7.0 ASSURANCE REQUIREMENTS

In the Preamble to Title 40 of the Code of Federal Regulations (CFR) Part 191 (EPA 1985) (50 FR 30879), the U.S. Environmental Protection Agency (EPA) points out that

> There are too many uncertainties in projecting the behavior of natural and engineered components for many thousands of years—and too many opportunities for mistakes or poor judgments in such calculations—for the numerical requirements on overall system performance in Subpart B to be the sole basis to determine the acceptability of disposal systems for these very hazardous wastes.

In view of this, the EPA developed assurance requirements (40 CFR § 191.14) to ensure that implementing agencies act cautiously and take steps to reduce the impacts of these uncertainties. According to the EPA, these assurance requirements are considered an essential complement to the containment requirements, which, when implemented, should ensure that the level of protection desired by the EPA is achieved. Contained in 40 CFR § 191.14 are these six separate assurance requirements:

- active institutional controls,
- monitoring,
- passive institutional controls,
- use of different types of barriers,
- resource disincentives, and
- waste removal.

Figure 7-1 provides a timeline illustrating the implementation of these assurance requirements. Waste removal is not included in Figure 7-1 because it is not a planned activity. Waste removal is discussed in Appendix WRAC. See Table 1-7 in Chapter 1.0 for a list of appendices that provide additional information supporting this chapter.

The provisions of 40 CFR Part 194 (EPA 1996a) contain detailed criteria that the U.S. Department of Energy (DOE) is to use in implementing the assurance requirements contained in 40 CFR Part 191. The following sections detail the DOE's compliance with the assurance requirements of 40 CFR Part 191 and the associated certification criteria in 40 CFR Part 194. In addition to addressing the six assurance requirements stated above, the DOE used some conservative assumptions in the performance assessment that provide additional assurance. Use of conservative assumptions in the performance assessment is discussed in Section 6.5.4.

7.1 Active Institutional Controls

Active institutional controls and passive institutional controls satisfy two roles:

(1) they meet assurance requirements per 40 CFR Parts 191 and 194, and

(2) they contribute to performance assessment per 40 CFR Part 194.

Once the facility at the Waste Isolation Pilot Plant (WIPP) is decommissioned and decontaminated (D&D), positive actions (active institutional controls) will be taken to ensure site access control. Active institutional control begins after final facility closure. The EPA has specified that no more than 100 years of active institutional controls can be assumed in predictions of long-term performance. The DOE interprets this requirement to mean that control programs should be implemented as long as such controls are useful and practical, but credit for active institutional controls cannot be considered in the performance assessment beyond 100 years from the final closure of the repository. Therefore, performance assessment does not consider credit for active institutional controls beyond 100 years.

The EPA defines active institutional controls as "(1) controlling access to a disposal site by any means other than passive institutional controls, (2) performing maintenance operations or remedial actions at the site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance" (40 CFR § 191.12). Active institutional controls to be used by the DOE include facility guarding, evaluation of land use in the area, postoperational monitoring, land reclamation, and maintenance of fences and buildings. In addition, active institutional controls are integrated with the D&D activities that are described in Appendix D&D.

7.1.1 Requirements for Active Institutional Controls

In prescribing active institutional controls, the EPA has specified that "active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal" (40 CFR § 191.14[a]). The EPA addresses the effectiveness of these controls and the length of the time for which such controls should be considered effective for the performance assessment.

Section 194.41(a) specifies that "any compliance application shall include detailed descriptions of proposed active institutional controls, the controls' location, and the period of time the controls are proposed to remain active." Section 194.41(a) also states that any assumptions pertaining to the effectiveness of active controls in preventing inadvertent human intrusion should be supported by such descriptions. This section provides support for the assumptions pertaining to the active institutional controls program for the WIPP facility. Prior to decommissioning of the facility and full implementation of the active controls program, the DOE will reevaluate the proposed active controls program and make any changes necessary as indicated by experience and evaluation of data. The design of the DOE's active controls program is described in Appendix AIC.

For the purposes of this application, the DOE will begin the active controls period within sixty days of completion of final facility closure. This start point will be simultaneous with the

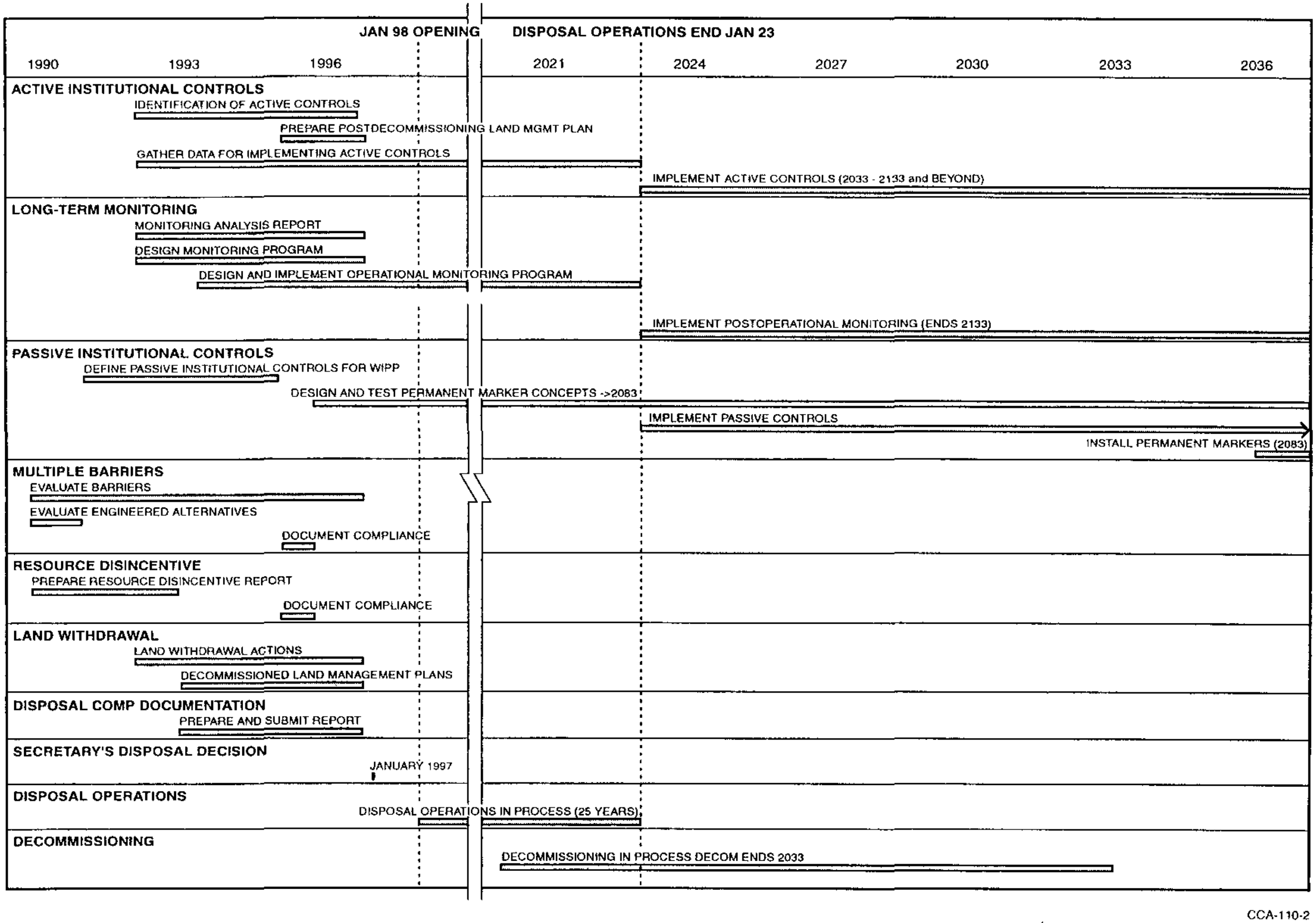


Figure 7-1. Implementation Timeline

THIS PAGE INTENTIONALLY LEFT BLANK

initiation of the postclosure care period mandated under the closure plan submitted to the New Mexico Environment Department (NMED) with the hazardous waste facility permit application.

7.1.2 Objectives for Active Institutional Controls

The primary goal of DOE's active institutional controls program is to prevent unauthorized use of the WIPP site. Because of the massive body of rock that separates the waste from the accessible environment, there are not many activities that pose a threat to the WIPP disposal system. The threats that are severe enough or likely enough to consider are addressed in Appendix SCR and in the conceptual models description located in Section 6.4. The DOE has identified four objectives for the design of the active controls program: (1) eliminating those site features that would cause future populations to develop the WIPP site (see Section 7.1.3.1), (2) identifying allowed and disallowed activities, (3) identifying and minimizing the impacts of the intentional user, and (4) controlling allowed activities and preventing unallowed activities. In addition, the DOE will install and protect monitoring equipment and any test facilities established for evaluating the long-term marker system.

In order to design an active controls program around these four objectives, the DOE has assumed the following:

- site restoration will be to as near the original condition as practicable,
- future authorized site uses will not be significantly different than they are now, as described in Appendix LMP, and
- a threat of future unauthorized use exists.

Restoration of the WIPP site includes any activities associated with demobilization following D&D. In addition, as part of the active institutional controls program, the DOE will implement monitoring systems suitable for assessing disposal system performance. The objectives of the active institutional controls program, the monitoring program, and the decommissioning plan overlap; therefore, the DOE believes it is both prudent and within the EPA's intent to conduct these programs simultaneously. This provides for a more comprehensive understanding of the multitude of activities that will be taking place during the active controls period.

7.1.3 Implementation of the Active Institutional Controls Program

The first step in the process of implementing the active institutional controls program was to identify measures needed to satisfy the active institutional controls requirements. Certain characteristics of active institutional controls measures have been identified, such as minimizing features that would attract future development of the site, warning of potential hazards through signage, implementing the measures for at least 100 years, addressing the standards, and preventing development. These characteristics were used to develop conceptual designs for active institutional controls.

Some active institutional controls were obvious at the outset, including site access control, site remedial actions, site maintenance, and site monitoring. Information and specifications useful in implementing these and possibly other controls have been gathered (see Appendix LMP). A detailed explanation of the resulting active institutional controls is provided in Appendix AIC (Section 2). The design will be reviewed periodically and updated as appropriate during WIPP's operations phase. Ongoing review and evaluation will ensure that the active institutional controls implemented are appropriate for the conditions that may exist at that time. The DOE will review the design prior to implementation and the recertification process will be used as a vehicle for modification to include any future enhancements. Any recertification will be accomplished in accordance with the requirements of the Land Withdrawal Act (LWA) and the provisions of 40 CFR Part 194.

The final operational activity at the repository will be closing the waste disposal area and sealing the shafts. All surface structures, except for the concrete hot cell structure (Appendix AIC), and a sufficient quantity of salt tailings to support construction of the permanent marker berm (Appendix PIC) will be removed and the site regraded and revegetated to as near its original condition as practicable. In addition, those structures erected during the disposal phase, as part of the permanent marker testing program (Section 7.3.3.2), will also remain in place after decommissioning. These will include a section of the berm, the salt filled trench that will serve as the berm base, and at least one monument marker used in long-term materials testing for the permanent marker system.

In order to determine the active controls that would be beneficial, the DOE analyzed the types of land uses anticipated and, based on that analysis, developed a design plan for active institutional controls. The following two sections summarize the analysis and the design plan.

