worked in government.

For the counties outside the primary impact area, 25.8% of all workers are in manufacturing, 19.4% are in wholesale and retail trade, 18.7% have professional or service jobs, and 19.6% are in government.

The presence of the DOE Uranium Enrichment Facilities (K-25), the production plant (Y-12) and ORNL in Anderson and Roane counties helps explain the relatively high percentage of workers in manufacturing and direct government jobs in 1983. K-25 uranium enrichment activities have since been suspended.

Much of the manufacturing activity in the area outside the primary impact area counties centers around the textile industry. Both the production of apparel and finished products and the production of mill products are important. Another large portion of manufacturing produces furniture, fixtures, and other wood products. This utilizes the extensive local timber resources. The manufacturing of metals and machinery is also significant, especially in the Knoxville MSA, Hamblen County, and McMinn County.

Table 5.11 summarizes the occupational mix of the employed labor force in the primary impact area and Knox County (Knoxville) at the time of the 1980

(a) In addition, the unemployment rate counts only those individuals in the labor force actively seeking work. It does not count persons not currently in the labor force who would be if they believed jobs were available.

TABLE 5.10. Labor Force and Distribution in Major Economic Sectors for the Clinch River/Oak Ridge Primary Impact Area, 1983 (Tennessee Department of Employment Security 1984)

County	Civilian Labor Force	Labor Force Employment Distribution (%)			
		Manufacturing	Wholesale and Retail Trade	Services	Government
Anderson[a]	33,276	22	16	33	25
Loudon	13,370	27	7	6	12
Meigs	2,970	10	4	1	22
Morgan	5,840	15	3	3	15
Rhea	11,750	35	6	6	23
Roane	16,780	18	8	8	19
Knoxville MSA[b]	231,100	21	20	16	19

(a) Separate information was not available on the 1983 labor force or its distribution for Anderson County since it is part of the Knoxville MSA. The values shown are for 1980 (U.S. Department of Commerce 1983).

(b) Metropolitan Statistical Area; includes Anderson, Blount, Knox, and Union Counties.

census. Although the skill mix is expected to change in the future, because of the closure of the Oak Ridge Gaseous Diffision Plant and related activities and efforts by the City of Oak Ridge and Roane County to diversify their economy, Table 5.11 gives some idea of the skills available in the region. As can be seen from the table, the Clinch River/Oak Ridge primary impact area has a relatively high proportion of craft workers, machine operators, and administrative and clerical workers. This would correspond to the requirements of any MRS facility. Knox County shows a heavier concentration of managerial, professional, clerical, and sales and service people. This reflects Knoxville's position as a regional trade center and Knoxville/Farragut's position as residence of many of the managerial and scientific workers at the Oak Ridge Reservation. About 9,800 construction workers were working in the Knoxville Metropolitan Statistical Area (MSA) in 1983 (including Anderson County). Roane County had 200, Rhea County had 1,140, Morgan County had 20, and Meigs County had 10.

Another factor affecting the degree of socioeconomic impact of MRS is the degree to which the overall baseline economy in the general Clinch River/Oak

TABLE 5.11. Occupations of the Employed Labor Force in the Clinch River/Oak Ridge Primary Impact Area and Knoxville, 1980 (University of Tennessee 1983)

Category	County: Anderson	Loudon	Meigs	Morgan	Rhea	Roane	Primary Impact Area	Knox (including Knoxville)
Total Employed	31,342	14,132	3,369	6,088	11,024	22,286	88,241	155,355
Executive, Administrative, Managerial:								
Number	2,330	635	173	290	611	1,221	5,260	14,890
Percent	7.4	4.5	5.1	4.8	5.5	5.5	6.0	9.6
Professional Speciality:								
Number	4,538	1,099	158	375	740	2,210	9,120	20,766
Percent	14.5	7.8	4.7	6.2	6.7	9.9	10.3	13.4
Technicians and Related Support:								
Number	2,081	347	37	88	175	836	3,564	6,227
Percent	6.6	2.5	1.1	1.4	1.6	3.8	4.0	4.0
Sales:								
Number	2,356	871	223	317	508	1,525	5,800	16,817
Percent	7.5	6.2	6.6	5.2	4.6	6.8	6.6	10.8
Administrative Support, Clerical:								
Number	4,370	1,555	289	540	973	2,708	10,435	24,485
Percent	13.9	11.0	8.6	8.9	8.8	12.2	11.8	15.8
Private Household:								
Number	227	52	40	19	36	70	444	730
Percent	0.7	0.4	1.2	0.3	0.3	0.3	0.5	0.5
Protective Services:								
Number	534	140	9	170	148	296	1,297	1,892
Percent	1.7	1.0	0.3	2.8	1.3	1.3	1.5	1.2
Services, Except Protective and Household:								
Number	2,852	1,422	222	465	992	2,162	8,115	17,719
Percent	9.1	10.1	6.6	7.6	9.0	9.7	9.2	11.4
Farming, Forestry, Fishing:								
Number	311	481	170	179	175	278	1,594	1,297
Percent	1.0	3.4	5.0	2.9	1.6	1.2	1.8	0.8
Precision Production, Craft, and Repair:								
Number	4,868	2,227	631	1,281	1,907	4,159	15,073	18,218
Percent	15.5	15.8	18.7	21.0	17.3	18.7	17.1	11.7
Machine Operators, Assemblers, Inspectors:								
Number	3,678	3,203	893	1,234	2.963	3,619	15,590	15,736
Percent	11.7	22.7	26.5	20.3	26.9	16.2	17.7	10.1
Transportation and Material Moving:								
Number	1,118	762	219	504	561	1,044	4,208	6,422
Percent	3.6	5.4	6.5	8.3	5.1	4.7	4.8	4.1
Handlers, Cleaners, Helpers, and Laborers								
Number	2,079	1,338	305	626	1,175	2,158	7,681	10,156
Percent	6.6	9.5	9.1	10.3	10.7	9.7	8.7	6.5

Ridge area will have grown between the present and the mid-1990s. Table 5.12 shows a baseline economic forecast for the 50-mile impact area surrounding the Clinch River/Oak Ridge sites. Total employment, based on a moderate growth scenario for the nation's economy, is forecasted to grow at about 2.0% per year between 1984 and 1991, the proposed first year of MRS construction. It is forecasted to grow another 1.6% per year without MRS before the year 2010, and 0.7% per year between 2010 and 2030, the most distant forecast year available. Assumptions underlying this scenario are documented in Appendix H.

TABLE 5.12. Baseline Employment Forecasts by Sector for the Oak Ridge/ Clinch River 50-Mile Impact Area[(a)]

Sector	1984	1991	2000	2030
Agriculture	4,000	4,000	4,000	3,900
Agricultural Services, Forestry, and Fisheries	1,100	1,100	1,200	1,500
Mining	7,300	7,600	7,900	7,000
Construction	15,900	18,400	26,900	35,600
Non-Durable Manufacturing	72,200	82,300	111,800	116,900
Durable Manufacturing	40,900	49,600	73,400	67,200
Public Utilities	13,600	14,600	17,500	21,200
Finance, Insurance, and Real Estate	23,100	27,900	37,500	33,500
Wholesale Trade	68,800	81,300	111,300	130,500
Retail Trade	15,000	17,500	22,500	24,700
Services	72,100	81,100	106,200	136,100
Government	87,700	97,600	129,500	174,500
TOTAL	421,700	483,000	649,700	752,600

(a) From PNL's MASTER Model (see Appendix H).

5.1.6.4 Income

Level of income is one of the key determinants of the wealth of the community, which, in turn, influences the variety and quality of products purchased, and the ability of the community to pay for community services such as parks, sewage disposal systems, and local road maintenance. Income level is also very useful in characterizing many "quality of life" aspects and patterns of spending.

This section discusses the present income levels of the counties in the Clinch River/Oak Ridge primary impact area and forecasts baseline income for the 50-mile impact area. MRS-related business and personal purchases would be made throughout the 50-mile impact area (and even in other states) and would therefore cause personal income to increase throughout the area. Although some impacts would be felt wherever payroll dollars were spent and MRS direct purchases were made, the most likely areas to receive increases in income would be the primary impact counties and Knoxville because of their proximity to the site. In Knoxville, however, the impact of MRS is likely to be small relative to activity already occurring; impact is likely to be noticed only in some of the primary impact counties.

Table 5.13 details 1983 data (U.S. Department of Commerce 1985a) for the Oak Ridge/Clinch River primary impact counties, Knoxville, and the state of Tennessee on levels of personal income and per capita income. Per capita income is the more revealing of the two, as it can be used to compare income levels across counties. Of the primary impact counties, Anderson County with a per capita income of $10,769 is wealthier than Roane County ($9,338) and the surrounding counties. It can be anticipated that, with this high income, Anderson County residents buy more consumer durables and have higher quality community services than those in lower income per capita counties, holding all other considerations constant. It can also be anticipated that Anderson County residents spend in other counties and that some of this income generates jobs and other benefits in adjacent counties, principally Knox County. Both Knoxville and the city of Oak Ridge serve as trade centers for these counties (DOE 1985b).

In 1983, personal income in 1985 dollars for the Clinch River/Oak Ridge primary impact counties totaled $2,016 million, while the Knox County figure was $3,623 million. For the 50-mile total impact area, personal income was about $10,300 million in 1985 dollars. Referring to Table 5.14, it can be seen how the Clinch River/Oak Ridge area magnitude of personal income changes over time from $14,400 million in 1991, the proposed initial year of MRS facility construction, to $27,900 million in 2030. Abstracting from the effects of inflation, these changes are a useful predictor (in part) of the demand for income-influenced goods and services over time, such as the demands for transportation and medical services.

TABLE 5.13. Personal Income for the Clinch River/Oak Ridge Primary Impact Area, Knoxville, and the State of Tennessee, 1983 (U.S. Department of Commerce 1985a)

County or Area	Total Personal Income 1983 (millions of $)	Per Capita Personal Income (1983 $)
Anderson County	$736	$10,769
Loudon County	292	9,697
Meigs County	58	7,472
Morgan County	105	6,093
Rhea County	214	8,666
Roane County	462	9,338
Total, Primary Impact Area	$1,867	$ 9,444[(a)]
Knox County (Knoxville)	$3,355	$10,368
Tennessee	$44,580	$ 9,515

(a) Based on 1983 Bureau of Census estimated population.

TABLE 5.14. Baseline Forecasts of Personal Income for the Clinch River/Oak Ridge 50-Mile Impact Area[(a)]

Year	Personal Income (million 1985 $)	Annual Average Change Over Previous Period (%)	Per Capita Income (1985 $)	Annual Average Change Over Previous Period (%)
1983	10,300	-	10,100	-
1991	14,400	4.3	11,100	1.2
2010	21,500	2.1	13,900	1.2
2030	27,900	1.3	17,400	1.1

(a) MASTER model baseline forecast.

5.1.6.5 Housing Characteristics

By examining a region's housing stock, it is possible to assess the ability of the area to absorb an influx of new inhabitants, the potential demand for goods such as yard tools and garden supplies, and the degree of transience of the local population. Housing characteristics are one indicator of the health of the local economy.

Table 5.15 describes the housing situation in 1980 in the six counties that compose the potential primary impact area of the Clinch River/Oak Ridge sites. This situation is projected to change somewhat with the ORGDP (K-25 Plant) closure in fiscal year 1985. Science Applications International Corporation projected that up to 265 units could go on the local market if the plant closed (DOE 1985b).

A current housing trend in the Clinch River/Oak Ridge area has been for new residents to live in outlying regions, primarily west Knox County (DOE 1985b). The city of Oak Ridge, in particular, has been losing potential residents to west Knox County (Folz 1984).

Table 5.15 shows higher rents and housing values in Anderson County (city of Oak Ridge) than in other parts of the primary impact area. However, Knox County values are higher still, reflecting a much newer and in some ways more attractive housing stock. (Much of the Oak Ridge housing--about 46%--is from the Manhattan Project in the 1940s, and, therefore, architectural variety is somewhat limited). Vacancy rates in Anderson County are low, reflecting a scarcity of housing in the city of Oak Ridge caused by a scarcity of land developers, unfavorable tax climate (due, in part, to the dominance of non-taxable federal facilities in the area), low turnover rate, and uncertainty in the local economy.[a]

Of the total 1980 housing stock in the primary impact area, 81% was single-family, and 8.9%, multi-family. This single-family and multi-family distinction is relevant for ascertaining, among other factors, the level of infrastructure demand for items like roads, telephone lines, and sewage lines, since individuals in single-family residence may require more of these than the same number of individuals residing in multi-family residences. Mobile homes constituted 10.1% of the year-round stock.

When characterizing Clinch River/Oak Ridge housing, it is also useful to make the distinction between residents who rent and those who own because the

(a) From City of Oak Ridge Comprehensive Plan, April 8, 1985 (Draft for City Council Review and Approval), Oak Ridge, Tennessee.

TABLE 5.15. Summary Housing Data for the Clinch River/Oak Ridge Primary Impact Area, 1980 (University of Tennessee 1983)[a]

	Anderson County	Loudon County	Meigs County	Morgan County	Rhea County	Roane County	Primary Impact Area
Total Year-Round Units							
Number	25,829	10,814	2,810	5,893	9,078	18,526	72,950
Number Vacant	1,213	525	290	504	793	1,448	4,773
% Vacant	4.7	9.2	10.3	8.5	8.7	7.8	6.5
Occupied Units							
Number	24,616	10,289	2,520	5,389	8,285	17,078	68,177
% Owner-Occupied	71.8	78.5	79.6	80.3	74.5	77.5	75.5
Number of Units Per Structure							
1 Unit	20,914	9,142	2,186	4,821	7,038	14,979	59,080
2 or More	2,876	715	137	254	812	1,714	6,508
Mobile Home	2,039	957	487	818	1,228	1,833	7,362
Median Value of Owner-Occupied Units							
Value($):	$36,200	$31,500	$33,500	$23,900	$28,100	$33,100	$32,600
As a % of Tennessee Median Value	99.2	86.3	91.8	65.5	77.0	90.7	91.6
Median Rent of Rental Units							
Amount ($/mo)	$ 151	$ 103	$ 113	$ 91	$ 123	$ 106	$ 126
% of Median Value for Tennessee	102.0	69.6	76.4	61.5	83.1	71.6	85.1

(a) From 1980 Census of Housing. Does not show Knox County, which had 7,826 units vacant.

two are taxed differently and purchase a different array of goods. In addition, temporary residents such as construction workers are more likely to rent. The primary impact counties have 75.5% of owned units, compared with a nationwide percentage of 64.4%. This reflects a slow-growing area, generally with many long-standing residents.

Within the primary impact area, the city of Oak Ridge represents a somewhat special case. Less than one-third of Oak Ridge's initial housing stock was categorized as being of permanent construction at the time the AEC assumed control of the townsite from the United States Army in 1974. While much of the temporary, poorly constructed housing was removed by the early 1950s, hundreds of units classified as temporary or semipermanent were sold to private purchasers. As a result, the city now faces problems dealing with potential deterioration of a significant portion of its housing stock.

Beyond housing conditions, the community has historically been beset by housing shortages. Although the AEC did attempt to alleviate housing shortages somewhat prior to the city's incorporation, during the 1940s and 1950s, the federal government encouraged project personnel who could not be housed in Oak Ridge to settle in surrounding communities within easy commuting distance. This influenced a steady growth in housing and population in surrounding communities. Faced with limited available land and higher construction costs as a result of difficult terrain and expensive infrastructure extension requirements, housing developers in Oak Ridge have found it difficult to compete. Compared with surrounding jurisdictions, Oak Ridge has a lower proportion of newer housing. The unusual collection of existing housing styles in Oak Ridge puts the community at a comparative disadvantage relative to many nearby communities.[a] This partially explains the movement of population from Oak Ridge to west Knox County, for example.

5.1.6.6 Fiscal Characteristics

This section provides a fiscal profile of the Clinch River/Oak Ridge primary impact area. Revenues, (described in total and by source), expenditures on public services (described by function) and the county and city tax effort and debt structure are discussed. Expenditures indicate how fiscal resources are divided and, to an extent, what the community values, as measured by financial outflows. A comparison of revenues to expenditures can indicate the financial health of the area and may reveal the area's ability to weather sudden economic changes such as recessions and booms.

Counties. Table 5.16 shows a number of measures of local government fiscal health for the six county governments in the Clinch River/Oak Ridge primary

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(a) From City of Oak Ridge Comprehensive Plan, April 8, 1985 (Draft for City Council Review and Approval), Oak Ridge, Tennessee.