7.1.3.1 Analysis of Activities

The purpose of the analysis of activities is to determine the types of disturbances that may be associated with each activity, the depth of such disturbances, and the need for any mitigation of these activities. These activities are supported with screening decisions in Appendix SCR. This section addresses the following activities:

- ranching,
- farming,
- hunting,
- scientific activities,

- utilities and transportation,
- groundwater pumping,
- surface excavation,
- potash exploration,
- hydrocarbon exploration,
- construction, and
- hostile and illegal activities.

Table 7-1 indicates the active institutional controls that will be applied to prevent unauthorized activities.

7.1.3.1.1 Ranching

Description of the Activity: Ranching involves the management of herds of cattle on the public lands surrounding and including the WIPP. These activities are regulated on federal lands such as the WIPP under a permitting process administered by the Bureau of Land Management (BLM). There is little surface-disturbing activity associated with ranching except for the construction of fences, the construction and operation of watering facilities, and the occasional drilling of groundwater wells. Currently, only the 277 acres within the Exclusive Use Area are not used for ranching. In the future, barbed wire enclosures will be constructed to provide security for monitoring facilities, test areas, and construction areas. Eventually, the entire surface is expected to be released for ranching activities. Only those activities associated with groundwater use could have any impact on the disposal system. These are discussed in Section 7.1.3.1.6. Figure 7-2 depicts the current grazing allotments on the WIPP site.

Goal of Active Controls: Active controls will ensure that grazing leases are administered consistently and in compliance with applicable regulations. Fencing will be needed to protect government property. In addition, areas will be fenced as needed to prevent cattle from disturbing reclaimed areas until vegetation has been reestablished.

7.1.3.1.2 Farming

Description of the Activity: Farming includes soil preparation, planting, irrigation, and harvesting. Significant quantities of water are needed to support crops in the Delaware Basin. Crops grown in the farming area nearest to the WIPP include cotton, alfalfa, peppers, and pecans. Small quantities of other crops are also grown. Farming using irrigation would require access to large amounts of fresh water, either through the diversion of surface water or

Table 7-1. Effectiveness of Active Controls Activities

Activities / *Active Institutional Control*	Ranching	Farming	Hunting	Scientific Activities	Utilities and Trans-portation	Ground-water Pumping	Excav-ation	Potash Explor-ation	Hydro-carbon Explor-ation	Construc-tion	Hostile and Illegal Activities
Land Management Plan	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Fence	▨	▨	▨				▨			▨	▨
Roadway				▨	▨	▨					
Signs		▨	▨		▨		▨	▨	▨	▨	▨
Contract for Inspec-tion and Maintenance	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Security Surveillance	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Testing				▨	▨						
Disposal System Monitoring				▨		▨					
Permanent Marker System Installation				▨							
Response	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Reporting	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

▨ indicates component addressed by active controls

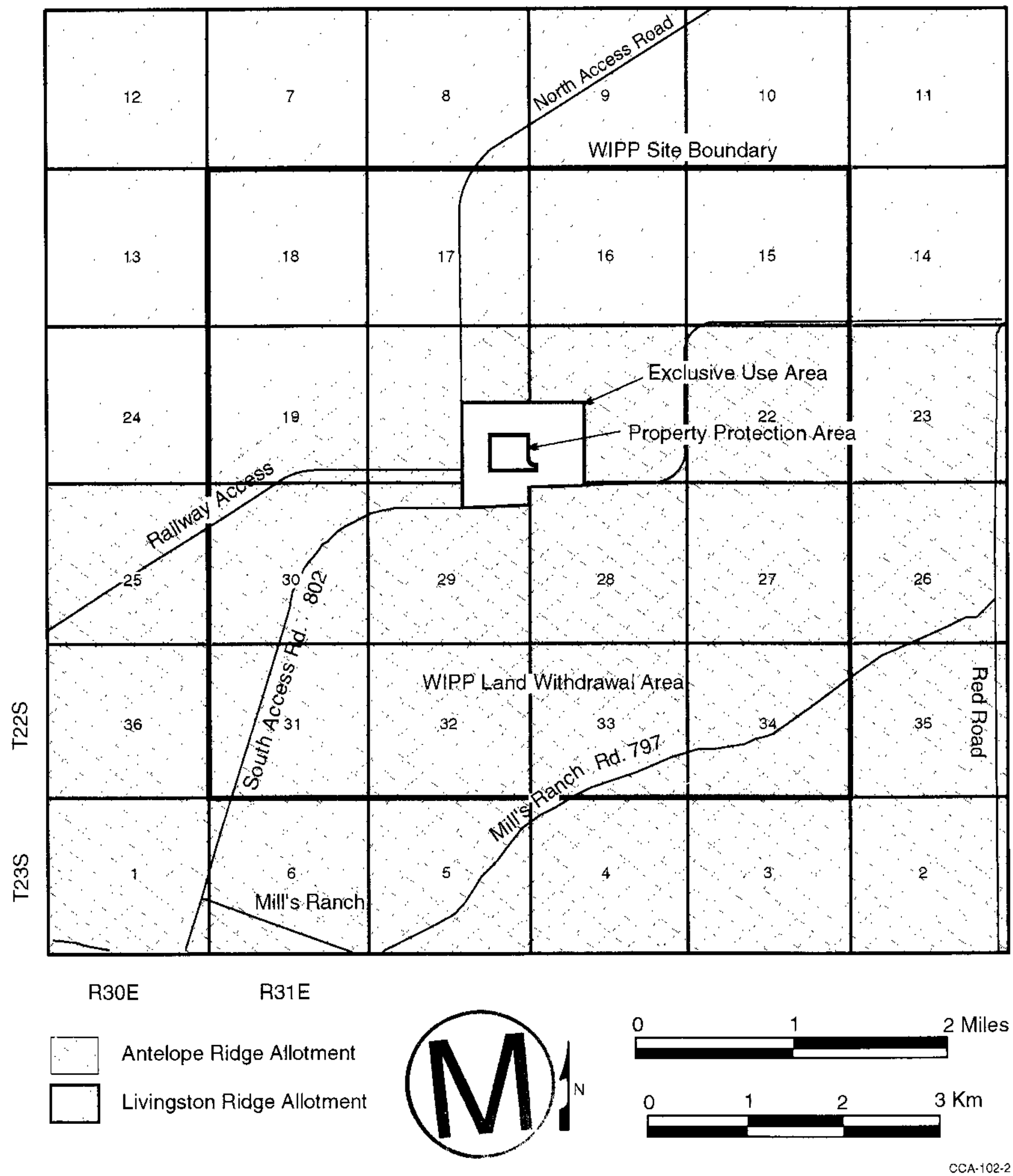


Figure 7-2. Grazing Allotments on the WIPP Site as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

the construction of groundwater wells. There is currently no known farming near the WIPP because of the lack of good quality water and the poor soil composition. Farming, therefore, is screened out of the performance assessment on the basis that any impacts are of low consequence to the disposal system (see Appendix SCR, Section SCR.3.8.1).

Goal of Active Controls: While farming is unlikely, the land management plan, fence, signs, and other measures will prevent farming activities from disturbing test areas or affecting monitoring locations.

7.1.3.1.3 Hunting

Description of the Activity: Currently, hunting occurs outside the WIPP Off Limits Area. The prohibition from hunting is mandated by DOE policy. Unless the restrictions are lifted, hunting will continue to be prohibited in this 1,454-acre (590-hectare) area. The restriction has been placed to provide protection for facilities and personnel working at the WIPP. Game animals in the vicinity include deer, small mammals, and birds. There are no hunting activities that are anticipated to impact the disposal system. Figure 7-3 depicts the area within the WIPP site boundary where hunting is allowed.

Goal of Active Controls: Protection of facilities and personnel engaged in monitoring, reclamation, and testing activities will be needed throughout the active controls period. Local and state hunting laws and restrictions will apply.

7.1.3.1.4 Scientific Activities

M

Description of the Activity: Scientific activities can include both those conducted by the DOE for the WIPP and those conducted by outside organizations. Types of activities include archeological investigations, wildlife studies, vegetation studies, grazing studies, geomorphic studies, passive marker testing, passive marker construction, hydrologic studies, disposal system monitoring, and others. Prolonged studies of vegetation, geomorphic features, or grazing impacts may require the construction of fenced enclosures. Some may involve the placement of monitoring or other types of equipment or monuments that need to be protected from vandalism.

Goal of Active Controls: In the case of scientific studies, active controls will ensure that scientific activities can proceed undisturbed without impacting the disposal system. Specific needs for protection may be identified with each study proposed for the area.

7.1.3.1.5 Utilities and Transportation

Description of the Activity: Currently, the WIPP site is traversed by several pipelines (natural gas), buried telephone lines, power lines, a highway, and a railroad. Future transportation needs are expected to remain the same. Construction and maintenance of utilities and transportation facilities involve significant surface-disturbing activities.

However, they are confined to the upper several meters of soil and will not impact the disposal system. Currently, the construction of utilities and transportation facilities are controlled by a permitting process administered by the DOE for the WIPP and the BLM for other federal lands. The BLM ensures that operators remain within designated rights-of-way and that they comply with applicable environmental protection regulations. Figure 7-4 depicts the current rights-of-way that have been granted for utilities or transportation on the WIPP site.

Goal of Active Controls: Active controls will ensure that utility and transportation activities are conducted in a manner that is consistent with permits and that locations are selected to avoid conflicts with permanent markers. Measures, such as fences, may be needed to provide mutual protection for personnel, livestock, and rights-of-way uses.

7.1.3.1.6 *Groundwater Pumping*

Description of the Activity: Groundwater wells are drilled for several uses near the WIPP. The most common use within the controlled area is in support of the WIPP groundwater monitoring program. These wells generally target waters in the Dewey Lake Redbeds and the Santa Rosa Formation. Before a groundwater well can be drilled, a permit must be obtained and the State Engineer must be notified of the final well configuration and its use (see Appendix USDW). Wells are abandoned in accordance with state regulations that govern the plugging of such wells (see Section 3.3.4). Groundwater well drilling unrelated to the DOE is prohibited by the LWA within the WIPP site boundary. Figure 7-5 shows the location of groundwater wells within the WIPP site boundary.

Goal of Active Controls: The active controls program will ensure that the prohibition on drilling groundwater wells and fluid injection within the WIPP site boundary is enforced and that those wells that currently exist, or that are drilled to support future WIPP activities, are plugged and abandoned in accordance with applicable regulations.

M

7.1.3.1.7 *Surface Excavation*

Description of the Activity: Both sand and caliche are mined locally for use in construction. Mining for sand and caliche is always limited to surface quarries. To mine these materials on public lands, a permit must be obtained from the DOE or the BLM. The permit limits the quantity that can be removed and specifies appropriate environmental protections, including reclamation. Sand or caliche removal will have no impact on the disposal system (Appendix SCR, Section SCR.3.4.1).

Many surface quarries within the WIPP site boundary have been remediated, which included recontouring the surface and planting vegetation. Others will be remediated either during the operational phase or as part of postdecommissioning land management. The development of surface quarries unrelated to the DOE is prohibited by the LWA. Figure 7-6 shows the location of surface quarries within the WIPP site boundary.

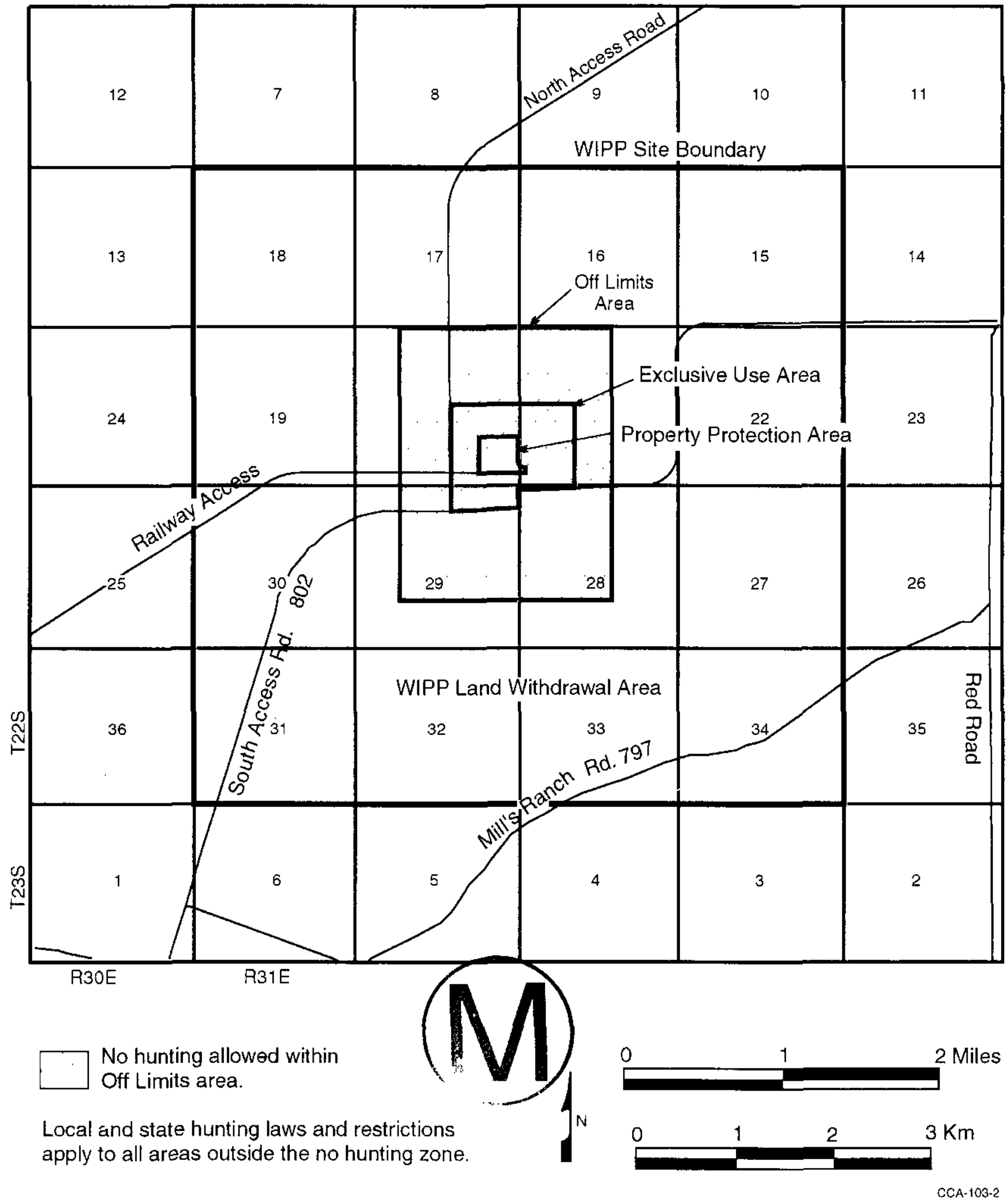


Figure 7-3. Area Where Hunting is Permitted Within the WIPP Site Boundary

THIS PAGE INTENTIONALLY LEFT BLANK

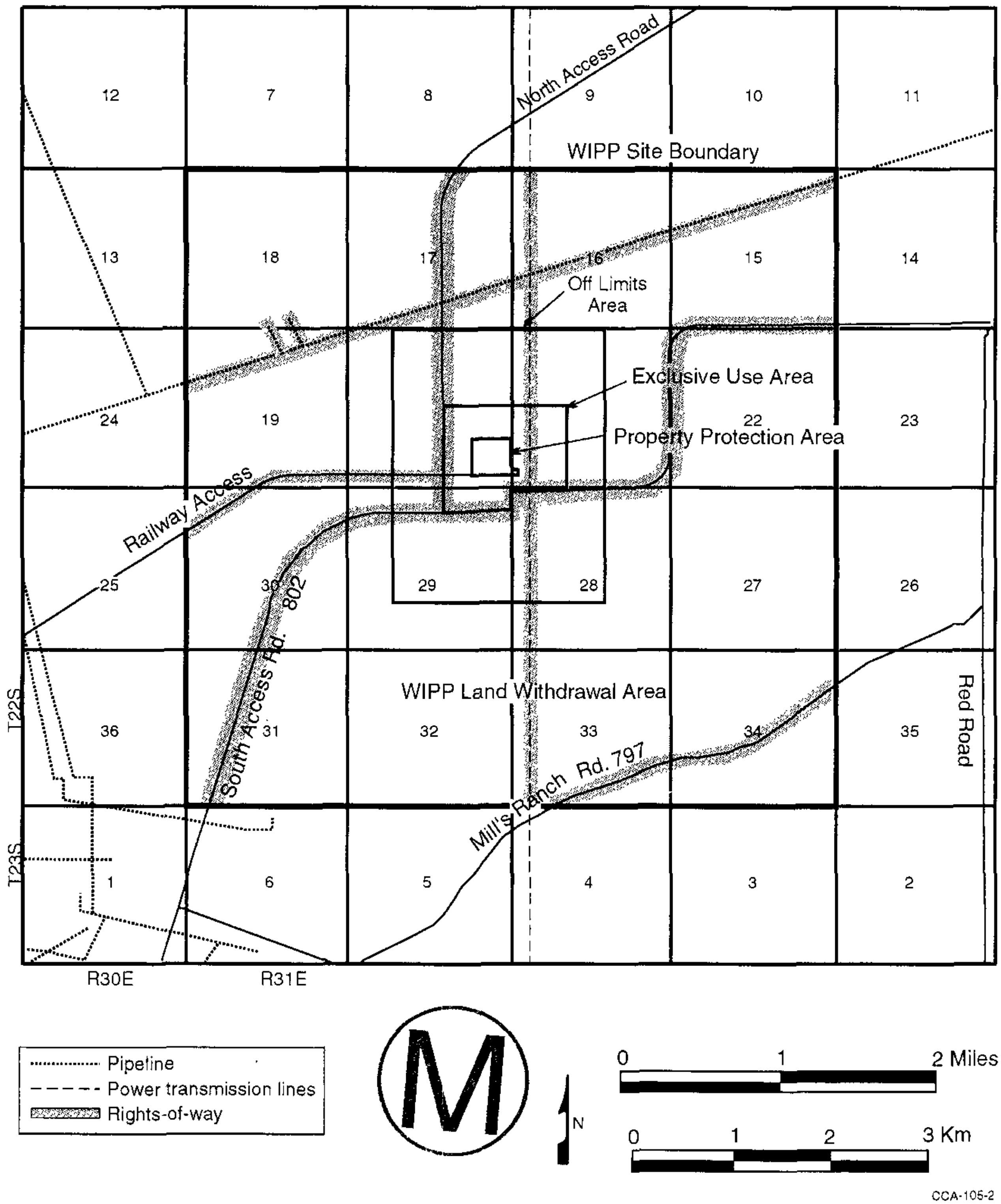


Figure 7-4. Location of Rights-of-Way Within the WIPP Site Boundary as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

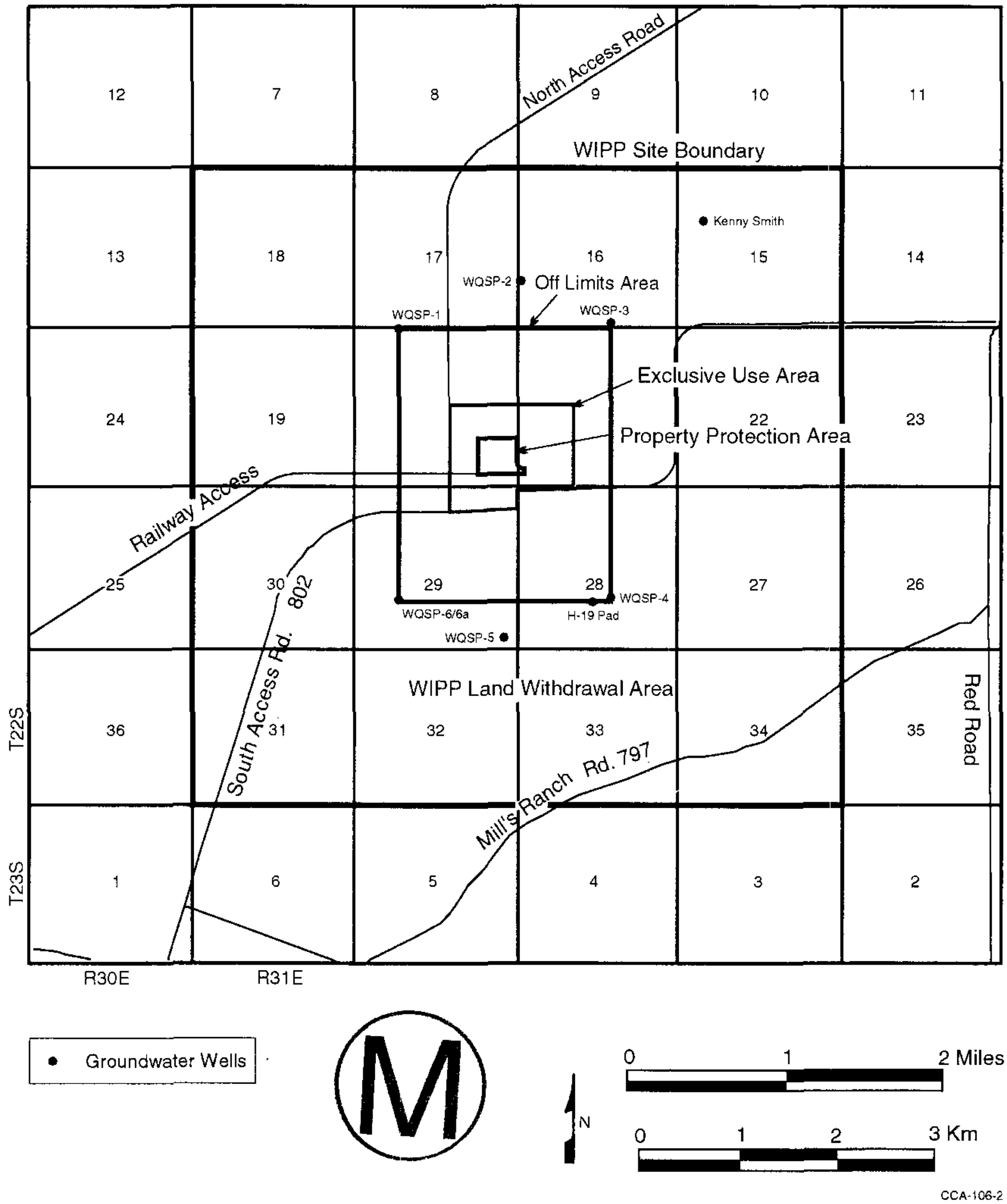


Figure 7-5. Location of Groundwater Wells Within the WIPP Site Boundary as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