TABLE 5.16. Selected Local Government Fiscal Data for the Clinch River/Oak Ridge Primary Impact Area Counties (Tennessee Taxpayers Association 1984; Tennessee Division of Community Development 1985a-e,g)

	Anderson County	Loudon County	Meigs County	Morgan County	Rhea County	Roane County
Operating Revenue, Fiscal Year Ended June 30, 1983 (thousand 1983 $)						
Total[a]	$24,142	$10,563	$4,133	$8,805	$9,303	$15,551
Local Sources:	12,456	5,738	1,529	4,220	4,295	7,455
Property Tax	8,426	3,078	677	2,168	2,394	3,681
Sales Tax	-0-	731	162	329	486	1,108
State Sources	7,823	3,955	1,861	3,213	3,906	6,121
Federal Sources	3,862	870	743	1,372	1,102	1,975
Revenue Per Capita,[b] Major Sources, Fiscal Year Ended June 30, 1983 (1983 $)						
Local Sources:						
Property Tax	$ 125	$ 108	$ 91	$ 130	$ 99	$ 76
Sales Tax	-0-	26	22	20	20	23
State Sources	116	138	250	194	161	126
Federal Sources	57	30	100	83	45	41
Operating Expenditures by Function, Fiscal Year Ended June 30, 1983 (thousand 1983 $)						
Total[a]	$23,815	$11,232	$4,075	$8,773	$9,212	$16,399
General Purpose	4,936	2,357	948	1,210	1,356	2,962
Schools	16,108	6,693	2,362	5,739	6,333	10,326
Highways	1,503	1,104	568	844	642	1,056
Debt Service	1,262	1,077	197	814	882	2,054
Assessed Value, 1983 (million 1983 $)						
Estimated Actual Value	$ 1,308	$ 778	$ 128	$ 242	$ 365	$ 794
Total Assessed Value	358	209	25	51	54	132
Assessed Value Per Capita	5,323	7,305	3,304	3,075	2,234	2,896
Residential and Farm	214	98	18	33	32	86
Public Utilities	27	12	4	11	8	13
Commercial and Industrial	85	57	1	9	10	25
Personal Tangible	26	24	1	3	4	7
Effective Tax Rate by Class of Property 1983 ($ per $100 of value)						
Commercial and Industrial, Real Property	$ 1.36	$ 0.94	$ 0.90	$ 1.44	$ 0.98	$ 0.81
Residential Real Property	0.85	0.59	0.56	0.90	0.61	0.51
Average, All Property	0.92	0.62	0.63	1.03	0.71	0.55

(a) Includes amounts not shown separately.
(b) Based on 1980 census population.

impact area for recent years. Each of the counties supplied between about one-half and one-third of its operating revenues from its own sources. Between one-half and three-fourths of this locally supplied revenue came from property taxes, and between 60% and 80% came from sales taxes and property taxes combined. Anderson County did not levy a local option sales tax in 1983, although it has since adopted one. Property tax revenues ranged from a low of $76 per capita in Roane County to $130 per capita in Morgan County.

Table 5.16 also shows operating expenditures by function for the county governments. In all cases, operating expenditures were less than operating revenues, with most of the difference accounted for by capital projects and transfers of funds to other governments. Excluding these other expenditures, Anderson, Morgan, Rhea, and Meigs Counties had surpluses in fiscal year 1983; Loudon and Roane Counties had deficits. Schools accounted for between 58% (Meigs County) and 69% (Rhea County) of total operating expenditures of county governments.

Finally, Table 5.16 shows a breakdown of assessed value and effective tax rates (rates accounting for assessment ratios) for various classes of property. Assessed value per capita ranged from only $2,234 in Rhea County to $7,305 in Loudon County. As might be expected, the more urbanized counties of Anderson, Loudon, and Roane have the highest total assessed value; however, Roane had among the lowest assessed values per capita and effective property tax rates. Morgan County had the highest tax effort measured in either per capita terms or per dollar of value, followed by Anderson and Rhea Counties. If new expenditures were required, these counties' tax bases would appear to be most pressured.

Cities. Table 5.17 presents selected financial data for some of the key city governments in the Clinch River/Oak Ridge primary impact area. Local effective property tax rates (taxes as a proportion of estimated market value) varied from $0.89 per hundred dollars of estimated value in Kingston to $1.88 in Oak Ridge. Because of the differences between jurisdictions in their appraisal and assessment of property, the effective rate is the best measure of relative tax effort. Part of the difference between property tax rates is accounted for by the fact that some of the cities have higher city or county sales tax rates, also shown in Table 5.17. Differences in assessed value do not account for differences in tax rates. The highest assessed value per capita is in the city of Oak Ridge, which also has one of the higher combined nominal tax rates. Lenoir City has one of the lower values for assessed value per capita, but it also has the lowest nominal combined property tax rate.

The cities and counties also varied in combined debt burden. In Wartburg the burden per hundred dollars of assessed value was only $3.60, while in Lenoir City it was $46.30.

TABLE 5.17. Selected Local Government Fiscal Data for Clinch River/Oak Ridge Primary Impact Area Cities (Tennessee Division of Community Development 1982, 1983, 1984, 1985 a-m; Tennessee Taxpayers Association 1984)

	Oak Ridge (Anderson/ Roane) (9/84)	Clinton (Anderson) (5/83)	Lenoir City (Loudon) (3/84)	Loudon (Loudon) (3/84)	Decatur (Meigs) (6/83)	Wartburg (Morgan) (4/84)	Dayton (Rhea) (4/84)	Harriman (Roane) (9/83)	Rockwood (Roane) (11/84)	Kingston (Roane) (1/85)
Property Tax Rates ($ per $100)[a]										
City	$ 3.51	$ 0.84	$ 1.03	$ 0.89	$ 0.85	$ 0	$ 1.00	$ 4.04	$ 3.15	$ 1.75
County	3.11	3.53	2.11	2.35	3.30	4.95	4.80	2.96	3.48	3.48
School	0	0	0	0	0	0	0	0	0	0
Total Nominal Rate	$ 6.62	$ 4.37	$ 3.14	$ 3.24	$ 4.15	$ 4.95	$ 5.80	$ 7.00	$ 6.63	$ 5.23
Average Effective Rate	$ 1.88	$ 1.27	$ 0.99	$ 1.09	$ 0.96	$ 1.03	$ 0.95	$ 1.29	$ 1.21	$ 0.89
Local Option Sales Tax Rates (%)										
City	0.75	2.00	0	0	0	0	0	0	0	0
County	0.75	0.75	1.5	1.5	2.0	2.0	2.25	1.5	1.5	1.5
City Assessed Valuation[b]										
Total (Millions)	$18.09	$28.4	$10.5	$ 8.8	$ 3.6	NA	$15.5	$23.7	$13.0	$13.3
Per Capita ($)[c]	$ 6,541	$ 5,422	$ 1,933	$ 2,243	$ 3,347	NA	$ 2,618	$ 2,852	$ 2,252	$ 2,985
Ratio of Bonded Debt to Assessed Valuation (Decimal)[b]										
City	0.048	0.031	0.331	0.195	0.375	0	0.078	0.223	0.335	0.101
County	0.043	0.037	0.132	0.132	0.037	0.036	0.133	0.083	0.083	0.083
Total	0.091	0.068	0.463	0.327	0.412	0.036	0.211	0.306	0.418	0.184

(a) From Tennessee Taxpayers Association (1984). Effective rate equals the nominal rate times the ratio of appraised value to market value, times the ratio of assessed value to appraised value.
(b) From Tennessee Division of Community Development (1982, 1983, 1984, 1985a-m).
(c) Based on 1980 Census population.

5.1.6.7 Community Services and Infrastructure

This section discusses the current capacities of many of the community service functions offered in Clinch River/Oak Ridge primary impact area. Data on current capacity and demand are expected to change before the mid-1990s; however, current data will at least provide an indication of potential service capacity problems in the Clinch River/Oak Ridge area.

Public Education. Table 5.18 summarizes public school data for the Clinch River/Oak Ridge primary impact area. While other school systems would be affected by project-related immigration, the school systems in the primary impact area would be most susceptible to impact because of their proximity to the MRS site. Table 5.18 also shows Science Application International Corporation's early 1985 estimate of the number of students that would be lost to local school systems as a result of closing the K-25 plant at Oak Ridge and loss of employees from the area.[a] The postulated layoffs at the K-25 plant would be about the same size as the operations workforce needed at the MRS facility, and have similar social and economic characteristics. Therefore, the number of school-age children involved in the K-25 plant closure could serve as a useful proxy for the addition of children to the local school systems at a later date if the MRS facility were built in the Clinch River/Oak Ridge area. The predicted loss of students from Knox county and Knoxville City schools from the K-25 plant closure is 124; this is less than 1% of the total enrollment of either school system.

Table 5.18 shows a fairly wide spread both in expenditures per pupil and in student/teacher ratios. City of Oak Ridge schools appear to have the highest service standards, spending appreciably more per student and having the lowest student/teacher ratios. The Morgan County, Meigs County, and Dayton city schools are at the other end of the distribution, with higher student/teacher ratios and lower expenditures per student. The Tennessee average student/teacher ratio in 1983-1984 was 18.5, and education expenditures in the state averaged $1,875 per student in average daily attendance.

Public Welfare. Table 5.19 summarizes selected social services (public welfare) data for the Clinch River/Oak Ridge primary impact area. These statistics are determined by demography (e.g., the number of households headed

(a) Gaseous diffusion activities at K-25 have since been placed on standby and contractor activities associated with centrifuge programs have been terminated. No conclusion should be drawn from this paragraph that MRS would replace K-25. MRS construction activities would not begin until 1991 and operations would not begin until 1996. The purpose of the table is only to show the current effect of a change in public education demand for an economic change of similar size.

TABLE 5.18. Public Education Statistics for Clinch River/Oak Ridge Primary Impact Area School Systems, Scholastic Year 1983-1984 (Tennessee Department of Education 1984; DOE 1985b)

School District	Total Enrollment[a]	Average Daily Attendance	Students Per Teacher[b]	Expenditures Per Pupil in Average Daily Attendance	Loss of Students from Closure of K-25 Plant (1985)
Anderson County	7,592	6,951	13.5	$2,383	68
Clinton	919	849	16.0	1,640	--
Oak Ridge	4,823	4,352	13.2	3,228	60
Loudon County	3,942	3,701	15.6	1,728	4
Lenoir City	1,867	1,688	18.2	1,730	--
Meigs County	1,649	1,500	17.6	1,546	--
Morgan County	3,462	3,203	19.2	1,573	9
Rhea County	4,447	3,922	17.9	1,461	--
Dayton	714	655	18.2	1,386	--
Roane County	6,846	6,248	17.9	1,638	94
Harriman	2,236	2,003	16.0	1,786	13

(a) Selected 1984 enrollments were: Anderson County, 7,789; Oak Ridge, 4,469; Loudon County, 3,903; Morgan County, 3,318; Roane County, 6,542; Harriman, 2,072.
(b) Includes all instructional staff.

TABLE 5.19. Selected Social Services Data for the Clinch River/Oak Ridge Primary Impact Area (University of Tennessee 1985)

	Anderson County	Loudon County	Meigs County	Morgan County	Rhea County	Roane County	Tennessee
Total Number of Families, 1979							
	19,174	8,407	2,075	4,512	6,640	13,895	4,476,000
Families with Incomes Less than Poverty Level, 1979							
Number	2,168	866	255	973	1,035	1,404	736,000
% of Total Families	11.3	10.3	12.3	21.6	15.6	10.1	16.4
Total Transfer Payments Per Capita, 1983							
	$1,691	$1,648	$1,344	$1,392	$1,579	$1,647	$1,526
Families Receiving Aid to Families with Dependent Children, FY 1983							
Children	1,135	252	82	429	554	803	103,425
Payment per Child	$ 776	$ 775	$ 910	$ 779	$ 868	$ 792	$ 781
Food Stamps, FY 1983							
Persons Participating	8,109	3,024	763	3,238	3,687	5,576	598,192
Value Per Person	$ 509	$ 497	$ 563	$ 522	$ 574	$ 508	$ 538
Caseload for Medical Assistance, June 1983							
Aged (including Medicaid)	235	157	0	69	94	181	14,643
Woman and Children	72	15	3	25	17	23	3,478
Others	26	16	0	17	9	11	2,718

by females), the economic conditions (especially household income), and eligibility and funding levels of the various programs. All of these are expected to change before the mid-1990s. However, these historical data do provide some indication of the relative demand for social services in the primary impact counties.

For the most part, the number of poor in the primary impact counties is a smaller percentage of the population than in Tennessee as a whole. Morgan County is the exception, with nearly 22% of all families having incomes below poverty levels. Transfer payments per capita are above the state average, except in Meigs and Morgan counties. The same is true of Aid to Families with Dependent Children. For food stamps, the highest participation rate is in Morgan County, with almost 20% of the population participating. Payment rates for both Aid to Families with Dependent Children and food stamps are near the state average in the primary impact area. Only Morgan County approaches having 1% of the population on medical assistance.

Health Care. A variety of health care services are available in the Clinch River/Oak Ridge area. Twenty-three hospitals are located within 50 miles (80 km), including short-term, long-term, emergency, and psychiatric care (PMC 1975). Table 5.20 shows selected health care statistics for the primary impact area in 1983-1984. In addition to these facilities, Knox County had 3,114 staffed hospital beds, 753 physicians, and 242 dentists to serve the entire east Tennessee area. In the primary impact area itself, the numbers of hospital beds, physicians, and dentists are below national averages. However, this is fairly typical of rural areas and small towns and does not mean the area is underserved. Alternative standards have been suggested for rural areas of 3.3 hospital beds, 0.83 physicians, and 0.83 dentists per 1000 population (Branch et al. 1982). At these lower standards, Anderson and Roane Counties would meet the standard for hospitals and physicians, and Anderson would meet the standard for the number of dentists.

Parks and Recreation. The counties of Roane and Anderson have numerous parks, golf courses, swimming pools, and tennis courts. Outdoor recreation activities include hunting, fishing, and boating at nearby TVA lakes, Tennessee state parks, and farther away, at Great Smoky Mountain National Park. Some unique facilities include the Oak Ridge Playhouse in Oak Ridge and a nearby hunting preserve (Tennessee Division of Community Development 1983) (see Table 5.21). With the increase in population projected by the baseline estimates, it is clear that some increase in usage of recreational facilities and parks will occur in the absence of an MRS facility.

Because of the nature of the MRS facility as a nuclear materials handling and storage site, local citizens are concerned about the potential for disrupting the tourism and outdoor recreation industries of the area. The DOE is unable to confirm or refute this concern. There is some evidence that when potential or actual threats to public health or safety are publicized, disruption to tourism can occur (see Section 6.2.6).

Law Enforcement and Fire Protection. Construction and operation of the MRS facility at either the Clinch River or Oak Ridge site would be expected to create some immigration of workers and their families, increasing the need for police and fire protection. The facility would also increase traffic and

TABLE 5.20. Selected Health Care Statistics for the Clinch River/Oak Ridge Primary Impact Area (University of Tennessee 1985; Statistical Abstract of the U.S. 1985)

Service/Capability	Anderson County	Loudon County	Meigs County	Morgan County	Rhea County	Roane County
Hospital Beds, 1983						
Number	328	50	0	0	57	187
Beds per 1,000 Population	4.80	1.66	0	0	2.31	3.78
National Average Beds per 1,000 Population (1982)	5.9	5.9	5.9	5.9	5.9	5.9
Physicians, 1984						
Number	100	15	1	3	8	37
Number per 1,000 Population	1.45	0.50	0.13	0.17	0.32	0.75
National Average Number per 1,000 Population (1981)	1.85	1.85	1.85	1.85	1.85	1.85
Dentists, 1984						
Number	49	13	1	2	5	23
Number per 1,000 Population	0.71	0.43	0.13	0.11	0.20	0.47
National Average Number per 1,000 Population (1982)	0.55	0.55	0.55	0.55	0.55	0.55

thus the need for police protection on the roads into the site. Table 5.22 summarizes the police and fire protection capabilities of several key communities and rural areas in the primary impact area. The rural areas of these counties are not as well served as the cities (PMC 1975); however, the areas would likely be able to absorb a limited population increase if the ratios shown continued to prevail. The Clinch River/Oak Ridge sites lie within the jurisdiction of the City of Oak Ridge and Roane County. These local governments would manage traffic near the site.