Ⓜ

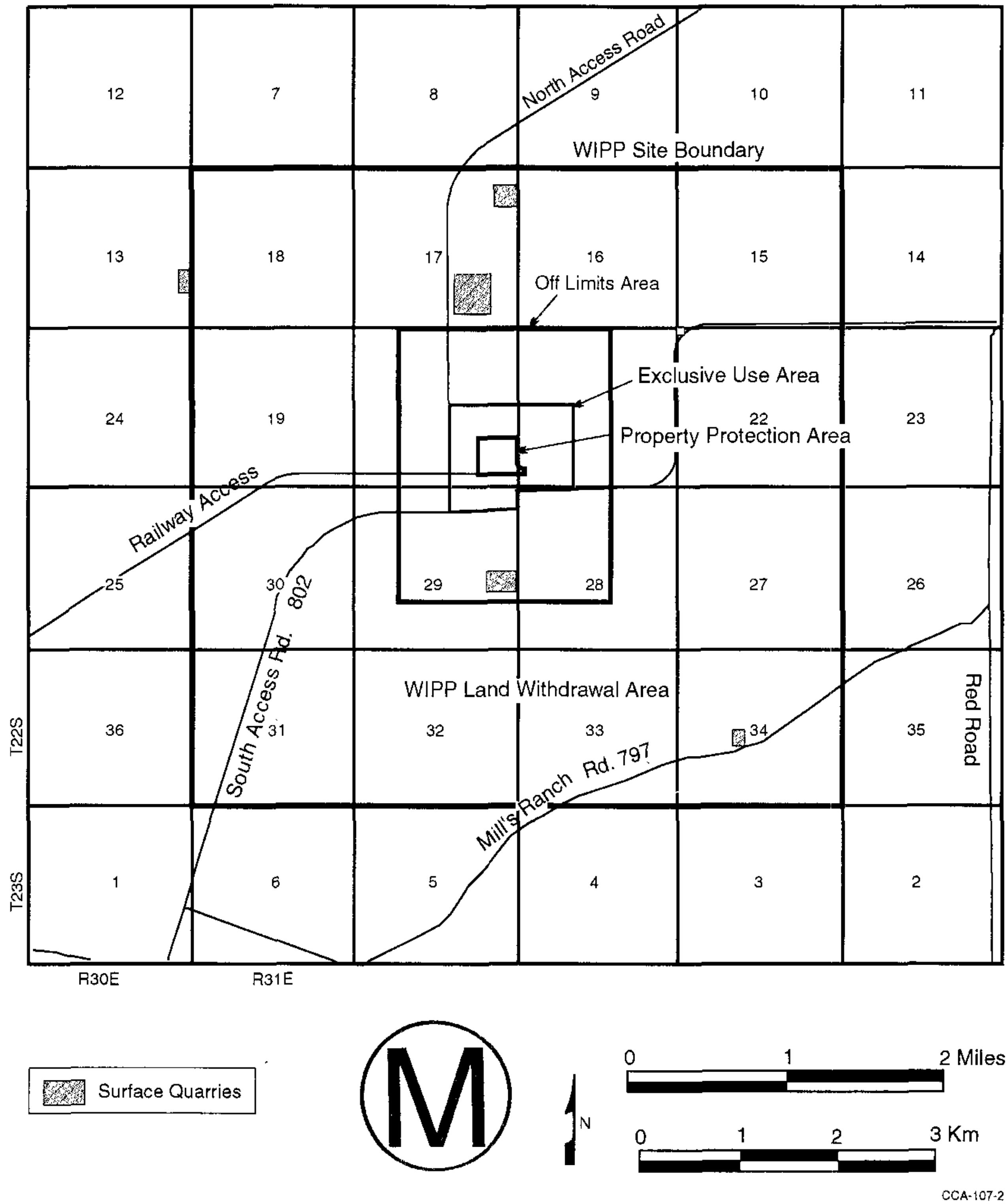


Figure 7-6. Location of Surface Quarries Within the WIPP Site Boundary as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

Goal of Active Controls: The objective of the DOE with respect to surface excavation is to ensure that the development of mineral leases does not affect the integrity of the disposal system. In accordance with the LWA requirement that no surface or subsurface mining unrelated to the DOE may be conducted within the boundaries of the land withdrawal area, the DOE and the state of New Mexico have entered into a memorandum of understanding (MOU). This MOU dictates that the state will forward any mining and reclamation plans to the DOE for review and comment in determining issuance of such permits within one mile of the withdrawal area boundary. In addition to the commitments in the MOU, the DOE will conduct perimeter surveillance and evaluate potential encroachment of ancillary activities associated with mines.

7.1.3.1.8 *Potash Exploration and Extraction*

Description of the Activity: Potash mineralization is known to exist beneath the WIPP site (see Section 2.3.1.1). The extent of mineralization is generally determined through the drilling of core holes and the examination and analysis of rock cores. Sufficient core holes have already been drilled within the WIPP site boundary to characterize the resident mineralization. Future drilling, however, is prohibited by the LWA. Holes drilled for the exploration of potash must be closed in accordance with state or federal regulations, depending on the location of the potash lease (see Appendix DEL, Section DEL.5.5). The closure of potash holes within the WIPP site boundary is discussed in Section 3.3.4.

Extraction of potash in the Delaware Basin is accomplished through the use of conventional underground mining technologies. Development of resources within the WIPP site boundary would require that a mine be built in the vicinity or that an existing mine be expanded to include the WIPP. Potash mining is conducted in accordance with the rules and regulations of the BLM on federal lands and the state of New Mexico on state lands. The impacts of mining are evaluated in the performance assessment in accordance with the requirements of 40 CFR § 194.32(b) and are discussed in Section 6.4. Figure 7-7 shows a map of the distribution of potash exploration holes and the extent of currently economically minable reserves.

Goal of Active Controls: The active controls program will ensure that mineral leasing and development within the WIPP site boundary are prevented and that existing or near future mines do not encroach on the site.

M

7.1.3.1.9 *Hydrocarbon Exploration*

Description of the Activity: Hydrocarbon resources are assumed to exist below the WIPP site. The amount of these resources and their locations are projected from information that the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) report compiled and interpreted for the DOE in 1995. (See Section 2.3 for a discussion of this report.) Exploration companies use surface-based geophysical techniques to determine likely locations for hydrocarbon accumulations and then investigate the prospect using deep drilling. Both the geophysical and the drilling activities have historically occurred on the WIPP site, but further drilling is prohibited by the LWA. Figure 7-8 shows the location of hydrocarbon wells within the WIPP site boundary.

Goal of Active Controls: The active controls program will ensure that the prohibition on the drilling of hydrocarbon wells is enforced. In addition, the BLM and the state of New Mexico will administer permits to perform geophysical investigations.

7.1.3.1.10 *Construction*

Description of Activity: The construction of a permanent building typically involves activities that disturb the surface only to a depth of a few meters, with the exception of the drilling of a groundwater well. Construction is currently prohibited by the DOE for public protection reasons during disposal operations. Because the WIPP site is federally owned, only federal facilities can be built there and any construction will require federal permits. After the conclusion of operations and during the active institutional controls period, construction will not be allowed within the areas reserved for the permanent marker system.

Goal of Active Controls: Controls will ensure that construction does not occur within the WIPP site boundary prior to the end of the active institutional controls period and that no construction will interfere with the goals of the passive controls system.

7.1.3.1.11 *Hostile and Illegal Activities*

Description of Activity: Activities in this category include vandalism, sabotage, theft, and artifact hunting. All of these activities are prohibited by federal and state law. None is expected to have an impact on the disposal system, although they could impact monitoring efforts, the construction and preservation of permanent markers, the integrity of fences and test areas, and other authorized uses.

Goal of Active Controls: Active controls will prevent the occurrence of hostile and illegal activities to the extent practicable within the WIPP site boundary. Controls may include access control and other security measures.

7.1.3.2 Active Controls Design Features

Based on these possible land uses, the DOE has specified the following design features for the active controls system. Additional detail is presented in Appendix AIC (Section 1).

- Signage will be established to control access to the WIPP site. A fence will be erected along the perimeter of the repository surface footprint. The fence will have gates placed approximately midway along each of the four sides.

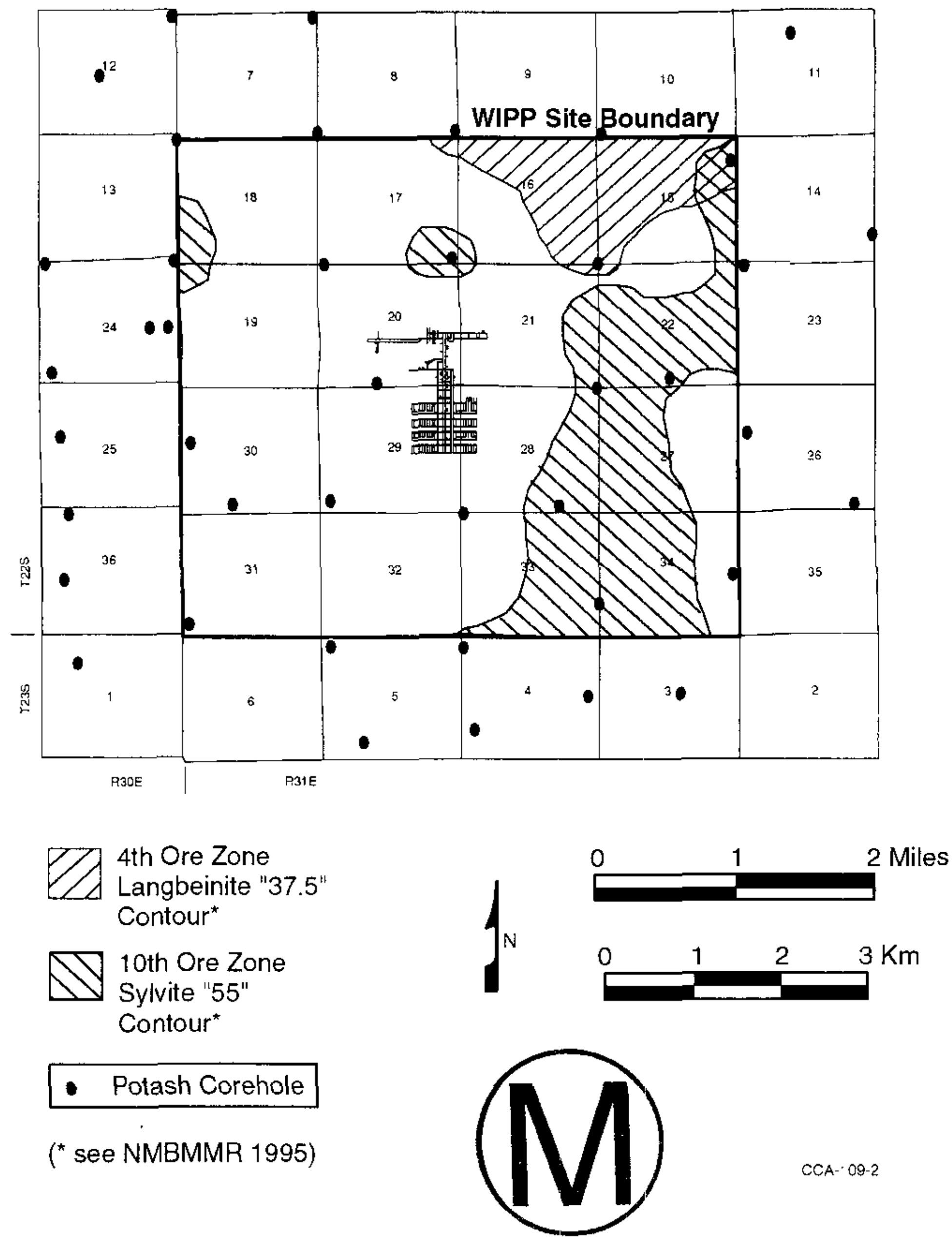


Figure 7-7. Location of Potash Exploration Holes and Economically Mineable Potash Within the WIPP Site Boundary as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

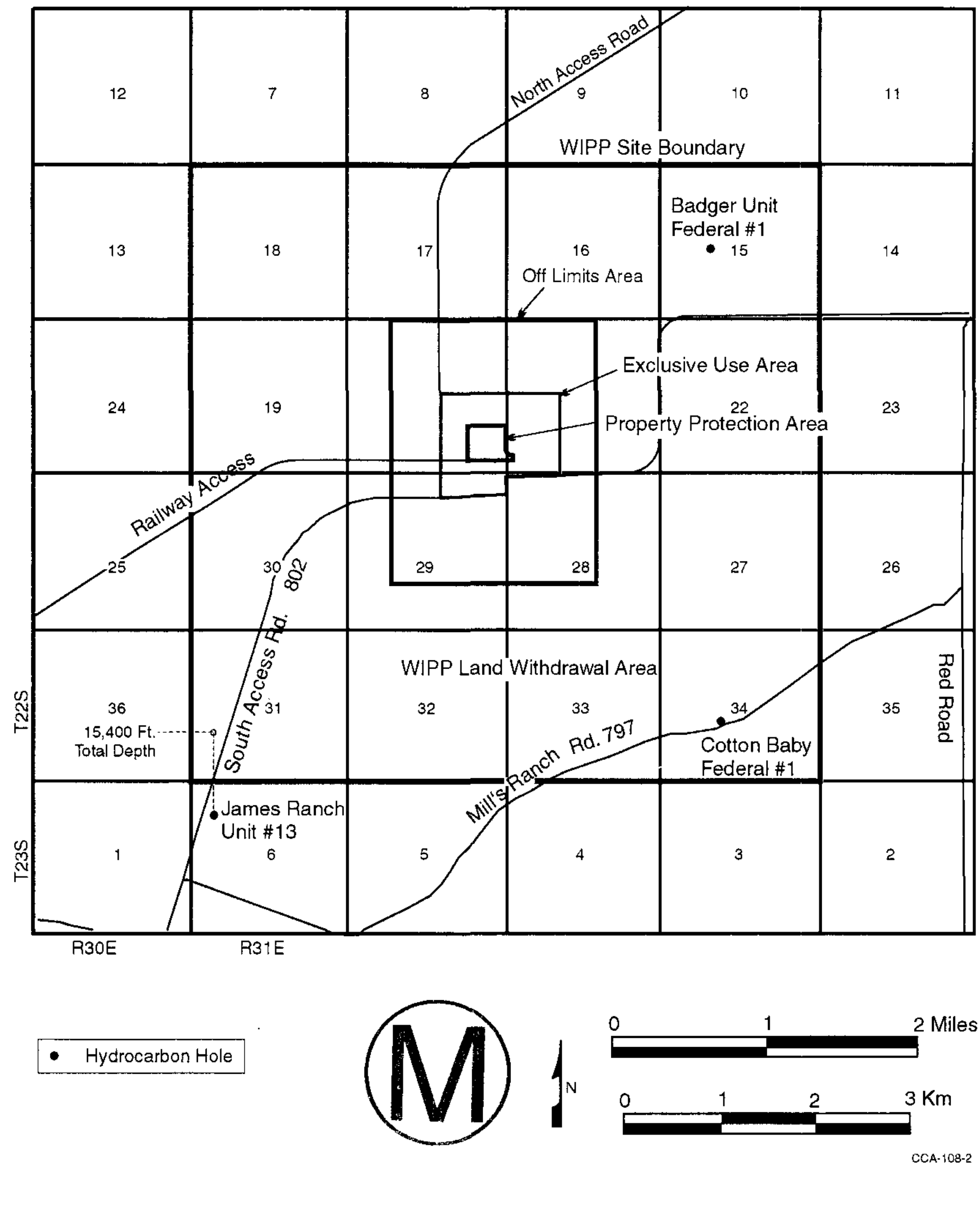


Figure 7-8. Hydrocarbon Holes Located Within the WIPP Site Boundary as of October 1996

THIS PAGE INTENTIONALLY LEFT BLANK

- Roadways will be constructed as needed to provide easy visual inspection and ready vehicle access to any point around the fenced perimeter and to facilitate maintenance of the fence line. These roadways will connect to the paved south access road.

- The fence line and the WIPP site perimeter will be posted with signs having as a minimum a legend reading "Danger—Unauthorized Personnel Keep Out" and a warning against entering the area without specific permission of the DOE. Signs prohibiting hunting will also be posted as appropriate. In addition, the DOE will include the area in the local one-call system.

- Periodic inspection and necessary corrective maintenance will be conducted on the fence line, associated warning signs, and the roadways.

- Routine periodic patrols and surveillance of the WIPP site by personnel trained in security surveillance and investigation will be established and maintained.

- A process will be developed and implemented for monitoring and controlling the long-term testing of the permanent marker system.

- Upon installation of the permanent marker system, the active institutional controls program will be revised as deemed appropriate.

- Guidelines will be developed for identifying and implementing the appropriate corrective measures to address any abnormal conditions identified during periodic surveillance and inspections.

- Reports of activities associated with the postdisposal active access controls will be prepared in accordance with regulatory requirements for submittal to the appropriate regulatory and legislative authority.

7.1.3.3 Description of Active Institutional Controls Features

Most of the active institutional controls measures, such as long-term site monitoring and site remedial actions, will be implemented simultaneously with facility closure and D&D. It may be possible, however, to implement some measures earlier. For example, salt disposal may begin prior to final facility closure. Reclamation and restoration of unused disturbed surface areas have already begun. Guarding and maintenance activities, which are in place, could evolve into an appropriate type of postclosure activity.

During the disposal phase, the DOE will manage and store waste in a manner that limits the public's exposure to radiation to the standards of 40 CFR Part 191, Subpart A. Subsequent to disposal and after shafts are backfilled and sealed, radioactive releases to the accessible environment, exposures to humans, and concentrations in groundwater cannot exceed the standards of 40 CFR Part 191, Subparts B and C. The periods of active and passive institutional controls begin when the disposal phase ends, and according to the EPA, run concurrently for at least 100 years. Also per the EPA, after 100 years, credit for active controls must end, but credit for passive controls may continue for up to 700 years after final facility closure.

The active controls program design described above is implemented through the following components. Additional detail is provided in Appendix AIC (Section 2):

- Signage that indicates the areal extent of the WIPP and a fence that restricts access to the repository footprint, respectively, and includes the area in which the passive markers will be constructed. This area (shown in Figure 7-9) is referred to as the repository footprint and represents the surface projection of all areas underground that contain waste. Note that additional fencing may be needed for remote locations that are used for disposal system monitoring. Such fences will meet the same construction specifications as those for the perimeter footprint.

- A 16-foot (4.9 meter) wide roadway around the perimeter of the WIPP site boundary. Roads to remote sites will also be constructed and maintained as needed.

- Surveillance that includes drive-by patrolling two or three times per week. This frequency will be sufficient to detect and remove the most severe threats to the disposal system, such as drilling.

- Maintenance services for fences, gates, cattle guards, signs, and monitoring equipment.

- Site restoration activities in accordance with the postclosure land management plan.

- Agreements with the BLM to administer grazing and other permitted land uses consistent with the DOE's postclosure land management plan.

- Monitoring of the disposal system.

- Construction of a permanent marker system.

7.1.4 Effectiveness of the Active Institutional Controls Program

Performance assessment for the WIPP assumes that the active institutional controls program will be 100 percent effective in preventing human intrusion into the repository for the 100 years immediately following disposal. The DOE believes that this assumption is supported by the proposed design features alone (that is, fencing, postings, perimeter inspections, surveillance, and mitigation measures) and the defense-in-depth nature of the features and resulting controls. The DOE believes that taking 100 percent credit for 100 years of active

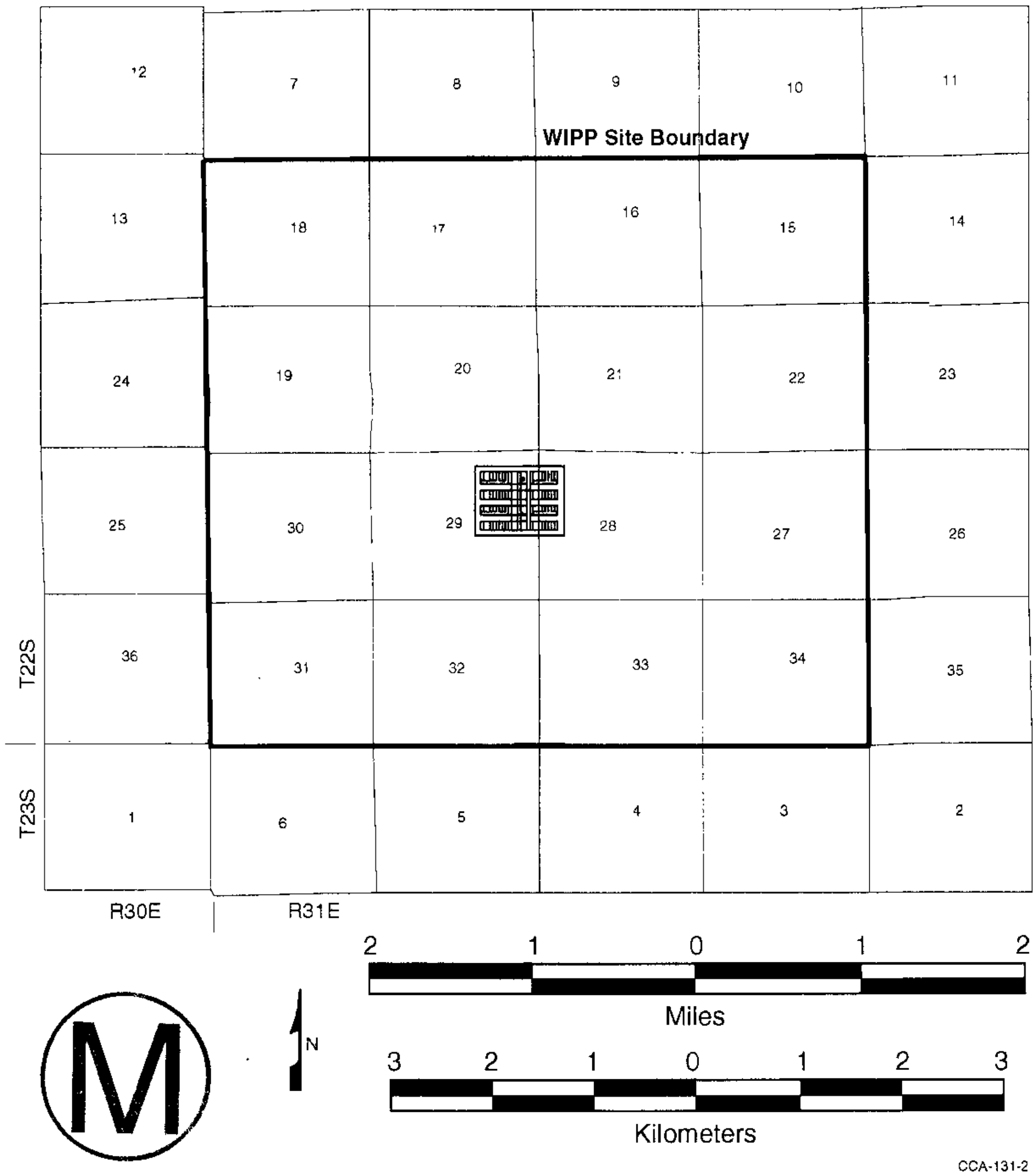


Figure 7-9. Planned Repository Footprint

THIS PAGE INTENTIONALLY LEFT BLANK

controls is justified by the repetitive and redundant nature of the active controls that will be implemented at the WIPP site. The DOE is committed to retaining active control over the site for as long as is practicable, but at least for 100 years.