TABLE 5.21. Outdoor Parks and Recreation and Tourist Facilities for the Clinch River/Oak Ridge Primary Impact Area (Tennessee Division of Community Development 1983; University of Tennessee 1985)

County/Location	Facility	Comments
Anderson County Oak Ridge	4 hotels (438 rooms), 2 golf courses, country club, 6 parks, TVA lakes, Oak Ridge Playhouse, American Museum of Science and Energy, University of Tennessee Arboretum, ORNL Graphite Reactor	American Museum of Science and Energy has about 210,000 visitors/yr; Graphite Reactor has 13,000/yr. Water-based recreation
Norris Dam	State park	620,000 visitors/yr
Clinton	4 hotels (170 rooms) 2 golf courses, country club, 4 parks, TVA lakes, state park, marina, state hunting reserve	Water-based recreation
Loudon County Lenoir City	4 hotels (250 rooms), 2 golf courses, country club, 2 parks, TVA lakes	Water-based recreation
Loudon	3 hotels (150 rooms), 2 golf courses, country club, 3 parks, TVA lakes	Water-based recreation
Meigs County Decatur	1 hotel (20 rooms) golf course, country club, 3 parks, TVA lakes	Water-based recreation
Morgan County Wartburg	1 hotel (40 rooms), Catoosa Game Preserve, TVA lakes	Water-based recreation
Frozen Head	State park	93,000 annual visits
Rhea County Dayton	2 hotels (50 rooms), 1 golf course, country club, TVA lakes	Water-based recreation
Roane County Harriman	5 hotels (180 rooms), Catoosa Game Reserve, TVA lakes, golf course, country club, 2 parks	Water-based recreation
Kingston	5 hotels, 2 golf courses, 1 country club, TVA lakes	Water-based recreation
Rockwood	1 hotel, 1 golf course, 1 country club, Catoosa Wildlife Reservation, Watts Bar Lake	Water-based recreation

TABLE 5.22. Police and Fire Protection Resources for the Clinch River/ Oak Ridge Primary Impact Area, 1983-1984

County and City	Police		Firefighters		Fire Trucks
	Staff	Vehicles	Full-Time Staff	Volunteers	
Anderson County					
Oak Ridge:					
Number	43	14	41	0	6
Per 1,000[a]	1.55	0.51	1.48	0	0.22
Clinton:					
Number	11	4	10	23	4
Per 1,000[a]	1.92	0.70	1.74	4.02	0.70
Loudon County					
Lenoir City:					
Number	10	3	2	30	5
Per 1,000[a]	1.84	0.55	0.37	5.51	0.92
Loudon:					
Number	8	4	6	22	4
Per 1,000[a]	2.03	1.02	1.52	5.59	1.02
Meigs County					
Decatur:					
Number	3	2	0	27	2
Per 1,000[a]	2.81	1.87	0	25.26	1.87
Morgan County					
Wartburg:					
Number	6	2	0	23	2
Per 1,000[a]	7.89	2.63	0	30.22	2.63
Rhea County					
Dayton:					
Number	9	6	5	25	4
Per 1,000[a]	1.52	1.01	0.85	4.22	0.68
Roane County					
Harriman:					
Number	15	4	18	12	9
Per 1,000[a]	1.81	0.48	2.17	1.45	1.08
Rockwood:					
Number	12	4	12	10	8
Per 1,000[a]	2.08	0.69	2.08	1.73	1.39
Kingston:					
Number	7	3	4	16	2
Per 1,000[a]	1.58	0.68	0.90	3.60	0.45
Standard per 1,000	1.5[b]	0.7[c]	2[b]	NA[b]	0.33[c]

(a) Per 1,000 people, based on 1980 census population. Numbers from Tennessee Division of Community Development (1983).
(b) From Stenehjem and Metzger (1976).
(c) From Branch et al. (1982).
NA = Not available.

5.1.6.8 Utilities

In determining the ability of the site's utility systems to support current and future demands, three factors must be considered: existing and planned resource or capacity estimates, existing and projected consumption rates, and existing and planned delivery/storage capacities. It is assumed that electrical and gas system capacity, driven by private market considerations, will increase (at a cost) to meet population increases as required. Therefore, only the sufficiency water and sewage utility systems are considered in this section.

Sewage systems consist of both waste water control and solid waste management. The adequacy of these systems is related to such issues as the capacity of waste treatment facilities and septic tank drain fields, and the adequacy of landfills. These issues are influenced by factors such as existing population, rate of population growth, population distribution and government planning.

Table 5.23 summarizes operating data for water and sewage systems for a number of communities in the Clinch River/Oak Ridge primary impact area. Most appear to have (or have planned) sufficient capacity to accommodate considerable population growth. This is especially true of the cities of Oak Ridge, Lenoir City, Wartburg, and Harriman.

5.1.6.9 Economic Development Plans and Capabilities

The Clinch River/Oak Ridge area and its economic growth and development have resulted from a number of causes, including national energy and defense policy decisions of the federal government, extension of the interstate highway system network throughout the southeast, and increase in the manufacturing and service base at Knoxville (including the University of Tennessee and the TVA). Manufacturing firms established in the Knoxville and primary impact areas include firms making dairy products, plastics, steel bathtubs, boats, clothing, air conditioners, and electrical components in Knoxville, a few specialty and precision manufacturing firms at Oak Ridge, and a number of more general manufacturing firms making locks and security systems at Lenoir City, auto pipes and mufflers at Loudon, and clothing and gas heaters at Dayton (Tennessee Division of Community Development 1983). Because the Clinch River and Oak Ridge sites are within the jurisdiction of the Roane County portion of the city of Oak Ridge, special attention is given to the city and to Anderson and Roane Counties, where the city lies.

Oak Ridge was established in 1942 as part of the Manhattan project and was maintained for many years as a federally-owned and operated "temporary" bedroom community for the workers at the defense and research facilities at the Oak Ridge Reservation. Most cities, unlike Oak Ridge, develop as a result of

TABLE 5.23. Water and Sewage System Capacity in Selected Communities of the Clinch River/Oak Ridge Primary Impact Area, 1981-1984 (gal/day)

County/City	Water Supply Capacity	Water Supply Current Use	Sewage Treatment Capacity	Sewage Treatment Current Use
Anderson County				
Oak Ridge (DOE Facility)	24,000,000	14,000,000[a]	5,500,000[b]	4,000,000
Clinton[c]	2,160,000	1,600,000	1,250,000	850,000
Oliver Springs[c]	1,200,000	570,000	1,000,000	350,000
Hallsdale-Powell[c]	4,020,000	2,800,000	NA	NA
Norris[c]	430,000	260,000	NA	NA
First[c]	300,000	300,000	70,000	30,000
Loudon County				
Lenoir City[d]	3,000,000	1,000,000	2,000,000	800,000
Loudon[d]	4,400,000	4,000,000	7,200,000	3,200,000
Dixie-Lee[c]	600,000	400,000	NA	NA
Piney[c]	200,000	200,000	NA	NA
Meigs County				
Decatur[d]	288,000	100,000	250,000	60,000
Morgan County				
Wartburg[d]	414,000	235,000	200,000	70,000
Rhea County				
Dayton[d]	2,000,000	1,000,000	2,670,000	1,750,000
Roane County				
Harriman[d]	2,000,000	1,650,000	2,000,000[b]	1,000,000
Rockwood[c]	6,000,000	3,000,000	2,000,000	1,500,000
Kingston[c]	2,000,000	700,000	600,000[b]	500,000
Cumberland[c]	864,000	450,000	NA	NA

(a) Oak Ridge municipal use is about 4.75 million gal/day.
(b) Capacity changes planned are: Oak Ridge, new 12 million gal/day plant; Kingston, new 1.3 million gal/day plant; Harriman, 4.5 million gal/day plant.
(c) From PMC (1975).
(d) From Tennessee Division of Community Development (1983).
NA = Data not available.

market responses to transportation networks, natural resource deposits, proximity of important markets or a combination of these. Consequently, the city has not had a natural private-sector economic base and continues to be extremely dependent on federal government policy decisions (Freeman et al. 1984). For over 30 years, Oak Ridge has had a relatively high and stable level of income in comparison with most one-industry towns and in comparison with surrounding jurisdictions and the State of Tennessee. In the past, employment losses of one Oak Ridge plant were offset by increases at another.[a]

Some aspects of the federal presence have not been positive for local development (Freeman et al. 1984). Beside the fact that Oak Ridge was strictly a federal city for many years (sited as a temporary community and developed in deliberate isolation from transportation facilities) the federal, non-taxable ownership of over 60% of the city's land area and almost all of its industrial base has caused the city to rely heavily on residential and farm property as a tax base. This, in turn, discouraged local housing and commercial development. The uncertainty created by past increases and decreases in federal programs, such as cancellation of the Clinch River Breeder Reactor (CRBR) program, some recent employment losses at ORNL, and termination of fuel enrichment activities have made it extremely difficult for Oak Ridge to attract new industry to diversify the local economy. Another negative aspect of past federal programs is that payments to local government in lieu of property tax have been declining as a proportion of total funding of local government, making the city of Oak Ridge even more reliant on its relatively narrow tax base.[b] Finally, recent publicity of environmental problems at the Oak Ridge reservation may also have contributed to difficulty in attracting new industry, whose workers want a healthy and safe environment in which to live and raise families (Popper 1985).

Local efforts to offset these negative aspects of the federal presence include more intensive industrial recruitment to attract knowledge-intensive industry, to diversify, and to make the local economy less dependent on the federal government. Recent discussions of closure of the K-25 plant may have partially undermined these efforts by contributing to uncertainty in planning and by further narrowing the local revenue base (DOE 1985b; Freeman et al.

(a) From City of Oak Ridge Comprehensive Plan (Draft). April 8, 1985. The cessation of gaseous diffusion activities at the K-25 plant may limit this "balancing" effect.

(b) Figures are available on the percentage of city of Oak Ridge revenues from local and federal sources from 1968 through 1983. For example, for 1983 the percentages were: local sources, 36.2 percent; state, 26.4 percent; federal, 37.4 percent. DOE payments were about 11.4 percent. In 1968, DOE payments represented 20.2 percent.

1984). Local efforts to stabilize government revenues have included consideration of a local option payroll tax to broaden the tax base. These stabilization efforts also include lobbying by local government for tying federal in-lieu-of-tax payments to DOE land values instead of DOE employment.

5.1.7 Archaeological and Historical Sites

The Clinch River site is rich in archaeological resources, with prehistoric sites dating from early Archaic through Mississippian periods located near the site. Twelve archaeological sites have been identified in the site vicinity. These are described in Table 5.24.

Three known historical sites have been identified near the site; these are described in Table 5.25.

No sites are presently listed under the National Historic Preservation Act.

5.1.8 Aesthetic Characteristics

This section describes aesthetic characteristics of the Clinch River site and surrounding area in terms of noise levels and visual qualities. Noise levels during previous construction activities at the site are also briefly discussed. Terminology used to describe noise levels is defined in Section 5.0.

5.1.8.1 Noise

At the Clinch River site, about 50 residents are located within 2,000 feet (610 m) of the eastern and western boundaries of the site. New residences built in recent years are located along the axis of prevailing winds from the site (northeasterly and southwesterly), and propagation to these homes from the site is not obstructed by major ridges. For these residents, noise levels could be a potential concern, particularly during the construction phase.

The acoustical setting in the vicinity of the Clinch River site consists of a quiet background noise floor interspersed with natural and manmade sounds typical of a rural area. Noise from vehicles passing by on Interstate 40 is the greatest contributor to the ambient noise environment south of the site.

A scale of typical noise levels was presented in Figure 5.2. A limited number of ambient noise measurements have been taken in the site vicinity. Equivalent daytime levels range from 31 to 51 dBA, and nighttime levels are

TABLE 5.24. Archaeological Sites Within the Area of Potential Disturbance at the Clinch River Site (Jolley 1982)[a]

Archaeological Number	Description
40RE105	Middle Valley component village site.
40RE106	Upper and Middle Valley Woodland village site.
40RE108	Upper and Middle Valley Woodland village site.
40RE152	Undetermined prehistoric habitation site.
40RE153	Undetermined prehistoric, probably a lithic extraction site.
40RE154	Undetermined prehistoric habitation site.
40RE156	Undetermined prehistoric, probably a lithic extraction site.
40RE157	Undetermined prehistoric, probably a lithic extraction site.
40RE158	Undetermined prehistoric, probably a lithic extraction site.
40RE159	Undetermined prehistoric, probably a lithic extraction site.
40RE163	Undetermined prehistoric habitation site.
40RE165	Early Archaic and Late Archaic site.

(a) From Fielder, G. F. Jr., Tennessee Department of Conservation. Letter to C. E. Cushing, Pacific Northwest Laboratory, October 7, 1985.

31 to 45 dBA (Thornton 1978). During excavation of the CRBR, which has since been canceled, daytime and nighttime levels were nearly equal, ranging from 51 dBA to 57 dBA (Rainey and Mills 1983).

To minimize offsite annoyance or interference during excavation for the CRBR, the activities with high potential for disturbance, such as blasting, were controlled. In addition to use of small multiple charges for blasting, this activity was scheduled early in the second workshift from about 3:30 to 6:30 p.m. It was estimated that activity interference, including sleep

TABLE 5.25. Historical Sites at the Clinch River Site (Jolley 1982)

Archaeological Number	Description
40RE119	This site was originally designated for the Hensley Cemetery, a Euro-American early twentieth century site that is presently fenced off. The site now designates the Fort Southwest Point.
40RE120	Historic site, located in the uplands, and consisting of a limestone fireplace, a limestone-lined root cellar, and a brick-lined well or cistern.
40RE121	Historic site in the uplands consisting of a well, a cellar and two small outbuildings. It probably dates to the middle of the nineteenth century. A well house and barn have subsequently been found on the site.

interference, could occur during evening and nighttime hours, but only for residents and transient facility users within about 1 mile (1.6 km) of the site (NRC 1982).

5.1.8.2 Visual Qualities

Prior to site preparation for the CRBR (which was canceled in fall of 1983), the Clinch River site was heavily wooded with a mixture of coniferous and deciduous trees (PMC 1975). As a result of site preparation, slightly more than half of the peninsula is now cleared and graded. A narrow fringe of riparian vegetation has been maintained around most of the cleared site.

No systematic visual analysis or view-sensitivity has been conducted for the site. However, a preliminary evaluation of visual resources is given. Figure 5.12 identifies locations from which the site can be viewed from roads and from the river.

From a long view, the site shows little difference from the surrounding areas. In general, the vegetation left on the site maintains the general character of the site.

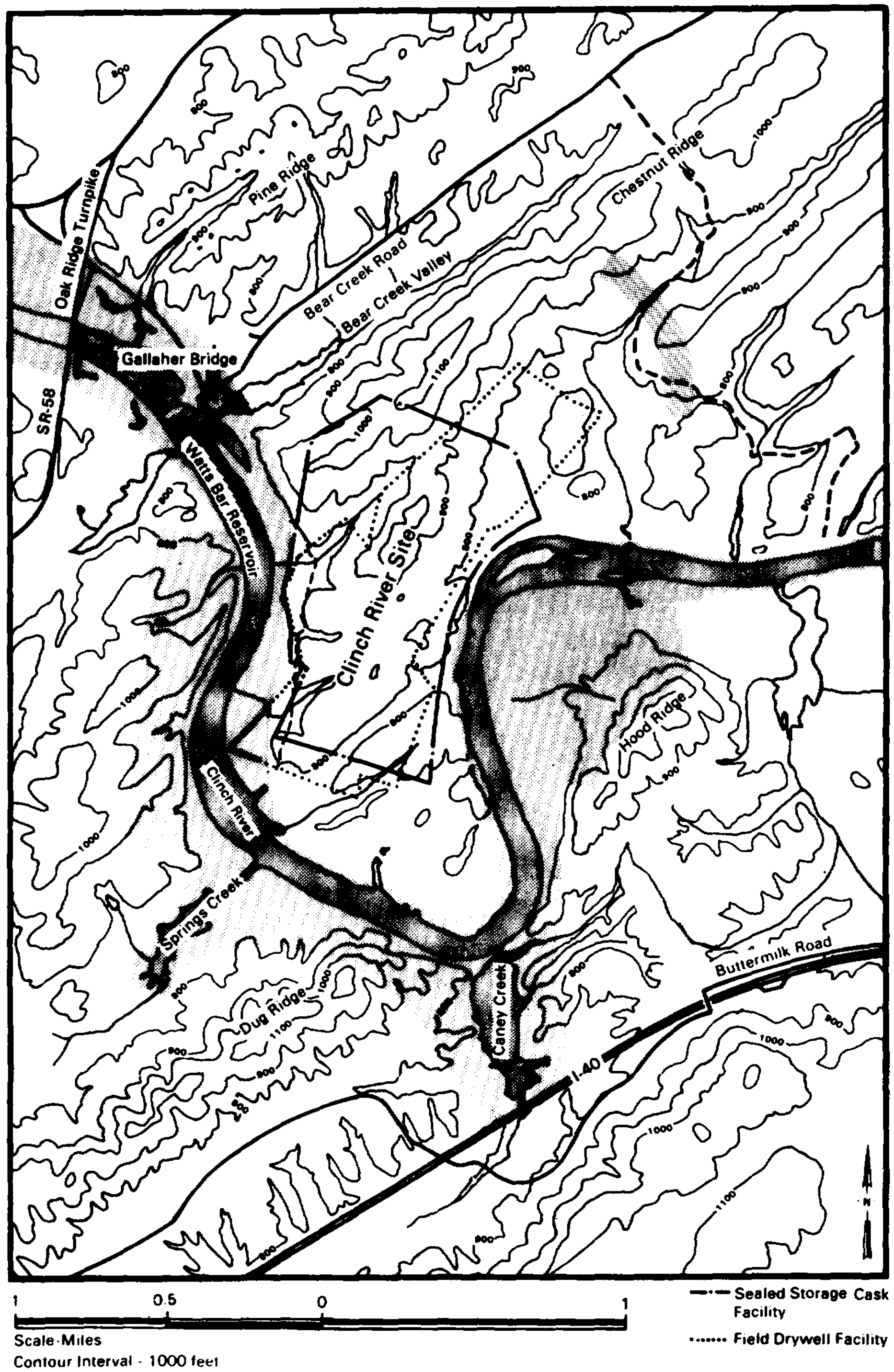

FIGURE 5.12. Viewing Points to the Clinch River Site

The site is visible from the south from I-40 for a short segment in the Caney Creek area, but existing vegetation does not allow the traveler to see the disturbed area. The site is also visible for a short distance along SR-58 from Gallaher Bridge.