Governments have successfully controlled and protected facilities of national importance for hundreds of years. The U.S. Government has existed and effectively maintained many facilities under its control for over 200 years. The DOE and its predecessor agencies have successfully maintained (preventing intrusion) several major facilities for over 50 years. Therefore, the DOE believes there is a reasonable expectation that active institutional controls will be effective for at least the assumed 100-year institutional control period, and are likely to be effective for substantially longer periods.

7.2 Monitoring

The requirements for disposal system monitoring are stated in 40 CFR § 191.14(b). In order to certify the DOE's compliance with these requirements, the EPA has established certification criteria that the DOE must satisfy in its application for certification. These criteria are stated in 40 CFR § 194.42. The requirements and the criteria form the basis for the DOE's monitoring program. Appendix MON, Pre-Closure and Post-Closure (Long-Term) Monitoring Plan, describes the details of the DOE's monitoring program.

The criteria provided in 40 CFR § 194.42(a) state

> The Department shall conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application. The results of the analysis shall be used in developing plans for preclosure and postclosure monitoring required pursuant to paragraphs (c) and (d) of this section. The disposal system parameters analyzed shall include, at a minimum:
>
> (1) Properties of backfilled material, including porosity, permeability, and degree of compaction and reconsolidation;
>
> (2) Stresses and extent of deformation of the surrounding roof, walls, and floor of the waste disposal room;
>
> (3) Initiation or displacement of major brittle deformation features in the roof or surrounding rock;
>
> (4) Ground water flow and other effects of human intrusion in the vicinity of the disposal system;
>
> (5) Brine quantity, flux, composition, and spatial distribution;
>
> (6) Gas quantity and composition; and
>
> (7) Temperature distribution.

Attachment 1 (MONPAR) to Appendix MON is an "Analysis of the Effects of Disposal System Parameters on Waste Containment" that the DOE has used to base decisions regarding disposal system monitoring. 40 CFR § 194.42 dictates the manner in which the stated analysis will be used in deriving the monitoring program, including the specification that the program consider preclosure monitoring as an integral component of meeting the monitoring requirements.

MONPAR's scope of analyzed parameters exceeds the minimum parameters identified in 40 CFR § 194.42(a). The following is a summary of the results of the analysis with respect to those parameters identified in 40 CFR § 194.42(a).

(1) *Properties of backfilled material, including porosity, permeability, and degree of compaction and reconsolidation;*

Backfill Material Properties. The mechanical and hydrologic properties of the backfill are not significant to the performance assessment. Therefore, they will not be monitored during the preclosure or postclosure periods.

See Appendix MON (Attachment 1, MONPAR, Section MONPAR.3.5) for additional detail regarding DOE's analysis of backfill.

(2) *Stresses and extent of deformation of the surrounding roof, walls, and floor of the waste disposal system; and*

(3) *Initiation or displacement of major brittle deformation features in the roof or surrounding rock;*

Stress and Extent of Deformation. Creep closure of the repository will occur, and is included within compliance assessment and performance assessment models as a control on waste consolidation and other time-dependent disposal room conditions. The individual creep closure parameters are not significant to performance assessment. Sufficient data have been collected for the purposes of verifying the underlying rock mechanics models. The numerical models of the repository used in performance assessment are based upon assumptions about long-term behavior that are not applicable to behavior during the operational period. Further monitoring of creep closure and stress would not provide information that is useful for calculating disposal system performance, nor would it lead to additional confidence in the performance assessment models.

The initiation or displacement of major brittle deformation features in the roof or surrounding rock, beyond that already accounted for in performance assessment calculations, is not significant to the containment of waste. The individual parameters that are used in modeling the mechanical behavior of brittle anhydrite interbeds are not significant to performance assessment. Monitoring mechanical behavior of the interbeds would not provide information that is useful for calculating system performance, nor would it lead to additional confidence in the performance assessment models.

Monitoring of creep closure and mechanical behavior will be conducted during preclosure monitoring to provide information that is relevant to repository operations.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.3.1 and MONPAR.3.2) for additional detail regarding DOE's analysis of creep closure and deformation features.

(4) *Ground water flow and other effects of human intrusion in the vicinity of the disposal system;*

Drilling Intrusions. Intrusion into the repository through drilling may occur during the regulatory time period. In accordance with regulatory requirements, such intrusions are modeled to occur randomly in time and space. Drilling leads to direct releases during the drilling itself and possible long-term releases due to effects on fluid flow in the disposal system. The drilling rate (boreholes per square kilometer per 10,000 years) is significant to repository performance. The DOE uses a drilling rate in performance assessment that is based on historical rates in the Delaware Basin.

The DOE will monitor the drilling activity in the Delaware Basin during the preclosure and postclosure periods and will use the results in performance calculations performed in support of recertification.

Borehole Properties. The properties of a borehole change over time, and are incorporated into performance assessment. The properties are established to be "consistent with practices in the Delaware Basin at the time a compliance application is prepared" (40 CFR § 194.33[c][1]). These parameters are significant to compliance. The current practices will be monitored and changes will be incorporated into the performance assessment models of borehole properties in future calculations in support of recertification.

Groundwater Flow. Historical, current, and near-future human activities in the vicinity of the repository could affect groundwater flow in the Culebra prior to closure of the repository, as well as subsequent to repository closure. The significance of these human activities depends on the extent and magnitude of the induced hydrological, geochemical, and mechanical disturbance. Changes in groundwater in the Culebra are moderately significant to performance. Such changes are incorporated into performance assessment as described in Appendix MON (Attachment 1, MONPAR, Sections MONPAR.4.4 and MONPAR.4.5). Changes in brine flow in the Salado as a result of any current or near-future human activities in the vicinity of the repository are not anticipated, and therefore are not significant to performance assessment.

The DOE will monitor water levels and groundwater flow direction in the Culebra during the operational period. Monitoring of groundwater flow conditions in the Salado could create additional pathways for radionuclide transport, and would potentially jeopardize long-term performance of the disposal system; thus the DOE will not perform such monitoring.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.4.1, MONPAR.4.3, and MONPAR.4.4) for additional detail regarding DOE's analysis of drilling intrusions, borehole properties, and groundwater flow in the vicinity of the repository.

(5) *Brine quantity, flux, composition, and spatial distribution;*

Salado Hydrology. Hydrologic properties (quantity, flux, and spatial distribution) of the intact Salado Formation are incorporated into performance assessment through use of parameters that are consistent with extensive experimental observations. Variations in these parameters have a moderate effect on system performance assessment. There is no indication that properties of the intact (far-field) Salado will change during the regulatory period; thus, they will not be monitored during the operational period nor during the postclosure period. Composition of Salado brines has been well established through investigations. Brine composition is significant and is incorporated into performance assessment calculations. Based on the extensive experimental evidence collected, there is no indication that Salado brine composition will change over the regulatory period; thus it will not be routinely monitored during the operational period nor during the postclosure period.

The presence of a disturbed rock zone (DRZ) surrounding the repository has also been incorporated into performance assessment calculations. The properties of the DRZ have been well characterized; they include altered hydrologic properties that are expected to enhance near-field fluid flow both to and from the repository. The initial conditions and enhanced fluid flow are moderately significant to disposal system performance. In an effort to simplify the calculations, the effects are maximized by the conceptual model and altered properties of the DRZ. This treatment is believed to be a conservative choice with respect to the ultimate impact on predicted release. Monitoring the DRZ hydrologic properties would not provide relevant information or verify assumptions used in performance assessment; therefore they will not be monitored during the operational period nor during the postclosure period.

Mechanical and hydrologic properties of the disposal room are incorporated into performance assessment as they affect gas generation and fluid flow into and out of the repository. These properties and parameters are moderately significant to disposal system performance. Additional properties are significant in the event of intrusion into the repository; these are discussed in Appendix MON (Attachment 1, MONPAR, Section MONPAR.4.2). The conceptual model of disposal room behavior is based on extensive experimental data that support a number of assumptions about long-term behavior that will not be applicable during the preclosure period. The closed disposal room will not achieve the expected long-term properties predicted in performance assessment during the operational or active control periods. Therefore, monitoring the mechanical and hydrologic properties would not provide relevant information or verify assumptions used in performance assessment. Thus the disposal room properties will not be monitored during the operational period nor during the postclosure period.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.1, MONPAR.2.2, MONPAR.3.3, and MONPAR.3.4) for additional detail regarding DOE's analysis of these parameters.

Culebra Hydrology. Hydrologic properties (quantity, flux, and spatial distribution) of the undisturbed Culebra Member of the Rustler Formation exhibit spatial variability and are incorporated into performance assessment through both fixed values and parametric ranges that are consistent with experimental observations to date. Variations in some of the parameters are significant to overall disposal system performance. The hydrologic properties of the undisturbed Culebra are not expected to change during the regulatory period, thus they will not be monitored during the operational period nor during the postclosure period. Culebra groundwater is less saline than Salado and Castile brines. The Culebra groundwater is spatially variable, and its composition has been well established through investigations. Groundwater composition is incorporated into performance assessment calculations; however it is not significant to performance. Based on extensive experimental evidence, there is no indication that Culebra groundwater composition will change over the regulatory period; however, monitoring will provide information that is relevant to a comprehensive environmental monitoring program.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.3 and MONPAR.2.4) for additional detail regarding DOE's analysis of these parameters.

Castile Hydrology. The Castile Formation underlying the WIPP may contain reservoirs of pressurized brine. This is incorporated into performance assessment through use of input parameters that address hydrologic properties and the probability that a reservoir will be encountered during an intrusion event. The hydrologic properties are significant to disposal system performance in such an intrusion event. The Castile is not significant to system performance except for the brine reservoirs. There is no indication that the properties of the undisturbed reservoirs will change over the regulatory period although the assumption is made in the modeling that intrusions into brine reservoirs lead to their eventual depletion. It is not possible to completely define the location and extent of brine reservoirs without jeopardizing the integrity of the disposal system. Composition of brines from two Castile brine reservoirs is moderately significant and is incorporated into performance assessment calculations. There is no evidence to suggest that the brine composition will change over the regulatory period. It is not possible to further investigate composition of any brine that may be present below the repository without jeopardizing the integrity of the disposal system. Therefore no further investigations or monitoring will be performed during the preclosure period nor during the postclosure period. However, monitoring of drilling activity in the Delaware Basin for instances of encountering pressurized brine reservoirs in the Castile will be a part of the preclosure and postclosure monitoring programs.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.5 and MONPAR.2.6) for additional detail regarding DOE's analysis of the Castile hydrology parameters.

(6) *Gas quantity and composition;*

Gas Quantity and Composition. Gas generated in the repository may retard creep closure, may fracture the anhydrite interbeds in the DRZ (enhancing fluid flow), and may enhance direct releases (Appendix MON, Section MONPAR.4.2) These effects are moderately significant and are accounted for in performance assessment. Gas composition (carbon dioxide concentration) and the corrosion rate of metals are controlled chemically by the backfill and are not significant. Gas generation is moderately significant to system performance. The conceptual model of gas generation processes is based on experimental data and incorporates a number of assumptions about long-term behavior that will not be applicable during the operational period (such as anoxic conditions). Monitoring the quantity and composition of gas generated in the closed panels would not provide information that is useful for calculating system performance, nor would it lead to additional confidence in the performance assessment models.

However, in accordance with requirements under RCRA regulations, gas sampling and analysis will be conducted as described in Appendices MON and VCMP, Confirmatory Monitoring Plan.

See Appendix MON (Attachment 1, MONPAR, Section MONPAR.3.6) for additional detail regarding DOE's analysis of gas generation.

(7) *Temperature distribution.*

Temperature Distribution. Natural geological thermal gradients have been well characterized and are not significant: they will not affect repository performance, either directly by affecting the containers and repository chemistry, or indirectly by altering fluid flow through the Salado or the Culebra. Similarly waste-induced and repository-induced thermal gradients in the repository are not significant: they will not affect repository performance, either directly by affecting the containers and repository chemistry, or indirectly by altering fluid flow through the Salado or the Culebra.

Therefore natural thermal gradients, waste-induced thermal gradients, and repository-induced thermal gradients will not be monitored during the preclosure period nor during the postclosure period.

See Appendix MON (Attachment 1, MONPAR, Sections MONPAR.2.7 and MONPAR.3.8) for additional detail regarding DOE's analysis of natural temperature distribution.

The criteria state that the DOE is to base decisions regarding disposal system monitoring on "an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application." The rule goes on to dictate the manner in which the stated analysis will be used in deriving the monitoring program, including the specification that the program consider preclosure monitoring as an integral component of meeting the monitoring requirements.

The DOE has completed the analysis and has designed a monitoring program (including both preclosure and postclosure monitoring techniques) that meets the requirements of 40 CFR § 191.14(b). The program is documented in a manner that addresses the certification criteria of 40 CFR § 194.42, and is described in this section. This monitoring program is described in this section. More detailed information is provided in Appendix MON.

Additional parametric areas of analysis included in MONPAR (Attachment 1 of Appendix MON) are:

- repository chemical conditions,
- shaft seal system,
- radionuclide transport and retardation,
- direct releases, and
- mining.

Table 7-2 is a list of the specific disposal system parameters discussed in MONPAR.

7.2.1 Monitoring Program Requirements

Requirements for monitoring of a disposal system[1] are included in the final disposal regulations as follows:

[1] Disposal system means "any combination of engineered and natural barriers that isolate...radioactive waste after disposal" (40 CFR § 191.12).

Table 7-2. Potentially Significant Disposal System Parameters

NATURAL PARAMETERS	
Impure halite effective porosity	Culebra diffusional porosity
Impure halite permeability	Culebra longitudinal dispersivity
Impure halite pore compressibility	Climate change index
Impure halite far-field pore pressure	Culebra groundwater quantity
Anhydrite permeability	Culebra groundwater flux
Anhydrite pore compressibility	Culebra groundwater spatial distribution
Anhydrite two-phase flow model choice	Culebra groundwater composition
Salado pore shape	Castile brine volume in reservoir
Salado residual brine saturation	Castile brine reservoir volume selection index
Salado residual gas saturation	Castile brine reservoir pressure
Salado brine quantity	Castile brine reservoir permeability
Salado brine flux	Castile brine reservoir rock compressibility
Salado brine spatial distribution	Castile brine composition
Salado brine composition	Castile brine flux
Culebra transmissivity	Castile brine spatial distribution
Culebra advective porosity	Natural temperature distribution
Culebra fracture spacing	
WASTE AND REPOSITORY PARAMETERS	
Closure rates and stresses	Probability factor for types of microbial degradation
Extent of deformation	Gas quantity
Initiation of brittle deformation	Gas composition
Displacement of major deformation features	Choice of oxidation state distribution
DRZ permeability	Solubility of nine radionuclides in Salado brine
DRZ effective porosity	Solubility of nine radionuclides in Castile brine
DRZ brine flux	Humic colloid concentration in Salado brine
DRZ brine quantity	Humic colloid concentration in Castile brine
Waste area residual gas saturation	Clay shaft seal member permeability
Waste area residual brine saturation	Concrete shaft seal member permeability
Brine wicking	Asphalt shaft seal member permeability
Waste area permeability	Shaft DRZ permeability
Backfill porosity	Crushed salt seal component permeability (permeability selection index)
Backfill permeability	Seal residual gas saturation
Degree of backfill compaction	Seal residual brine saturation
Backfill reconsolidation	Seal pore shape
Inundated steel corrosion rate with CO_2	Waste- and repository-induced temperature distribution
Inundated steel corrosion rate without CO_2	Salado K_ds for dissolved radionuclides
Inundated microbial degradation rate	Culebra K_ds for six dissolved radionuclides
Humid microbial degradation rate	Salado K_ds for colloidal radionuclides
β-factor for microbial degradation process	
HUMAN INITIATED PARAMETERS	
Drilling rate	Borehole permeability
Waste particle diameter	Borehole plugging pattern (probability index)
Effective shear resistance to erosion	Change in Salado brine flow
Gravity correction factor for spalling	Change in Culebra groundwater flow
Strength correction factor for spalling	Probability that mining will occur
Time between intrusions	Mining index for adjusting Culebra transmissivity
Borehole location	Waste activity
Probability of encountering a Castile brine reservoir	Waste tensile strength
Borehole diameter	

> Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring (§ 191.14[b]).

Within this context, monitoring becomes one of several activities to be implemented at the WIPP facility during the active institutional controls period. Monitoring the WIPP disposal system is designed to address significant concerns associated with the performance of the isolation system. The EPA points out that monitoring approaches to address significant concerns should be limited to those that can provide meaningful data in a relatively short period of time (50 FR 38081).

In addition, the EPA points out that monitoring must not become a reason to relax the degree of care with which the compliance determination is made. Finally, the EPA specifies that monitoring must not jeopardize the integrity of the disposal system (50 FR 38081).

The DOE has addressed the need for monitoring the disposal system during both the preclosure period and the postclosure period in its application for a hazardous waste facility operating permit (see Appendix MON). In its Pre-Closure and Post-Closure (Long-Term) Monitoring Plan (Appendix MON), the DOE incorporates three monitoring programs that will be used to ensure compliance with the hazardous waste regulations of RCRA as implemented by the NMED. These programs include (1) a confirmatory volatile organic compound (VOC) monitoring program to demonstrate that the numerical predictions of VOC releases are reasonable, (2) a groundwater monitoring program to verify knowledge regarding the characteristics of groundwater flow, including periodic testing for releases from the repository, and (3) a geomechanical monitoring program to support decisions regarding operations and maintenance of underground openings. Only the groundwater program is expected to extend into the 30-year RCRA postclosure period. The EPA has established, as a certification criterion, that the monitoring programs in this application must be complementary with the RCRA programs that the DOE will be required to implement.

7.2.2 Monitoring Program Design

The requirements in 40 CFR § 191.14(b) and the criteria in 40 CFR § 194.42 can be translated into five screening criteria for selecting monitoring parameters and for developing monitoring plans. The monitoring plan should

- address significant disposal system parameters,
- address important disposal system concerns,
- obtain meaningful data in a short time period (50 FR 38081),
- preserve disposal system integrity, and

- be complementary with RCRA programs.

Each of these screening criteria is discussed below.

7.2.2.1 Significant Disposal System Parameters

In the certification criteria, the EPA states that

> The Department shall conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application. The results of the analysis shall be used in developing plans for preclosure and postclosure monitoring required pursuant to paragraphs (c) and (d) of this section (40 CFR § 194.42[a]).

The EPA also states that to the extent practicable, preclosure monitoring shall be conducted of significant disposal system parameter(s) as identified by the analysis conducted pursuant to paragraph (a) of this section (40 CFR § 194.42[c]). Though not explicitly stated in the criteria, it is appropriate that the same requirement hold for postclosure monitoring. The EPA defines significant parameters as follows: "A disposal system parameter shall be considered significant if it affects the system's ability to contain waste or the ability to verify predictions about the future performance of the disposal system" (40 CFR § 194.42[c]).

The terms significant, important, and sensitive have been used in the WIPP program to describe parameters with variability that impact the outcome of performance assessment. While these terms are for the most part interchangeable, the term significant is used in this discussion to maintain consistency with the terminology in the 40 CFR Part 194 criteria.

The DOE has conducted the requisite study of parameters that are inputs to the performance assessment. MONPAR (Attachment 1 of Appendix MON) provides a description of the methodology and results of that study. The DOE has implemented the criteria for significance in Appendix MON.

Verification of parameters used in the system performance analysis may occur in one or both of the following ways:

- measurement of physical or chemical conditions to see if they remain consistent with expected conditions or within the range of conditions incorporated into the assumptions and models, and

- measurement of physical and chemical processes that are currently based on professional judgment or regulatory guidance because data are not available.

The DOE considered the major processes and models described in Section 6.4 and the regulations and developed an initial list of potentially significant parameters as discussed in

Attachment 1 to Appendix MON (MONPAR). Parameters were screened for inclusion in the list based on the following criteria:

- the parameter represents one or more important aspects of a chemical or physical process or model,

- the parameter represents subjective uncertainty (such as spatial variabililty in a physical property or process),

- the parameter represents stochastic uncertainty (such as drilling rate), and

- the parameter proved to be moderately to highly sensitive in terms of modeling results in previous preliminary performance assessments.

The parameters identified through this screening process are summarized in Table 7-2 and discussed in MONPAR (Attachment 1 of Appendix MON).

The parameters identified in Table 7-2 are assigned high, medium, and low significance values. Those parameters that would significantly affect a release are assigned a HIGH level. Parameters that influence a release are assigned a MEDIUM value. Parameters that are not significant (represent spatial variability or an uncertainty in a given value) are assigned a LOW value. Those that were determined as having a high significance are shown in Table 7-3.

7.2.2.2 Important Disposal System Concern

This criterion is closely tied with the first in that, in the final analysis, the most significant parameters are related to important disposal system concerns. However, the DOE has included this category as a separate criterion to identify any other parameters that, while they are not significant in performance assessment, do describe important disposal system features. For example, the creep properties of the Salado can be considered an important feature of the disposal system, although the parameter analysis identified them as having a minor effect on the outcome of the analysis. Creep properties are identified in Appendix MON (Attachment 1, MONPAR) because they can provide a body of information that allows the DOE to evaluate its conceptual model of Salado creep closure.

In order to select these parameters for further evaluation, the DOE divided the disposal system into five major components: Salado and repository physical properties, Salado and repository hydrological properties, non-Salado hydrological properties, waste properties, and engineered barrier properties. Based on this division, the DOE revisited the list of potentially significant parameters and determined those parameters that were related to a measurable property of the disposal system. Those parameters are shown in Table 7-4.