Short views of the site from the south and west, and both short and long views from the hillside of Dug Ridge to Bear Creek Valley show the site as unusual in comparison to the surrounding area. The site is visible from about 20 to 30 homes from the south to west (Dug Ridge to Bear Creek Valley). The site is also visible to residents on Hood Ridge. It is believed that residential viewers would have a major concern for the scenic qualities of the area (TVA 1985).

5.1.9 Transportation Conditions

The Clinch River site is within easy access of local transportation systems. The site has access to a spur of a main rail line about 2 miles (3 km) north of the site, and, since it is located on a peninsula, could be accessed by barge. In addition, the site is adjacent to Bear Creek Road and within 5 miles (8 km) of the nearest interstate highway, as shown in Figure 5.13.

5.1.9.1 Highways

Major highway routes providing access to the Clinch River site are Interstate 40 (I-40), which extends east-west and connects Nashville and Knoxville; and Interstate 75 (I-75), which extends north-south and connects Knoxville with Chattanooga and Atlanta, Georgia to the South, and Lexington, Kentucky and Cincinnati, Ohio to the north. State Route 58 (SR-58)/Gallaher Road/Oak Ridge Turnpike is the primary access route from I-40 to the site. SR-58 extends as far south as Chattanooga, and ends at White Wing Road/State Route 95 (SR-95), north of the proposed site. The roadway becomes SR-95 at this point, and proceeds northeast into the city of Oak Ridge. Other important roadways would include Bear Creek Road and Bethel Valley Road, both of which are located southeast and parallel to SR-58. The characteristics of roads providing access to the Clinch River site are given in Tables 5.26 and 5.27. Table 5.28 provides additional explanation and definitions for the level of service information listed in Table 5.27.

In general, the rural highway system around the proposed Clinch River site is adequate to handle the existing number of ORNL commuters However, some congestion does occur near the Clinch River site from 7:00 to 8:00 a.m. and from 4:00 to 5:00 p.m. because of commuter traffic to and from nearby ORNL facilities.

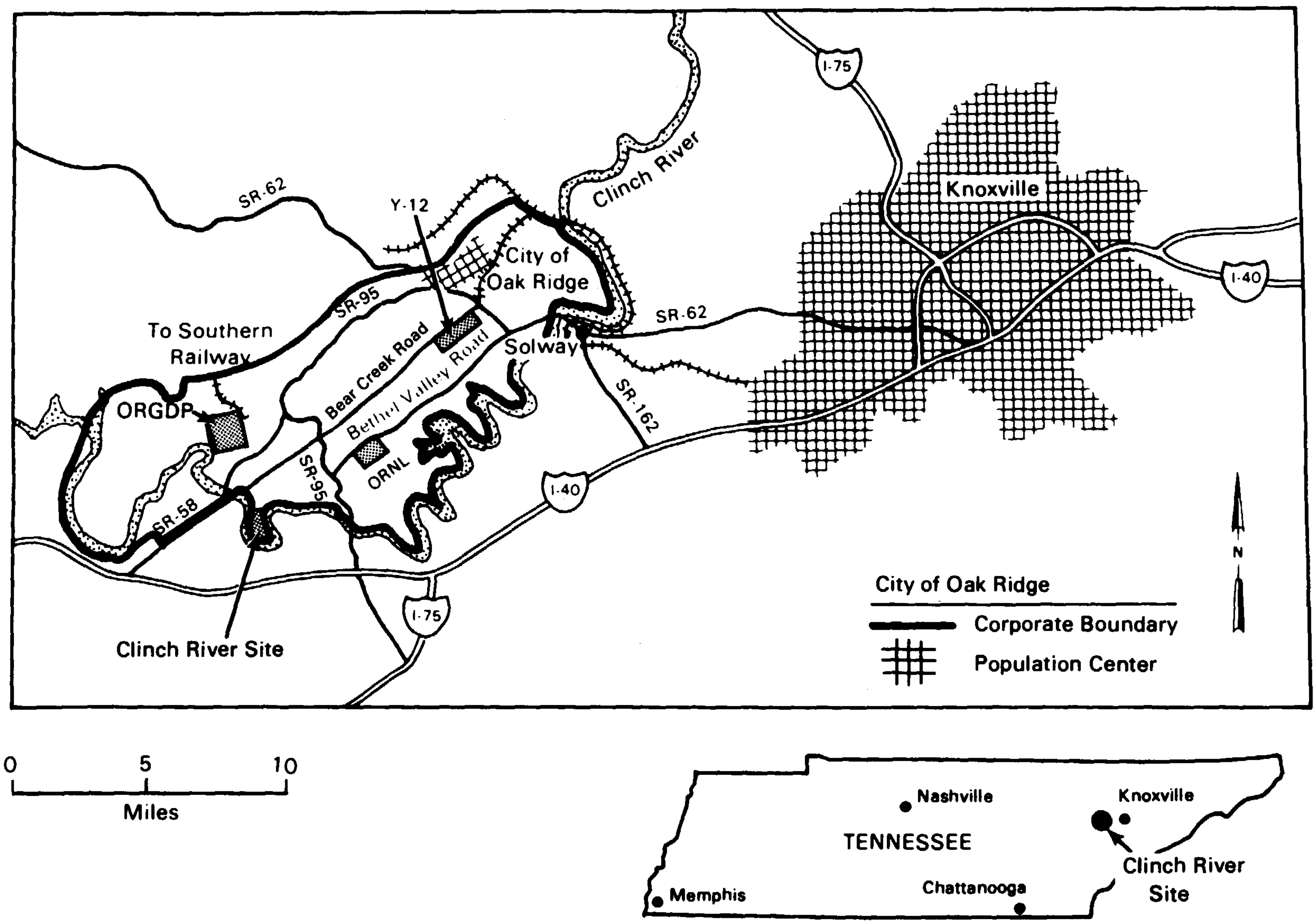

FIGURE 5.13. Clinch River Site Transportation Systems

TABLE 5.26. Characteristics of Roads Providing Access to the Clinch River Site[a]

Highway Segment	Number of Lanes	Annual Average Daily Traffic (Both Directions)
I-40, East of SR-58	4	18,840
I-40, West of SR-58	4	21,990
SR-58, North of I-40	2	7,910
SR-58, South of I-40	2	2,820
SR-58 (Oak Ridge Turnpike) South of White Wing Road	2	8,790
SR-95 (Oak Ridge Turnpike) North of White Wing Road	2	7,700
White Wing Road, South of SR-58/ SR-95 (Oak Ridge Turnpike)	2	4,920

(a) From PMC (1975); Tennessee Department of Transportation (1984).

TABLE 5.27. Level of Service for Highway Segments Near the Clinch River Site (TVA 1982b)

Highway Segment	Existing Peak Hour Level of Service[a]
SR-58, North of I-40, South of Bear Creek Road	D
SR-58, North of Bear Creek Road, South of ORGDP	D
SR-58, North of ORGDP South of White Wing Road (SR-95)	D
SR-95, North of White Wing Road to 4-lane in Oak Ridge	E
SR-95 (White Wing Road), North of I-40, South of Bear Creek Road	E

(a) See Table 5.28 for definitions.

TABLE 5.28. Definitions for Level of Service (National Academy of Sciences 1965)

Level of Service	Operating Condition	Volume to Capacity
A	Free flow, low volumes, high speeds, little or no driver restriction	0.00 - 0.60
B	Stable flow, drivers have reasonable freedom of speed and lane choice	0.61 - 0.70
C	Stable flow but maneuverability limited by high volumes, speed still satisfactory	0.71 - 0.80
D	Approaching unstable flow, tolerable speeds but affected by fluctuating high traffic volume. Driver has little freedom of maneuverability	0.81 - 0.90
E	Volumes at or near capacity, queues of vehicles wait at signal. Unstable flow and possible blockages of momentary duration	0.91 - 1.00
F	Blockage due to down stream restriction backing into subject intersection. Stoppages may be for long periods.	>1.00

5.1.9.2 Railroads

No main rail lines exist within a 5-mile (8-km) radius of the proposed site. The Southern Railway System has a main line about 7 miles (11 km) northwest of the site, and the Seaboard System (formerly the Louisville and Nashville Railroad System) is approximately 14 miles (23 km) northeast of the site. However, a spur of the Southern Railway System extends to within 2 miles (3 km) of the site, and a spur of the Seaboard System extends to within 10 miles (16 km) of the proposed site.

5.1.9.3 Airports

No major airports are located within a 5-mile (8-km) radius of the Clinch River site. The McGee-Tyson Airport is the only airport near the site with scheduled commercial flights. It is located 10 miles (16 km) south of Knoxville, in Blount County, approximately 23 miles (37 km) southeast of the site. This airport is serviced by several commercial airlines to all major cities and has a well-established air freight terminal as well (Fitzpatrick 1982; Martin Marietta 1984b).

Three small airports that handle private and/or small business planes are located in the area. The closest of these are the Oak Ridge Air Park (sport), about 11 miles (18 km) northeast of the Clinch River site, and the Meadowlake Air Park (sport), about 11 miles (18 km) southwest of the site. The Rockwood Municipal Airport, which handles both sport and business aircraft, is about 18 miles (29 km) west-southwest of the site. Other airports within a 20-mile (32 km) radius that accept small aircraft include Ferguson and Little Creek, which are located 12 miles (19 km) south and 18 miles (29 km) east of the Clinch River Site, respectively (PMC 1975).

5.1.9.4 Waterways

The Clinch River site is bounded on three sides by the Clinch River. The United States Army Corps of Engineers operates the locks at Melton Dam and keeps records of all barge traffic. Total tonnage of commercial traffic and the number of recreational craft passing through Melton Dam for the period of 1966 to 1978 are given in Table 5.29. Completion of the Tennessee-Tombigbee

TABLE 5.29. Traffic Locked Through Melton Hill Dam (PMC 1975)

Year	Number of Recreational Craft	Commercial Traffic (Total Tonnage)
1966	1,198	1,000
1967	1,014	1,000
1968	1,256	2,000
1969	1,301	1,000
1970	929	4,000
1971	718	10,000
1972	761	4,000
1973	815	1,000
1974	631	6,000
1975	554	3,000
1976	471	4,000
1977	492	7,000
1978	460	3,000

barge canal could increase barge traffic into the area (Martin Marietta 1984b). The nearest barge terminal is about 2 miles (3 km) north of the Clinch River site. No rail line from the barge dock to the proposed site exists.

5.2 OAK RIDGE SITE

The Oak Ridge site is located on the Oak Ridge Federal Reservation, which is owned by the United States government and controlled by the DOE (see Figure 5.14). Like the Clinch River site, the Oak Ridge site lies within the city

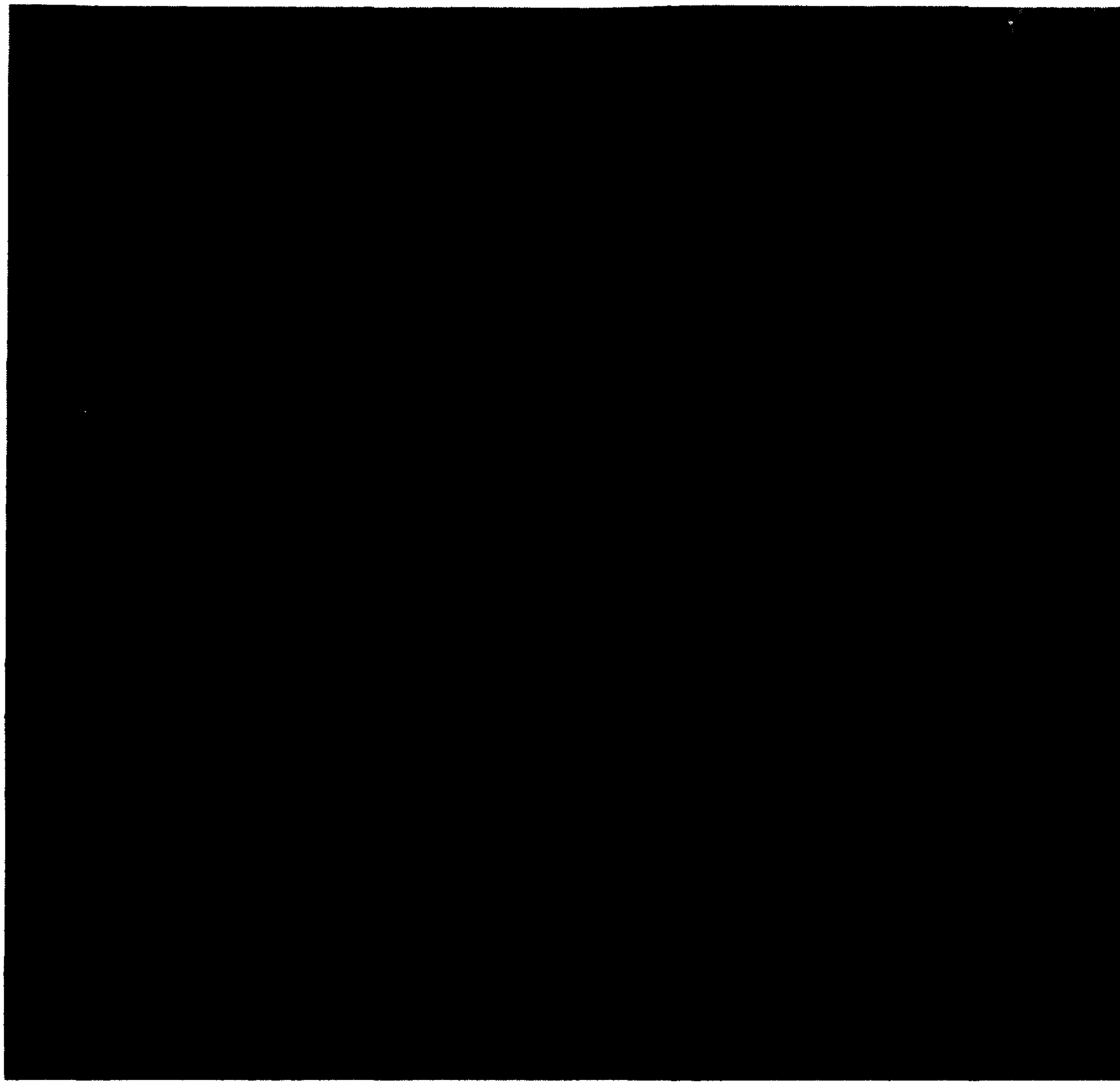

FIGURE 5.14. Aerial Photograph of the Oak Ridge Site

limits of Oak Ridge (see Figure 5.4). Power cables currently cross the site; if MRS development were to proceed, these lines would be relocated.

The topography of the Oak Ridge site (see Figure 5.15) is typical of the Valley Ridge Province in this area. The site is divided by two northeast-southwest (true) trending ridges, Pine Ridge to the north and Chestnut Ridge to the south, with Bear Creek Valley between. The floor elevation of Bear Creek Valley ranges from 800 to 900 feet (244 to 275 m) above mean sea level (MSL). At a point adjacent to the facilities area, the valley elevation is approximately 880 feet (270 m) above MSL. To the north, Pine Ridge reaches an average elevation of 1,050 feet (320 m) with isolated points reaching 1,100 feet (336 m). About 0.75 miles (1.2 km) to the southeast, Chestnut Ridge reaches an average elevation of about 1,000 feet (305 m). Grade elevation for this 100-acre site is 890 feet (271 m) above MSL.

The ecological systems of the site are characteristic of those found in the intermountain regions of Appalachia from the Allegheny Mountains in southern Pennsylvania to the southern extension of the Cumberlands in northern Alabama. The area has been under governmental control for the past 30 years and has not been unduly disturbed except for experimental use and regulated forest management.

5.2.1 Radiological Characteristics

Because of the proximity of the Clinch River site and the Oak Ridge site, their radiological characteristics are very similar. These radiological characteristics are discussed in Section 5.1.1.

5.2.2 Meteorology

Climatological data for the Oak Ridge site are from Exxon (1977). Air temperatures range from -8°F (-23°C) to 103°F (41°C), with summer temperatures usually in the 80°F (27°C) range and winters in the 40°F (4.4°C) range. The annual mean temperature is 57.9°F (14°C). Precipitation is predominantly in the form of rainfall, although, under unusual conditions, snowfall can represent a significant portion of the total winter precipitation. This occurred in the winter of 1959-1960 when 41.4 inches (105 cm) of snow fell. The average annual rainfall in the Oak Ridge area is 53.5 inches (140 cm). Annual snowfall averages 10.3 inches (26 cm), and 95% of the precipitation occurs between December and March. The average number of thunderstorms per year is 53, and the average number of days of heavy fog is 24. Clear conditions prevail 30% of the time; partly cloudy, 25%; and cloudy, 45%. Rain, snow, and fog occur about 127, 3, and 34 days per year, respectively.

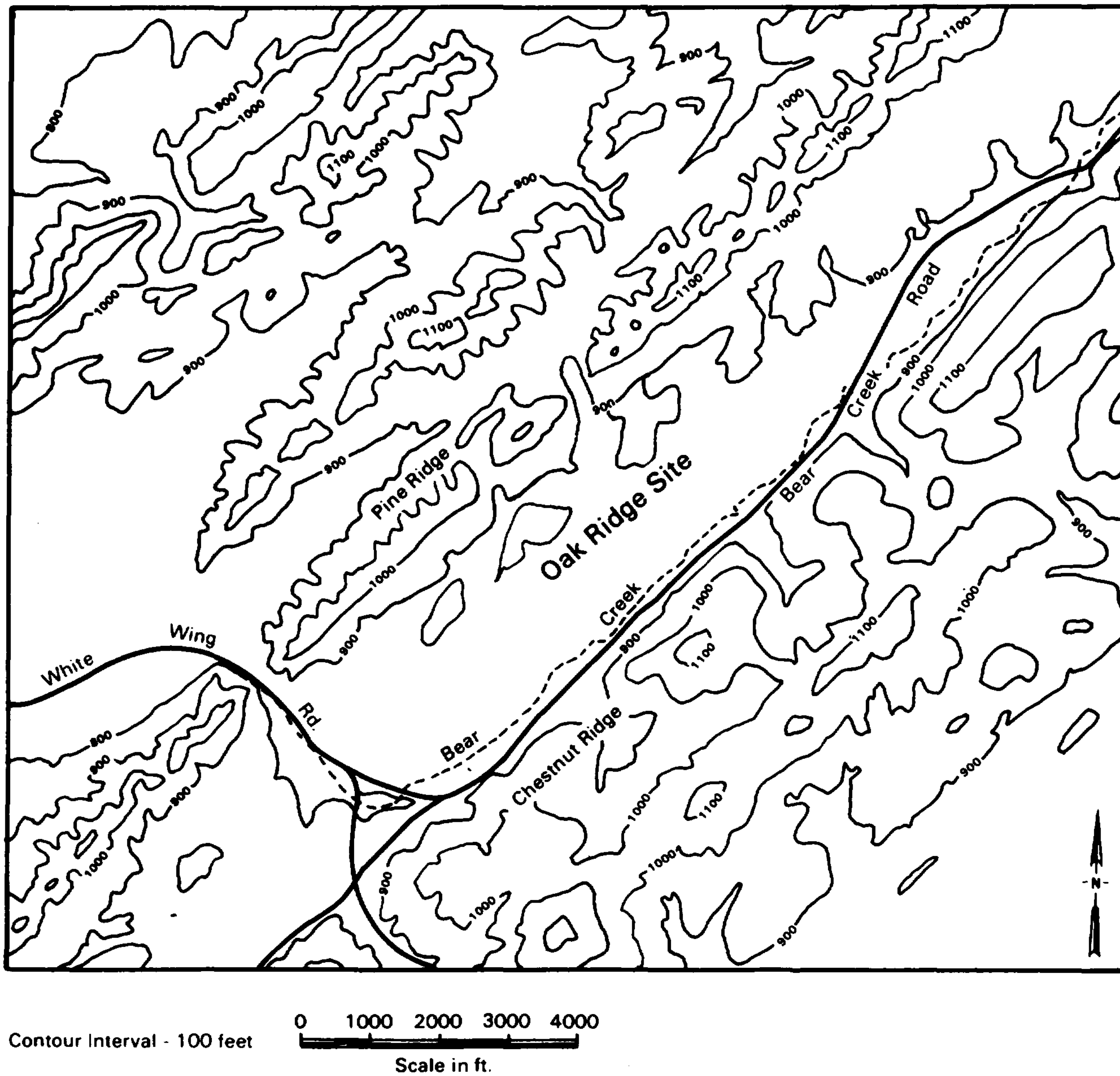

FIGURE 5.15. Topography of the Area Surrounding the Oak Ridge Site

Tropical storms occur about three times in every 10 years. The recurrence interval of tornadoes at the site is 2760 years. Wind is usually from the northeast and averages about 4 miles (6.4 km) per hour; maximum speeds of 59 miles (95 km) per hour have been recorded.

Low wind speeds and high-pressure systems limit the vertical dispersion of material in the atmosphere, which creates the potential for high levels of air pollution. Eastern Tennessee is in a region that has a relatively high potential for air pollution. Limited vertical dispersion and thus potential air pollution are more prevalent in the fall and winter. An inversion layer typically exists at elevations of 1,100 to 1,800 feet (350 to 550 m) in the mornings and at 3,300 to 5,900 feet (1,000 to 1,800 m) in the afternoons.

Because of proximity, results of ambient monitoring for both the Oak Ridge and Clinch River sites are given in Section 5.1.

5.2.3 Geology and Hydrology

This section discusses the geologic and hydrologic characteristics of the Oak Ridge site. A brief description of the geology, soils, and seismicity is included as background information.

5.2.3.1 Geology

The Oak Ridge site in Bear Creek Valley is bounded by parallel ridges that strike northeast-southwest. Pine Ridge on the northwest has a sharp crest and is underlain by interbedded sandstone and shale of the Rome Formation. Chestnut Ridge on the southeast is underlain by the cherty dolomite of the Knox Group and has a broad, well-rounded crest. The valley is underlain by the more easily weathered and eroded shale and limestone of the Conasauga Group.

Group elevations at the Oak Ridge site range from 800 feet (244 m) in Bear Creek Valley to about 1,125 feet (343 m) on Pine Ridge and 1,075 feet (330 m) on Chestnut Ridge. Along the northwest side of Bear Creek Valley is a line of knolls with crests at about 950 feet (290 m) elevation.

The Rome Formation and the Conasauga Group lithologic units underlie the site (Exxon 1976). The Rome Formation consists of gray, green, maroon, and tan fine siltstone, and shale, with minor calcareous strata. The sandstone layers range from a few inches to a few feet in thickness, constitute about half of the upper portion of the Rome Formation, and alternate with siltstone and occasional shale laminations. Sandstone occurs much less frequently in the lower portion of the formation where nearly equal amounts of alternating shale and siltstone predominate (Exxon 1976).

Soil cover is typically 20 feet (6.1 m) or less across the site. The soil consists predominantly of in-place, weathered, clay-like rock residuum, and overlies weathered bedrock. Thin alluvial deposits occur along Bear Creek and other small tributaries and gulleys (Exxon 1976).

The Oak Ridge site is located approximately 6 miles (9.7 km) northeast of the Clinch River site and is not considered to differ significantly from the Clinch River site in regards to seismicity and vibratory ground motions (Parsons 1985).

The safe shutdown earthquake calculated for the CRBR would result in ground accelerations at the site of 0.25 G (PMC 1982). The ground acceleration values are based on an MMI VIII earthquake, which is equal to the largest historic earthquake within the southern Appalachians, occurring adjacent to the site. Because no capable faults have been identified in the site vicinity, occurring these values are reasonably conservative for this evaluation.

5.2.3.2 Hydrology

The hydrology of the Bear Creek Valley has been recently investigated with regard to the control of contamination in the Bear Creek Valley Waste Disposal Area adjacent to DOE's Y-12 Plant. Generally, the surface water and groundwater systems are rather closely coupled.

Surface Water. The main surface water feature of the Oak Ridge site is Bear Creek, which flows westward from its headwaters in the Bear Creek Valley Waste Disposal Area for approximately 4.5 miles (7.2 km), where it flows into East Fork Poplar Creek. East Fork Poplar Creek ultimately enters Poplar Creek, which discharges to the Clinch River.

The Oak Ridge MRS site is near the confluence of Bear Creek and the East Fork Poplar Creek. The location of the Oak Ridge site with respect to surface waters and existing waste disposal areas is shown in Figure 5.16.

Based on 1984 data, the mean annual flow of Bear Creek at gauging point S-3 is about 2 cfs (0.056 m^3/sec) (Geraghty and Miller 1985). Instantaneous peak flow was calculated at 75 cfs (2.1 m^3/sec), and minimum flow observed at the site was 0.1 cfs (0.0028 m^3/sec) (Geraghty and Miller 1985).

During high flow periods, Bear Creek is a gaining (influent) stream; but during low flows, at least along part of its course, it is a losing (effluent) stream. This is particularly evident in August and September, during long periods without rainfall.

The solution-cavity system is believed to play an important role during low-flow periods and even during high-flow periods. Flow from Bear Creek is lost to the cavity system, and the water continues to flow westward. The

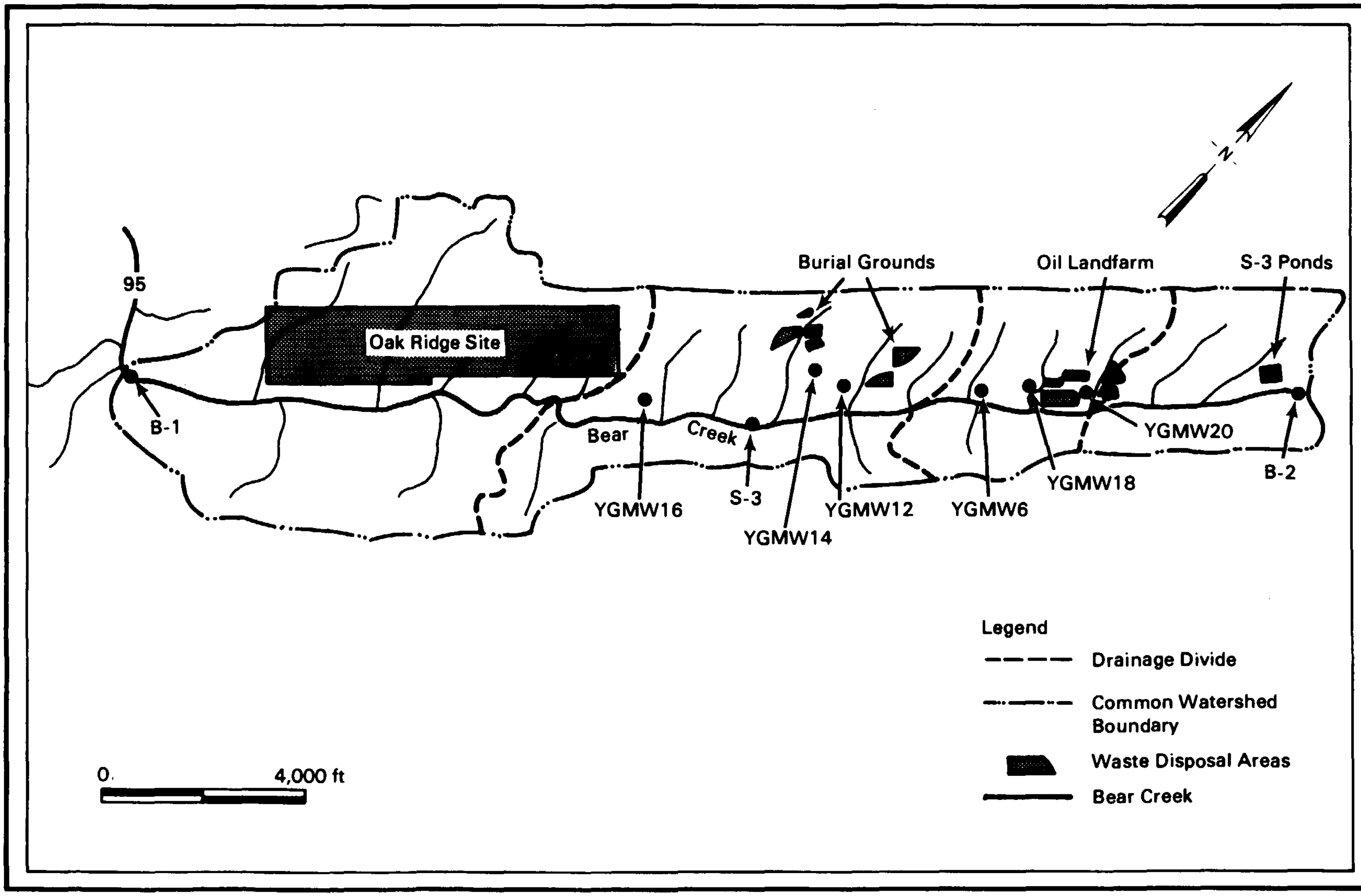

FIGURE 5.16. Surface Water and Ground Water Monitoring Locations at the Oak Ridge Site in Relation to the Bear Creek Watershed and Subwatersheds and Existing Waste Disposal Areas

cavity system is thought to be an important avenue for transport of contaminants. There is evidence that at least some flow from the cavity system emerges in springs, which generally discharge from solution openings along bedding planes and joints in the geologic formations.

Drainage of the area is to the Clinch River by way of various small streams. Included among these streams is White Oak Creek, which courses through ORNL and forms the principal drainage system for the site. The average annual discharge measured at White Oak Dam for the period 1968-1972 is 11 cfs.

The elevation of the probable maximum flood for Bear Creek is 826 feet (252 m) above MSL.

Surface-Water Use. Twelve public water supplies and 15 industrial water supplies that use surface-water sources are located within a 20-mile (32-km) radius of the Oak Ridge site. Four of the 12 public water supplies and five of the 15 industrial water supplies could be influenced by activities at the site.

Surface-Water Quality. Surface-water quality for the Oak Ridge site is monitored by station B-1, located about 2 miles (3.2 km) downstream from the Y-12 Area (see Figure 5.16). Monitoring station B-1 has indicated high levels of copper and nitrate in exceedance of Tennessee Water Quality Criteria (Table 5.30). The sensitivity of analytical methods used to measure cadmium, mercury, and lead adequate to determine compliance with Tennessee Water Quality Criteria, EPA-approved analytical procedures are used (Martin Marietta 1984a).

Monitoring station B-2 is located near the headwaters of Bear Creek (at the boundary of the Y-12 area), which is influenced by discharges from the S-3 waste ponds in the Y-12 area. Neutralization and treatment of the S-3 ponds have improved the quality of the water drained from this area (Martin Marietta 1984a).

Surface water in the upper part of Bear Creek has been contaminated with nitrate, volatile organic compounds (VOC) and uranium, mostly from seepage from the S-3 pond area. The major sediment containment in the S-3 area is uranium. Heavy metals and VOC have been identified in soil and sediments in the Bear Creek watershed.

Past practices at the Y-12 Plant Bear Creek Valley Waste Disposal Areas (BCVWDA) have resulted in the presence of some radionuclides (particularly uranium isotopes) in water, sediments, and soil in the Bear Creek Valley. Results of samples taken between September 1983 and October 1984 have been compiled by McCauley (1985a). A remedial action program is underway (Geraghty and Miller 1985).

TABLE 5.30. Water Quality Data for Bear Creek (Location B-1), 1983

Substance	Number of Samples	Concentration, mg/L Maximum	Minimum	Average	Standard[a]	% of Standard
Cd	12	0.002	<0.002	<0.002	0.000025[b]	<8000[c]
Cl^-	12	20	2	8 ± 14	250	3
Cr	12	0.08	<0.01	<0.01 ± 0.04	0.05	<20
Cu	12	1.10	0.012	0.13 ± 0.62	0.02	650
F^-	12	0.3	<0.1	<0.2 ± 0.2	1	<20
Hg	12	<0.001	<0.001	<0.001	0.00005[d]	<2000[c]
NO_3(N)	12	37	0.8	12 ± 22	10	120
Pb	12	0.07	<0.01	<0.01 ± 0.04	0.0038[b]	<263[c]
$SO_4^=$	12	31	<10	<13 ± 16	250	<5
TDS	12	370	140	237 ± 176	500	47
Zn	12	0.06	<0.02	<0.03 ± 0.04	0.05[b]	<60

(a) Tennessee Water Quality Criteria for Fish and Aquatic Life (Martin Marietta 1984a). Assumed hardness = 100 mg/L as $CaCO_3$.
(b) Monthly Average (Daily Maximum is Cd 0.003 mg/L, Pb 0.17 mg/L, Zn 0.32 mg/L).
(c) Analytical tests are not sufficiently accurate to determine compliance with standards.
(d) Current EPA water quality criteria for fish and aquatic life (Water Quality Criteria; Corrections) is 0.0002 mg/L 24-hour average and 0.0041 mg/L maximum.

Mercury contamination in the East Fork of Poplar Creek has been investigated and tracked to the Y-12 plant. Identification and cleanup of contamination sources is continuing (Martin Marietta 1984a).

Storm runoff is a major issue in the steep area of the Bear Creek drainage area where streams form in gullies after rains.

Ground Water. The hydrogeologic system underlying Bear Creek Valley is, for all practical purposes, a single aquifer of relatively low water-transmitting capacity. The upper unconsolidated part of this aquifer is somewhat more permeable than the deeper parts, but no sharp discontinuity in permeability between the two parts is apparent, and both respond in the same general way in terms of water-level fluctuations and the movement of ground water toward Bear Creek.

Water-level data show that the water table near Bear Creek is within a few feet of the land surface. At the proposed site, ground water occurs within 10 feet (3 m) of the surface. At nearby existing waste-disposal areas, ground water is estimated to be 10 to 25 feet (3 to 7.6 m) deep.

Water infiltrating into the ground from precipitation in Bear Creek Valley ultimately moves toward and into Bear Creek, which is at the lowest topographic elevation in the valley.

Solution cavities in Bear Creek Valley commonly occur in the upper part of the saturated zone. The solution cavity system has a very important bearing on the transport of contaminants in the valley.

A study made by the U.S. Geological Survey in Bear Creek Valley west of the Y-12 Plant and east of White Wing Road indicated that a persistent cavernous zone is present between 60 and 80 feet (18 to 24 m) below land surface in that area (Geraghty and Miller 1985).

Discharging ground water sustains the flow of Bear Creek or, at times of low flow, moves through the solution cavities underlying Bear Creek. Some water from the cavity system emerges further downstream in Bear Creek or in springs.

Transmissivities determined in a 1983 test from closely spaced observation wells varied widely, ranging from 35 to 1,022 gallons (132 to 3,900 L) per day per foot, and averaging 260 gallons (980 L) per day per foot (Geraghty and Miller 1985). Storage coefficients determined in this 1983 test were about 3×10^{-3}, indicative of semi-confined conditions. Geraghty and Miller (1985) found that transmissivities determined in wells open only to bedrock averaged about 180 gallons per day per foot, and storage coefficients averaged about 5×10^{-4}, suggesting increasing confinement with depth. In both tests, the wells yielded about 5 gallons (19 L) per minute with a considerable water-level drawdown.

Ground-Water Use. Within the Oak Ridge site area, major aquifers are associated with the Knox Dolomite Formation. The Knox Group is one of two major rock units that underlie the Oak Ridge and Clinch River sites. The Knox Dolomite Formation is susceptible to solutioning. Water occurs to a lesser extent in small openings along joints and bedding planes in the shale and sandstone rocks of Pottsville age and the Rome Formation. Belts of residual materials overlying bedrock are relatively thick, reducing the volume available for groundwater storage. Consequently, it is estimated that the average well in the Oak Ridge area would yield less than 10 gallons (38 L) per minute.

Ground-Water Quality. Ground-water monitoring programs within the Oak Ridge facilities complex were expanded in 1983 to meet Resource Conservation and Recovery Act regulations. More than 150 monitoring wells have been installed at and near the waste-disposal sites, mostly into the shallow unconsolidated deposits (Geraghty and Miller 1985). In all of the monitoring wells, measurements of ground-water levels have been made and water samples have been collected periodically for chemical analysis.

Plumes of ground-water contamination have been defined at all three principal disposal sites. Generally, the contaminated ground water extends only a few hundred feet away from the waste sources, except at the S-3 ponds where nitrate contamination in ground water has been detected about 2,000 feet (610 m) from the source. Ground water containing nitrate in excess of 10 mg/L is found in a large area adjacent to the S-3 ponds, both downstream and to the east. Ground water is also contaminated by metals, small amounts of VOC, and radioactivity (Geraghty and Miller 1985). At the burial ground area, there are some elevated levels of heavy metals (lead and chromium), but VOC is the major concern. Locations of monitoring wells are given in Figure 5.16. Data from ground-water monitoring locations downgradient from the Y-12 Plant (Bear Creek Burial Grounds) are given in Table 5.31.

The contamination in the Bear Creek Valley Waste Disposal Area poses no direct threat to drinking water supplies since Bear Creek is not utilized for that purpose and the nearest water-supply wells are in other valleys across the ridges to the north and south (Geraghty and Miller 1985).

5.2.4 Ecology

The following description of the ecological characteristics of the Oak Ridge site were taken from Exxon (1977) and Martin Marietta (1985).

5.2.4.1 Flora

Two major naturally occurring forest associations dominate the Valley Ridge Province. Oak/pine (*Quercus-Pinus*), and oak-hickory (*Quercus-Carya*) are both prevalent. Nearly pure stands of Virginia pine (*P. virginiana*) occur as successional forest, particularly on drier sites, throughout the region. Cove hardwoods, including such species as the commercially valuable yellow poplar (*Liriodendron tulipifera*) and white oak (*Q. alba*), occupy mesic, well-drained sites. Bottomland hardwoods, including sycamore (*Platanus occidentalis*), sweet gum (*Liquidambar styraciflua*), and elms (*Ulmus* spp.), occur on less well-drained areas. Red cedar (*Juniperus virginianus*) occurs occasionally in nearby pure stands, particularly on drier sites associated with limestone substrate.

Nine forest cover types (from criteria prescribed by the Society of American Foresters) occur on the site, with three of these types occupying significant acreage. Loblolly pine composes 39% of the forested acreage; white

TABLE 5.31. Ground-Water Monitoring Data from Wells YGMW6-YGMW12, YGMW12-YGMW16, YGMW18-YGMW20 - Bear Creek Burial Grounds Y-12 Plant (Martin Marietta 1984a)

Parameter	Number of Samples	Concentration (mg/L) Maximum	Minimum	Drinking Water Standard[a]	Maximum % of Standard
Al	25	210	<1		
As	32	0.080	<0.005	0.5[b]	160
Cd	32	0.004	<0.002	0.1	40
Cr	32	0.02	<0.01	0.05	40
Cu	16	0.022	0.004	1.0	2
Fe	16	19.0	0.11	0.3[c]	6,300
Mn	16	4.80	0.03	0.05[c]	9,600
Pb	32	0.03	<0.01	0.06	60
Zn	16	5.6	<0.02	5.0	112
Cl	16	76	<2	250.0[c]	30
F	16	0.2	<0.1	1.4 - 2.4[d]	14
$NO_3(N)$	32	7.7	<0.1		
SO_4	16	56.0	<2.9	250[c]	22
pH (pH units)	32	12.0	6.1	6 - 9	
TOC	32	32	<2		
Th	32	0.032	<0.003		
U	32	0.014	<0.001		
Alpha Activity (pCi/L)	7	200	<200		
Beta Activity (pCi/L)	32	400	<4		
^{235}U (%)	32	4.12	<0.36		
Spec. Conductance (mmhos/cm)	32	1500	110		
Color	16	2500	<5		
Coliform (colonies/100 mL)	35	30	<1	1,000/100 mL	3
Chloroform	31	1.60	<0.01		
Methylene chloride	31	0.02	<0.01		
Tetrachloroethylene	31	10.50	<0.01		
Toluene	31	0.02	<0.01		
Dichloroethane	31	0.21	<0.01		
Trichloroethane	31	0.34	<0.01		
Trichloroethylene	5	2.50	0.02		
Dichloroethylene	4	10.00	0.03		

NOTE: Parameters listed are only those whose concentrations were above the analytical detection limit and where more than one sample was obtained.
(a) Tennessee Criteria for Domestic Water Supply, unless specified.
(b) From 40 CFR 141, National Primary Drinking Water Regulations.
(c) From 40 CFR 143, National Secondary Drinking Water Regulations.
(d) Standard for fluorine is temperature-dependent.

oak/red oak/hickory compose 34%, and short-leaf pine-oak, 15%. Each of the remaining six forest cover types occur on less than 4% of the area.

A majority of the site is presently occupied by mature oak/pine and mixed hardwood forest types. These types probably represent climax vegetation on the sites that they occupy, and they likely will not be replaced by natural succession, barring catastrophic events that would destroy significant areas.

No rare or endangered plant species have been found on the site. A complete list of the plants considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.2.4.2 Fauna

The mammalian fauna of the Oak Ridge site is generally southern in its geographic affinity, though many of the species have widespread distribution in North America. Mammals occurring specifically on this site are predominantly those species normally associated with forested habitat, as the site is approximately 94% forested. Of more than 70 species of mammals presently residing in Tennessee, about 50 have geographic ranges that include the Oak Ridge site. Some of these species, such as the spotted skunk (Spilogale puterius), otter (Lutra canadensis) and certain shrews and bats are uncommon or sporadic in their distribution. Others, such as several of the bats and the southern flying squirrel (Glaucomys volans), are primarily nocturnal, leave little identifiable sign, and are difficult to capture for identification though they may be relatively common.

Eighteen species of mammals, representing ten Families and six Orders, have been positively identified on the Oak Ridge site. Small mammal communities occupying the site are composed of six species; two of these belong to the family Soricidae (shrews) and four to the family Cricetidae (mice and moles). Flying squirrels (Sciuridae) are also known to live on the site. Seven species of mammals known to occur on the site may be ranked as important species because of their status as game and/or fur-bearing animals. These seven are the white-tailed deer, cottontail rabbit, gray squirrel, raccoon, opossum, striped skunk, and mink. At least one of these species, the white-tailed deer, may also be considered significant in relation to its potential or actual impact on the ecology of the area.

A total of 96 species of birds was observed on the area since November 1974. Permanent residents composed 45 species, winter residents numbered 7 species, 38 species were summer residents, and the remaining 6 species were believed to be present only during migration. Of the 96 species, only six are believed to be purely migrants, spending neither winter nor summer on the area. Those species include the American bittern (Botaurus lentiginosus), Swainson's thrush (Hylocichla ustulata), and four warblers. The other species, while not necessarily establishing residence on the site, are known to do so in the region.

Four species of upland game birds occur regularly on the Oak Ridge site. These four are the bobwhite quail, the ruffed grouse, American woodcock, and mourning dove. Hunting is not permitted on the site.

A diversified herpetofauna occurs in the geographic region encompassing the site. Eleven snakes, seven salamanders, five frogs, one toad, one turtle, and five lizards were recorded on the Bear Creek site. Although only a few species of reptiles and amphibians were found in large numbers, the diversity of the species appeared to be rather high on the site. Judged by the criterion of diversity, the Bear Creek site is probably more favorable than average in reptile and amphibian habitat compared with similar-sized units in the vicinity.

None of the terrestrial fauna collected and classified to date on or around the site are described by the federal government as endangered or threatened. Two birds presently on the Federal List of Endangered Species may occasionally visit the site. These are the peregrine falcon and the southern bald eagle. A complete list of the animals considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.2.4.3 Aquatic Life

Zooplankton collections taken from May 1975 through April 1976 at four sites in the Clinch River contained a total of 58 species. Eight species of Cladocera (14%), six species of Copepoda (10%), two species of Insecta (3%), and 42 species of Rotifera (72%) were identified.

January 1976 was the only month in which Rotifera did not dominate the percentage contribution by group. During this month the Rotifera dropped to their lowest value of 32% at Clinch River RM 15. In January, the Crustacea were dominant except at Clinch River RM 14.4 where Rotifera and Crustacea were approximately equal in number. Polyarthra and Keratella were the most numerous genera taken in the zooplankton samples. Although Crustacea was represented by a low proportion of total organisms, a high percentage of species contribution was persistent. The groups Tardigrada, Insecta, Annelida, and Nematoda had little, if any, influence on the total percentage of organisms or species present. Most of the species of Cladocera identified, including Bosmina, Diaphanosoma, and Ceriodaphnia, are common limnetic organisms. The rotifers found are typical of alkaline hard waters. The genera Asplanchna, Brachionus, Filinia, Mytilina, and Notholca are confined to waters with a pH above 7.0.

In the phytoplankton taken from the Clinch River, a total of 197 species were identified from May 1975 through April 1976. Chlorophyta dominated the collections with 87 species, or 44% of the total number of species observed. Chrysophyta composed 36% (71 species) and Cyanophyta (blue-green algae) 8% (16 species). Euglenophyta and Pyrrophyta (dinoflagellates) were each represented with 11 species, or 6% of the total number of species. Cryptophyla was represented by one species (0.5%).

In May at Clinch River RM 12 Chrysopohyta was 54% of the total phytoplankton community. Relative abundance of Chrysopohyta rose in June and declined slightly in July before reaching the highest densities observed for the study periods in November (92%). This division dominated the species composition in all months, although it was surpassed by Chlorophyta in May and July by numbers of species present.

A total of 124 species of periphytic algae were collected on artificial substrate samplers positioned at each station, 0.5 meters below the surface. Members of the division Chrysophyta made up 63% of the total number of species collected. Chlorophyta contributed 23% of the total species, Cyanophyta, 8%; Euglenophyta, 4%; Pyrrophyta, 2%. The diatoms dominated all collections at the four river sites for the eight-month study period in both total cell count and percentage of species contribution.

The greatest number of benthic macroinvertebrates occurred at RM 14.4 in October. A total of 41 genera with 5 phyla were represented: Annelida (seven species, 17%), Arthropoda (30 species, 73%), Mollusca (one species, 2%), Nematoda (one species, 2%, and Platyhelminthes (one species, 2%). The phylum Arthropoda had the greatest number of species, including 33 species of Insecta representing 73% of the total. Annelida contained eight species (18%); Mollusca, three species (7%); and Platyhelminthes, one species (2%). Though a single phylum dominated in the percent number of organisms, as Annelida did with a mean population of 73% of total organisms, no single phylum was exclusively collected in any month. Within the family Chironomidae (midges), 24 species were collected, representing over 50% of the total number of genera.

The fish community is dominated by 21 species of rough fish (42%). Game fish compose 32% (16 species) of the fish community, and forage fish, 26% (13 species). The bulk of fish samples (72% of the total number and 71% of the total weight) was composed of 6 species: gizzard shad, threadfin shad, carp, skipjack herring, bluegill (Lepomis macrochirus), and sauger. Threadfin shad were the most numerous at 42% of the total number of fish; sauger, at 22% had the greatest total weight. Bluegill was the most abundant game fish at 7% of the total number. Sauger contributed the highest percentage of game fish weight. Forage fish tend to dominate the community·in terms of numbers (66%), while rough fish contribute the greatest percentage of the biomass (57%).

The biota in Bear Creek have been severely impacted in the past by effluents from the Oak Ridge operations. However, some of the effluents previously entering Bear Creek have been eliminated, and the fauna, especially the fish, have shown signs of recovery.

Presently, the organisms found in Bear Creek and Grassy Creek, a nearby control stream, are common to streams in the region, and include snails, aquatic worms, crustaceans, and numerous aquatic insect groups. Forty-one genera of Chironomidae have been found in Bear Creek and Grassy Creek and were the most diverse group. Mayflies (Ephemeroptera) and stoneflies (Plecoptera) are represented by considerably fewer genera than the chironomids and are more sparsely distributed, especially in Bear Creek. No clams (Pelecypoda) are present in Bear Creek. Crustaceans (isopods, amphipods, and decapods) are commonly found in Grassy Creek and lower Bear Creek. The virtual absence of the pollution-intolerant Ephemeroptera and Plecoptera in the upper reaches of Bear Creek reflects the adverse impact of Y-12 Plant effluents.

Fish communities in Bear Creek a downstream increase in numbers of species, abundance, and total fish standing crops. Thirteen species of fish are present in Bear Creek, with the blacknose dace (Rhinichthys atratulus) and creek chub (Semotilus atromaculatus) being the dominant association.

A complete list of the aquatic species considered by the State of Tennessee to be rare or endangered is provided in Appendix K. A similar list of species, in adjoining counties, is available upon request from the Department of Conservation in Nashville.

5.2.5 Land Use

Because of the proximity of the Oak Ridge and Clinch River sites, land use for both sites is discussed together, in Section 5.1.5.

5.2.6 Socioeconomics

Baseline socioeconomic characteristics for the Oak Ridge site are essentially the same as for the Clinch River site due to geographic proximity. Therefore, the data were combined and presented in Section 5.1.6.

5.2.7 Archaeological and Historical Sites

No comprehensive archaeological survey has been conducted at the Oak Ridge site to determine if archaeological sites are present, and little information is available to assess the probability of prehistoric sites.

Historic sites probably exist since there were structures on the site prior to the Manhattan Project according to TVA maps from that period (TVA 1974a). The existing north-south road in the center of the project area had structures along it, as well as some along Grassy Creek and Bear Creek Valley. No structures more than 50 years old have been identified within the project area.

5.2.8 Aesthetic Characteristics

Aesthetic concerns for the Oak Ridge site are the noise levels generated by construction and operation of the MRS facility and the visual qualitities of the site.

5.2.8.1 Noise Levels

The acoustic setting near the Oak Ridge site consists of natural and human-generated sounds typical of a forested area in a semi-rural/suburban environment. Noise from vehicles passing by on SR-58 and other roads in subdivisions are the greatest contributor the ambient noise level. Heavily loaded coal and gravel trucks produce the greatest noise levels noticeable at residences along the highway. Daily commuter traffic to the Y-12 Plant, ORGDP, and ORNL produce marked temporary changes in the local noise environment.

The nearest residents in the area are within three-fourths mile (1.12 km) of the northeastern boundary of the site in the community of Country Club Estates (about 100 homes). More homes will be located to the east of these homes, according to present development plans. These homes are separated from the site by Pine Ridge, which is up to 100 feet (31 m) higher than the homes.

No ambient noise measurements are known to have been taken in the site vicinity. Typical existing equivalent daytime levels in the Country Club Estates community are expected to range from 40 to 50 dBA for most residences located more than 200 feet (61 m) from the highway. (See Figure 5.2 for a scale of typical noise levels.) At night, the noise background near the Oak Ridge site decreases to about 35 to 40 dBA, with maximum levels of 60 dBA produced by nighttime traffic.

5.2.8.2 Visual Qualities

The Oak Ridge site is located in a long valley paralleled by ridges that are 200 to 400 feet (61 to 120 m) higher than the valley floor. The site is densely forested internally and along most of its perimeter. It is partially visible from the south along an existing power line route on which low vegetation is maintained.

No systematic visual analysis has been done of the site, but an indication of the site's visual aesthetic conditions is presented in Figure 5.17.

5.2.9 Transportation Conditions

The Oak Ridge site is located about 3 miles (5 km) northeast of the Clinch River site; thus, the local transportation systems for the two sites are very similar. The Oak Ridge site is adjacent to Bear Creek Road and within 5 miles (8 km) of the nearest interstate highway, as shown in Figure 5.18.

5.2.9.1 Highways

Major highway routes providing access to the Oak Ridge site are I-40, which extends east-west and connects Nashville and Knoxville; and I-75, which extends north-south and connects Knoxville with Chattanooga and Atlanta, Georgia to the south, and Lexington, Kentucky and Cincinnati, Ohio to the north. SR-58/Gallaher Road/Oak Ridge Turnpike is one of the primary access routes from I-40 to the site. It extends as far south as Chattanooga and ends at White Wing Road/SR-95, west of the site. White Wing Road provides access to Bear Creek Road, which is immediately adjacent to the Oak Ridge site and is closest to the proposed entrance/exit.

The alternative primary access route is east of the I-40/I-75 junction, at their intersection with State Route 162/Pellissippi Parkway. Pellissippi Parkway proceeds northwest to Solway and intersects with SR-62 Oak Ridge Road. SR-62 continues northwest to Bethel Valley Road. Access to Bear Creek Road may be gained by proceeding west on Bethel Valley Road, and then north on Scarboro Road.

Information on Oak Ridge site transportation capacity was presented in Table 5.26 (Clinch River site) for segments of local highways, including annual average daily traffic and level of service. Table 5.32 provides additional information for three roads near the proposed Oak Ridge site.

5.2.9.2 Railroads

A Seaboard System (formerly Louisville and Nashville Railway system) substation is located about 5 miles (8 km) from the Oak Ridge site, and a spur

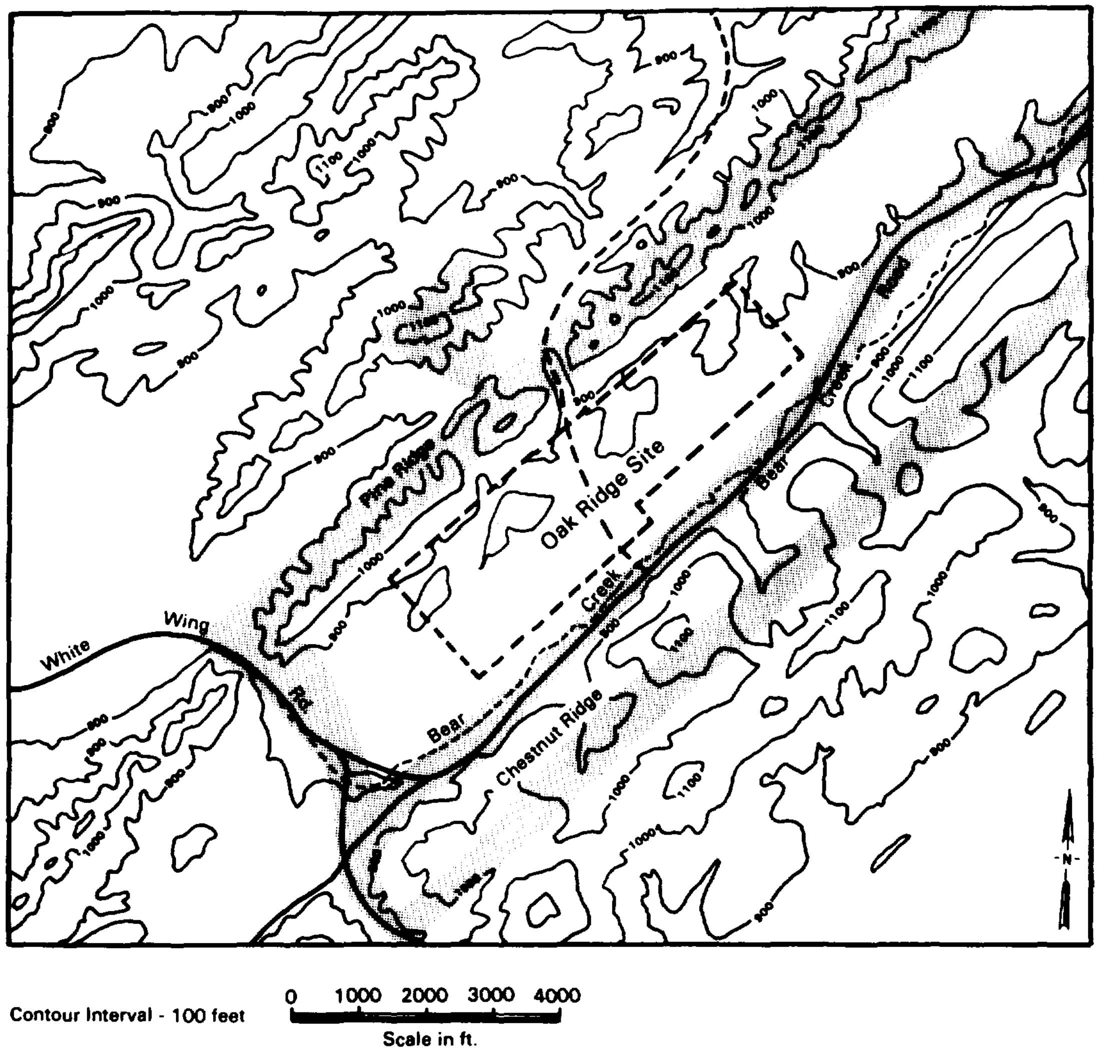

FIGURE 5.17. Viewing Points to the Oak Ridge Site

from the substation serving the Y-12 Plant is approximately 2 miles (3 km) away. The main line of the Southern Railway System is about 10 miles (16 km) northwest of the Oak Ridge site. However, a spur that serves the ORGDP is about 4 miles (6.4 km) from the site.

5.2.9.3 Airports

The location of airports in the vicinity of the Oak Ridge and Clinch River sites is discussed in Section 5.1.9.3.

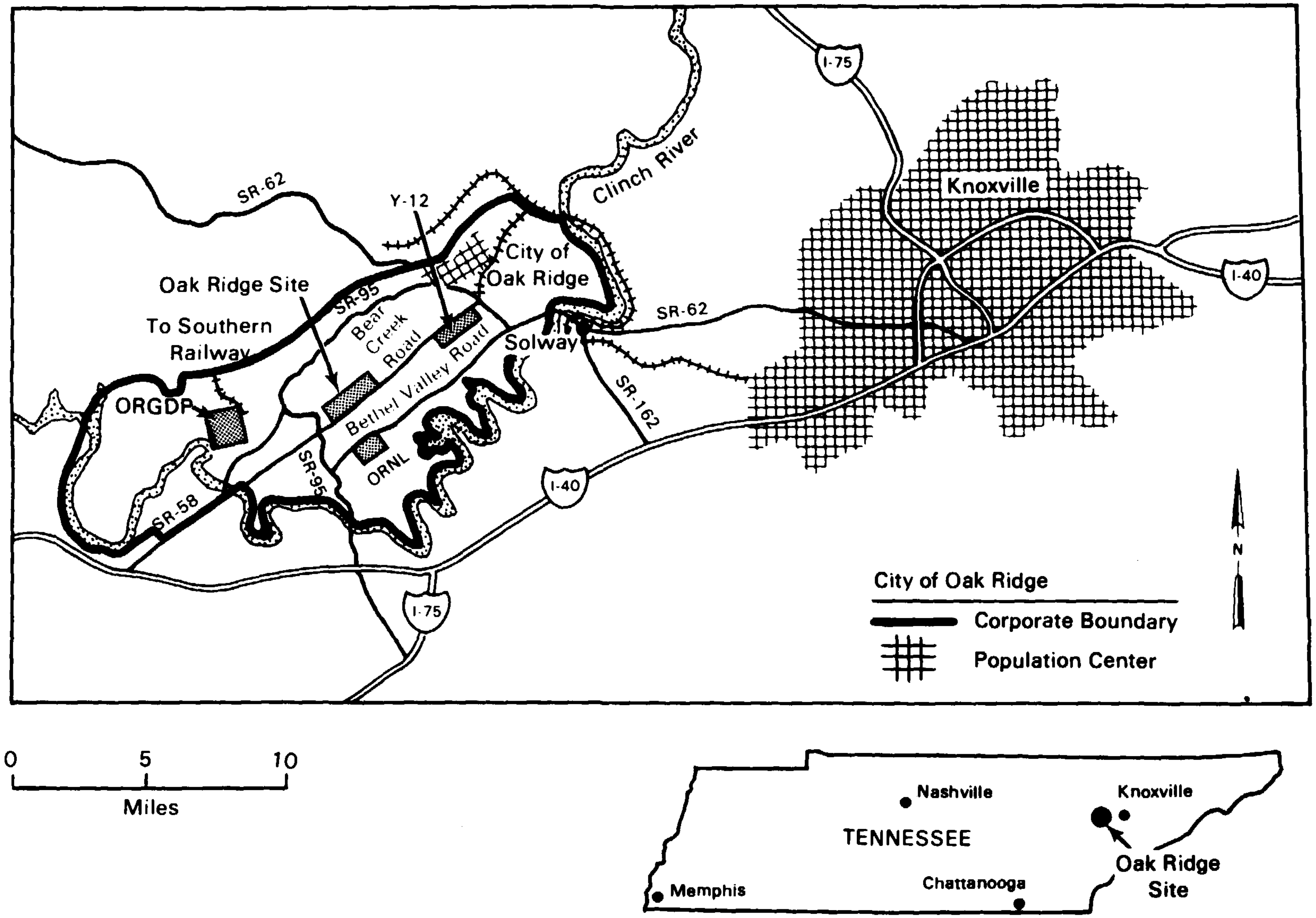

FIGURE 5.18. Oak Ridge Site Transportation System

TABLE 5.32. Characteristics of Roads Providing Access to the Oak Ridge Site

Route Segment	Number of Lanes[a]	Annual Average Daily Traffic (Both Directions)[b]
Bethel Valley Road, East of South Illinois Avenue (SR-62)	2	19,200
Bethel Valley Road, West of South Illinois Avenue (SR-62)	2	4,200
South Illinois Avenue (SR-62), North of Bethel Valley Road	2	16,010

(a) From ORNL (1984).
(b) From DOT (1984).

5.2.9.4 Waterways

The nearest barge terminal is on the Clinch River, approximately 7 miles (11 km) west of the proposed Oak Ridge site. No rail line from the barge dock to the proposed site exists.

5.3 HARTSVILLE SITE

The Hartsville site, located in the central portion of Tennessee, is owned by the TVA (see Figure 5.19). Construction of a four-unit nuclear power plant was initiated at the Hartsville site by TVA. When canceled, none of the units were yet operational. Two of the units were canceled in 1982; the other two were canceled after June 1984.

At present, the TVA is in the process of salvaging equipment and materials from the Hartsville Nuclear Power Plants and is currently using some of the warehouses on the site for central storage and distribution of materials and equipment.

The Hartsville site is in the Nashville or Central Basin physiographic province, within the western forest region. The site is located in north central Tennessee in Smith and Trousdale counties, approximately 140 miles (224 km) northeast of Nashville. The nearest communities are Hartsville, about 5 miles ([illegible] km) to the west, and Dixon Springs, about 1.5 miles (2.4 km) to the east. The site is located on the Cumberland River at approximately RM 285. The site topography (as shown in Figure 5.20) generally consists of low rolling

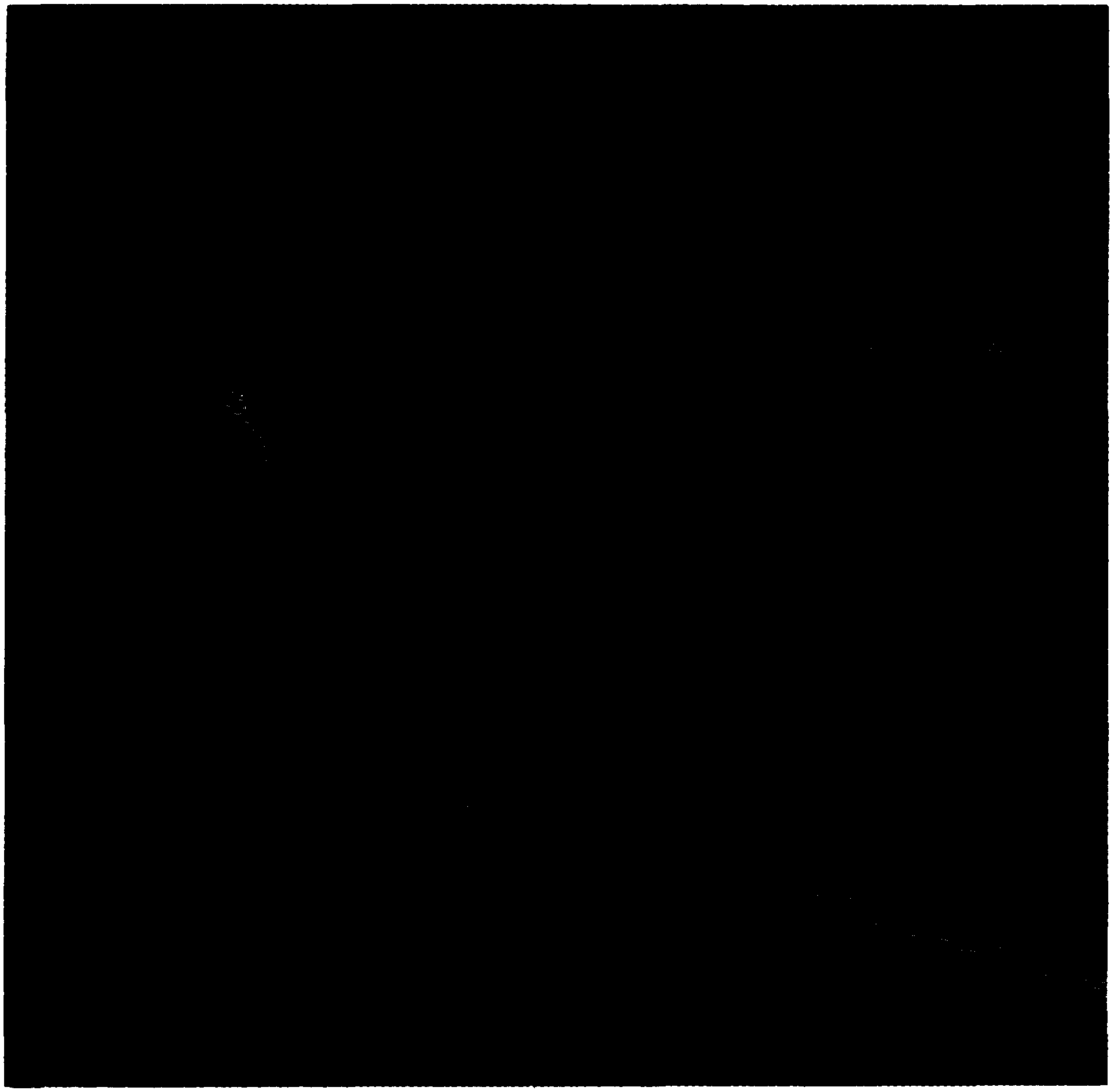

FIGURE 5.19. Aerial Photograph of the Hartsville Site

hills with bottom lands along the Cumberland River and the creeks. Site elevation ranges from 460 feet (140 m) above MSL near the river to approximately 800 feet (244 m) above MSL in the north and northwest portions of the site.

5.3.1 Radiological Characteristics

Background radiation levels of the Hartsville site have been reported in rad, roentgen (R), and rem. Based on the assumption that:

$$1\ R \sim 1\ rad \sim 1\ rem,$$

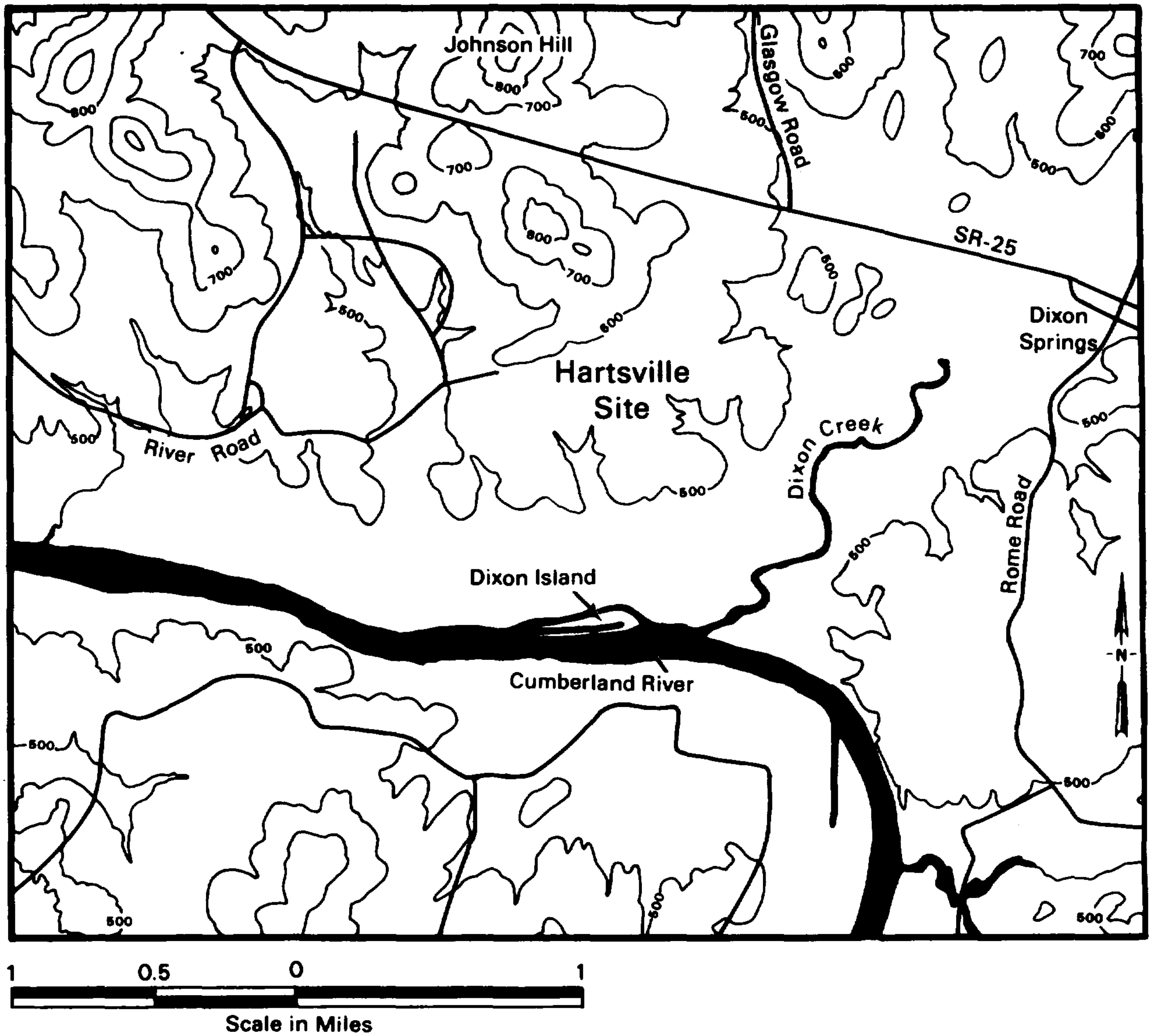

FIGURE 5.20. Topography of the Area Surrounding the Hartsville Site

all radiation levels here have been consistently reported in rem.

Myrick et al. (1981) reported on two measurements made within 50 miles (80 km) of Hartsville site. One measurement, taken 35 miles southwest of the city of Hartsville at East Nashville, was 55 mrem per year. The other, taken about 35 miles southeast of the city of Hartsville [20 miles (32 km) west of Cookeville on I-40], was 27 mrem per year. Oakley (1972) reported on one other value for Nashville: 88 mrem per year (42 mrem per year from cosmic radiation and 46 mrem per year from terrestrial radiation).

Two remote measurements reported were within 55 miles (88 km) of the Hartsville site (Martin Marietta 1984a). At Great Falls Dam, approximately 55 miles (88 km) southeast of Hartsville the level was 60 mrem per year and at Dale Hollow Dam, 55 miles (89 km) northeast of Hartsville, the level was 69 mrem per year.

The range for terrestrial radiation appears to be about 30 to 70 mrem per year, and a value of 50 mrem per year seems to be appropriate for the Hartsville site. This is also almost equal to the one measurement at the largest metropolitan region within 50 miles (80 km) of Hartsville (Nashville, 46 mrem per year). Table 5.33 summarizes these background radiation findings. As for the Clinch River site, the cosmic radiation is about 45 mrem per year (see Section 5.1.1).

5.3.2 Meteorology

The predominant air masses affecting the Hartsville site area may be described as continental and maritime in winter and spring, predominantly maritime in summer, and continental in fall. A summary of 89 years of temperature data collected at the Carthage, Tennessee, Cooperative Observer's Station shows a mean annual temperature of 59.3°F (15°C) with the mean monthly temperature ranging from 39.4°F (4°C) in January to 78.3°F (26°C) in July. The highest temperature on record is 111°F (44°C) in August and the lowest is -18°F (28°C) in February, resulting in an extreme annual range of 129°F (54°C). Normally, 40 days in the year have maximum temperatures of 90°F and above, and 81 days have minimum temperatures of 32°F and below.

Precipitation patterns, based on a 22-year period of data (1951-1972), show that the average annual precipitation is 52.49 inches (130 cm), with the average monthly maximum [5.79 inches (15 cm)] occurring in December and the

TABLE 5.33. Summary of the Background Radiation Sources for the Hartsville Site

Radiation Type	Dose Rate (mrem/yr)
Terrestrial	50
Cosmic	45
Internal	25
TOTAL	120[a]

(a) Fallout radiation adds another 4 mrem/yr to this total.

average monthly minimum [2.72 inches (7.0 cm)] occurring in October. The extreme monthly maximum and minimum are 13.00 inches (33 cm) in March and 0.51 inches (1.3 cm) in October. The maximum 24-hour precipitation is 8.35 inches (21 cm) in August. Rain occurs an average of 110 days per year; snow, four days per year; and fog, 17 days per year.

Appreciable snowfall seldom occurs at the Hartsville site. The average annual snowfall for the approximate 74-year period (1887-1960) is only 7.4 inches (19 cm) and occurs mostly December through March.

Wind is generally from the east-northeast and averages about 8 miles (13 km) per hour; maximum wind speeds of 73 miles (117 km) per hour have been recorded. Severe windstorms may occur several times a year, particularly during the winter, spring, and summer with winds reaching 35 miles (56 km) per hour and occasionally exceeding 60 miles (97 km) per hour. Records show that in a 58-year period (1916-1973), nine tornados were reported in Smith and Trousdale Counties. The probability of a tornado at the site is 0.0012, or a recurrence interval of about 840 years.

The Hartsville site topography, with its shallow valleys and low rolling hills, affects atmospheric dispersion of gaseous effluents with limited confinement within the shallow valley. Dispersion characteristics at the site are given in Appendix G. Dispersion is calculated from joint percentage frequencies of wind direction and wind speed for the Pasquill stability classes.[a] The most stable conditions occur at night, probably because of weaker down-valley or drainage winds at that time. Inversion layers generally cover the region at an elevation of 1,100 to 1,800 feet (350 to 550 m) in the mornings and 3,300 to 5,900 feet (1,000 to 1,800 m) in the evenings.

Air quality monitoring in the vicinity of Hartsville is centered at the Gallatin Steam Plant [Gallatin is about 15 miles (24 km) west of Hartsville]. Concentrations of sulfur dioxide and TSP, which are monitored, do not exceed National Ambient Air Quality Standards. Monitoring data from two TSP monitoring stations and five SO_2 monitoring stations are presented in Table 5.34.

5.3.3 Geology and Hydrology

The geologic and hydrologic characteristics of the Hartsville site are discussed in this section. A brief description of the geology, soils, and seismicty of the Hartsville site is included as background information.

(a) Pasquill stability classes categorize atmospheric conditions into seven classes ranging from "very unstable" to "extremely stable."

TABLE 5.34. Concentrations of Pollutants in the Hartsville (Gallatin Steam Plant) Area (Tennessee Department of Health and Environmental Air Pollution Control Division, Annual Report for 1984)

Pollutant	24-hr Maximum Concentration ug/m^3	Annual Average Concentration	TDAPC Standard	% of Standard
Suspended Particles (TSP) (2 stations)	81-144	34-37	75	45-49
Sulfur Dioxide (SO_2) (5 stations)	102-326	8-24	80	10-30

5.3.3.1 Geology

The Hartsville site is located on the northeast flank of the Nashville Basin section of the Interior Low Plateaus Physiographic Province. The Nashville Basin contains predominantly Ordovician to Mississippian limestone, shale, and sandstone. These sedimentary rock units are relatively flat-lying with only shallow dips. Four rock formations occur at the site: the Leipers-Cathey Formation, the Bigby-Cannon Formation, the Hermitage Formation, and the Carters Limestone (TVA 1974b).

The Leipers-Cathay Formation and Bigby-Cannon Formation are confined to the ridge along the north edge of the site. As a result, most of the MRS facilities would be underlain by the Hermitage Formation and the Carters Limestone. The Hermitage Formation consists of a thin-bedded to laminated, sandy and argillaceous limestone with shale. The thickness of the Hermitage Formation at the site varies from 0 to 40 feet (12 m), depending on surface elevation. Beneath the Hermitage Formation lies the Carters Limestone, a medium- to fine-grained, thin- to thick-bedded limestone with shaly partings. The total thickness of the Carters Limestone in the Hartsville site area is approximately 139 feet (42 m) (TVA 1974b).

The topography across the site is low and rolling, with the exception of a ridge immediately to the north, which rises approximately 300 feet (91 m) above the surrounding site. The general elevation of the land surface slopes gently to the south toward the Cumberland River. Approximately 470 feet (143 m) elevation above MSL, the ground surface is underlain with an average of 12 feet (3.6 m) of residual clay soil overlying bedrock. Below 470 feet (143 m) MSL, thicker accumulations of alluvial sediments overlie bedrock (TVA 1974b).

The Carters Limestone is susceptible to solutioning due to ground-water movement. In areas where the overlying Hermitage Formation is thin or absent, solution cavities are common. The solution cavities typically occur along joint and bedding planes and are partially to completely soil filled (TVA 1974b).

The lithologic characteristics of the Hermitage Formation and the Carters Limestone, as well as other key horizons, allow excellent correlation and structural interpretations. As a result, it has been determined that no active or capable fault exists within the site vicinity.

The greatest reported ground motion at the Hartsville site is estimated to have had a Modified Mercalli intensity of VII to VIII (see Table 5.3) and was a result of the New Madrid earthquakes (of 1811 and 1812) that occurred about 200 miles (320 km) from the site (Parsons 1985). The Hartsville site is located approximately 110 miles (175 km) from the New Madrid Faulted Zone. At this distance, an event such as the New Madrid earthquakes would result in a Modified Mercalli intensity of VIII to IX at the site (Parsons 1985).

The nearest earthquake to the Hartsville site occurred about 20 miles southwest, with a modified Mercalli intensity of III (Parsons 1985). The largest earthquake within 100 miles (160 km) of the site was reported to have had Modified Mercalli intensity of VI (Parsons 1985). The largest known earthquake within the tectonic province (not to be associated with a geologic structure) was the Anna, Ohio, earthquake of 1937. This earthquake had an epicentral Modified Mercalli intensity of VII to VIII (Parsons 1985).

The Safe Shutdown Earthquake for the Hartsville Nuclear Power Plants was determined to result in a ground acceleration of 0.2 G. No capable faults were identified within the site vicinity, and this value is reasonably conservative for the MRS facility.

5.3.3.2 Hydrology

The Hartsville site is located on the north shore of Old Hickory Reservoir on the Cumberland River. This section discusses the characteristics and use of the Cumberland River and other existing surface waters and ground waters near the site.

Surface Water. The Cumberland River is the major surface water body at the Hartsville site, flowing in a general southwesterly direction. The site is located at RM 285, about 10 miles (16 km) northwest of Carthage, Tennessee. The drainage area of the Cumberland River at the Hartsville site is about 10,914 square miles (28,000 km^2). Elevation in the headwaters ranges up to over 4,000 feet (1,200 m). The largest tributary of the Cumberland River is the Caney Fork River, which enters the Cumberland River at RM 309.2 and drains an area of 2,586 square miles (6,698 km^2). Other major tributaries above the Hartsville site are the South Fork Cumberland River, which has a drainage area of 1,382 square miles (3,579 km^2) and enters from the southeast at RM 516; the Obey River, which enters from the southeast at RM 380.9 with a drainage area of 947 square miles (2,453 km^2); and the Rockcastle River, which enters from the north at RM 546.4 and drains 763 square miles (1,976 km^2).

In the immediate vicinity of the site, Dixon Creek enters the Cumberland River from the north at RM 285 and drains 27.4 square miles (71 km^2). Other nearby minor tributaries include Round Lick Creek, which enters from the south at RM 292.4 and drains 85.5 square miles (221 km^2); and Goose Creek, which enters from the north at RM 280.1 and drains 107 square miles (277 km^2). During periods of drought, the minor tributaries experience extreme low flow and many go completely dry (TVA 1974a, 1974b). Cumberland River discharge ranges from 5,980 to 46,600 cfs (167 to 1,300 m^3/sec), with an estimated average flow at the site of 17,000 cfs (480 m^3/sec).

At the site, the elevation of the Cumberland River during the 100-year flood is 469 feet (143 m) above MSL. The probable maximum flood, including dam failure, is 510 feet (156 m) above MSL.

Probable maximum flood levels are as follows (in feet above MSL): Old Hickory Reservoir, 517 feet (158 m); Dixon Creek, 465 feet (142 m); and Unnamed Creek, 468 feet (143 m).

The flood surge level is 540 feet (165 m) above MSL. This level is calculated by assuming instantaneous and simultaneous disappearance of four upstream dams, coincident with extreme precipitation. The analysis also accounts for wind-generated waves.

Surface-Water Use. In addition to electrical power generation, the Cumberland River provides water for public use. The industrial water supplies are approximately 794 million gallons (3 billion L) per day and public water use is aproximately 72 million gallons (280 million L) per day. The city of Nashville is a major user of Cumberland River water [60 million gallons (230 million L) per day].

Surface-Water Quality. Cumberland River temperatures range from 60°F to 71°F (15.5°C to 22°C). The water is slightly basic, with moderate hardness and alkalinity. Total dissolved and suspended solids are fairly low, with low biological oxygen demand. Data taken in the vicinity of the site in 1974 showed good sanitary-chemical quality, but there is some evidence of contamination with low levels of lead, chromium, and cadmium.[a] Mean concentrations of

(a) Levels of zinc and copper are above those specified by Tennessee Water Quality Criteria for Fish and Aquatic Life.