Table 7-3. Disposal System Parameters Determined to be of Highest Significance to Disposal System Performance

Parameter	Significance to Containment	Significance to Verification
NATURAL PARAMETERS		
Salado anhydrite permeability	HIGH	HIGH
Salado brine composition	HIGH	HIGH
Culebra fracture spacing	HIGH	HIGH
Castile brine reservoir volume selection index	HIGH	HIGH
Castile brine reservoir pressure	HIGH	HIGH
Castile brine reservoir permeability	HIGH	HIGH
Castile brine reservoir rock compressibility	HIGH	HIGH
Castile brine reservoir volume selection index	HIGH	HIGH
Castile brine flux	HIGH	HIGH
Castile brine spatial distribution	HIGH	HIGH
Castile brine composition	HIGH	HIGH
WASTE AND REPOSITORY PARAMETERS		
Inundated steel corrosion rate without CO_2	HIGH	HIGH
Choice of oxidation state distribution	HIGH	HIGH
Solubility of nine radionuclides in Salado brine	HIGH	HIGH
Solubility of nine radionuclides in Castile brine	HIGH	HIGH
Humic colloid concentration in Salado brine	HIGH	HIGH
Humic colloid concentration in Castile brine	HIGH	HIGH
Culebra K_ds for dissolved radionuclides	HIGH	HIGH
Crushed salt seal component permeability (permeability selection index)	HIGH	HIGH
HUMAN INITIATED PARAMETERS		
Drilling rate	HIGH	HIGH
Waste particle diameter	HIGH	HIGH
Borehole permeability	HIGH	HIGH
Borehole plugging pattern (probability index)	HIGH	HIGH
Time between intrusions	HIGH	HIGH
Borehole location	HIGH	HIGH
Probability of encountering Castile brine reservoir	HIGH	HIGH
Waste activity	HIGH	HIGH
Effective shear resistance to erosion	HIGH	HIGH

Table 7-4. Parameters Related to Measurable Disposal System Properties

Parameter	Significance to Containment	Significance to Verification
SALADO PHYSICAL PARAMETERS		
Creep closure and stresses	LOW	LOW
Extent of deformation	LOW	LOW
Initiation of brittle deformation	LOW	LOW
Displacement of major deformation features	LOW	LOW
Natural temperature distribution	LOW	LOW
SALADO HYDROLOGICAL PARAMETERS		
Impure halite pore compressibility	LOW	LOW
Impure halite far-field pore pressure	MEDIUM	MEDIUM
Salado pore shape	MEDIUM	MEDIUM
Impure halite effective porosity	MEDIUM	MEDIUM
Impure halite permeability	MEDIUM	MEDIUM
Anhydrite permeability	HIGH	HIGH
Anhydrite pore compressibility	MEDIUM	MEDIUM
Salado residual brine saturation	MEDIUM	MEDIUM
Salado residual gas saturation	MEDIUM	MEDIUM
Salado brine quantity	LOW	LOW
Salado brine flux	MEDIUM	MEDIUM
Salado brine spatial distribution	LOW	LOW
Salado brine composition	HIGH	HIGH
Salado K_ds for dissolved radionuclides	LOW	LOW
Salado K_ds for colloidal radionuclides	LOW	LOW
Salado change in groundwater brine	LOW	LOW
Natural temperature distribution	LOW	LOW
DRZ permeability	MEDIUM	MEDIUM
DRZ effective porosity	MEDIUM	MEDIUM
DRZ brine flux	MEDIUM	MEDIUM
DRZ brine quantity and spatial distribution	LOW	LOW

Table 7-4. Parameters Related to Significant Disposal System Properties (Continued)

Parameter	Significance to Containment	Significance to Verification
NON-SALADO HYDROLOGICAL PROPERTIES		
Culebra transmissivity	MEDIUM	MEDIUM
Culebra advective porosity	MEDIUM	MEDIUM
Culebra fracture spacing	HIGH	HIGH
Culebra diffusional porosity	MEDIUM	MEDIUM
Culebra longitudinal dispersivity	LOW	LOW
Culebra groundwater quantity	LOW	LOW
Culebra groundwater flux	MEDIUM	MEDIUM
Culebra groundwater spatial distribution	LOW	LOW
Culebra groundwater composition	LOW	LOW
Castile brine reservoir pressure	HIGH	HIGH
Castile brine reservoir permeability	HIGH	HIGH
Castile brine reservoir rock compressibility	HIGH	HIGH
Castile brine reservoir brine volume	HIGH	HIGH
Castile brine flux	HIGH	HIGH
Castile brine spatial distribution	HIGH	HIGH
Castile brine composition	MEDIUM	MEDIUM
Natural temperature distribution	LOW	LOW
Culebra K_ds for six dissolved radionuclides	HIGH	HIGH
Culebra K_ds for humic and actinide-intrinsic colloidal radionuclides	MEDIUM	MEDIUM
Drilling rate	HIGH	HIGH
Effective decay constant for microbes	MEDIUM	MEDIUM
Culebra change in groundwater flow	MEDIUM	MEDIUM
WASTE RELATED PARAMETERS		
Waste area residual gas saturation	MEDIUM	MEDIUM
Waste area residual brine saturation	MEDIUM	MEDIUM
Waste area permeability	MEDIUM	MEDIUM
Brine wicking	MEDIUM	MEDIUM
Inundated steel corrosion rate with CO_2	LOW	LOW

Table 7-4. Parameters Related to Significant Disposal System Properties (Continued)

Parameter	Significance to Containment	Significance to Verification
Inundated steel corrosion rate without CO_2	MEDIUM	MEDIUM
Inundated microbial degradation rate	LOW	LOW
Humid microbial degradation rate	LOW	LOW
Gas quantity	MEDIUM	MEDIUM
Gas composition	LOW	LOW
Choice of oxidation state distribution	HIGH	HIGH
Solubility of nine radionuclides in Salado brine	HIGH	HIGH
Solubility of nine radionuclides in Castile brine	HIGH	HIGH
Humic colloid concentrations in Salado brine	HIGH	HIGH
Humic colloid concentrations in Castile brine	HIGH	HIGH
Waste particle diameter	HIGH	HIGH
Effective shear resistance to erosion	MEDIUM	MEDIUM
Waste activity	HIGH	HIGH
Waste tensile strength	MEDIUM	MEDIUM
Gravity factor for spalling	MEDIUM	MEDIUM
Strength factor for spalling	LOW	LOW
ENGINEERED BARRIER PROPERTIES		
Shaft DRZ permeability	MEDIUM	MEDIUM
Backfill porosity	LOW	LOW
Backfill permeability	LOW	LOW
Degree of backfill compaction	LOW	LOW
Backfill reconsolidation	LOW	LOW
Clay seal member permeability	MEDIUM	MEDIUM
Concrete seal member permeability	MEDIUM	MEDIUM
Asphalt seal member permeability	MEDIUM	MEDIUM
Seal residual gas saturation	LOW	LOW
Seal residual brine saturation	LOW	LOW
Seal pore shape	LOW	LOW
Long-term borehole permeability	HIGH	HIGH

7.2.2.3 Meaningful Data in a Relatively Short Time

The amount of time available for the DOE to obtain data regarding important disposal system parameters is approximately 150 years. This assumes a 50-year preclosure period and 100 years of active institutional controls. However, the DOE will continue monitoring programs for as long as needed if meaningful data are collected or are expected.

In screening parameters using this criterion, the DOE applied two qualifications. First, parameters had to be amenable to measurement within the disposal system and, second, parameter changes expected to occur within the first 150 years and affecting long-term disposal system performance had to be predictable. For example, parameters such as the shape of pore spaces cannot be reasonably measured and, therefore, would not become candidates for a monitoring program. Likewise, changes in parameters such as the actual brine concentration within the Salado are likely to be rapid initially and not necessarily diagnostic of the steady state that will exist over most of the regulatory time period.

The results of the screening of the parameters in Tables 7-3 and 7-4 are given in Table 7-5.

Table 7-5. Listing of Parameters That Can Produce Meaningful Data During Monitoring Period

Parameter	Comment
SALADO PHYSICAL PARAMETERS	
Creep closure and stresses	Can be measured during operations
Extent of deformation	Can be measured during operations
Initiation of brittle deformation	Can be measured during operations
Displacement of deformation features	Can be observed during operations
SALADO HYDROLOGICAL PARAMETERS	
Salado brine composition	Can be measured during operations
NON-SALADO HYDROLOGICAL PROPERTIES	
Culebra groundwater composition	Can be measured for entire period
Castile brine reservoir location	Can be observed for entire period
Drilling rate	Can be observed for entire period
Culebra change in groundwater flow	Can be observed for entire period
WASTE RELATED PARAMETERS	
Waste activity	Can be calculated using measurements made during waste characterization

In some cases, the parameter is indicated as a measurable parameter, meaning that it can either be directly monitored or be deduced from a monitoring program. Other parameters are indicated as observed. This means that the parameter represents an event that occurs at unspecified intervals or changes too slowly or too intermittently to be a viable monitoring candidate. For example, displacements of deformation features occur intermittently and can be observed only when they occur, even though other processes leading up to displacement (such as creep) can be monitored.

7.2.2.4 Preservation of Disposal System Integrity

Disposal system integrity could be compromised by drill holes, conduits, or other entries that are left in place to allow access to monitoring equipment. The requirement to avoid such conditions leads to the conclusion that the only viable monitoring systems are those that can be operated directly during operations, those that can transmit information without cabling (telemetry), and those that can be used to evaluate parameters using remote sensing techniques. Each is discussed briefly below. Table 7-6 shows the final screening of parameters in order to determine those that are candidates for a monitoring program. Table 7-7 identifies those parameters included in the preclosure and postclosure monitoring programs. The differences in Tables 7-6 and 7-7 are explained as follows. The presence of a DRZ surrounding the repository has been incorporated into performance assessment calculations. The properties of the DRZ have been characterized; they include altered hydrologic properties that are expected to enhance near-field fluid flow both to and from the repository. The initial conditions and enhanced fluid flow are considered moderately significant to disposal system performance. In an effort to simplify the calculations, the effects are maximized by the conceptual model and altered properties of the DRZ. This is believed to be a conservative choice with respect to the ultimate impact on predicted release.

Monitoring the DRZ hydrologic properties would not provide relevant information or verify assumptions used in performance assessment; therefore they will not be monitored during the operational period nor during the postclosure period. For more detail regarding DRZ-related parameters, see Appendix MON (Attachment 1, Section MONPAR.3.3).

Composition of Salado brines has been established through investigations. Brine composition is significant and is incorporated into performance assessment calculations. Based on the extensive experimental evidence collected, there is no indication that Salado brine composition will change over the regulatory period; thus it will not be routinely monitored during the operational period nor during the postclosure period. For more detail regarding Salado brine composition see Appendix MON (Attachment 1, Section MONPAR.2.2).

7.2.2.4.1 Evaluation of Monitored Parameters

The preclosure and postclosure parameters identified in Table 7-7 will be evaluated as a part of the plan described in Appendix MON. Significant deviations in expected values of any of these parameters from those ranges of values in the performance assessment models will be

Table 7-6. Parameters That Can Be Measured Without Violating Repository Integrity

Parameter	Comment
SALADO PHYSICAL PARAMETERS	
Creep closure	Direct measurement in open areas of the repository
Extent of deformation	Direct measurement in open areas of the repository
Initiation of brittle deformation	Direct measurement in open areas of the repository
Displacement of deformation features	Directly observed from other open areas of the repository
NON-SALADO HYDROLOGICAL PROPERTIES	
Culebra groundwater composition	Can be measured using existing or additional groundwater surveillance wells
Probability of encountering a Castile brine reservoir	Can be developed based on observations of drilling activity in Delaware Basin
Drilling rate	Can be developed based on observations of drilling activity in Delaware Basin
Culebra change in groundwater flow	Can be determined using existing or additional groundwater surveillance wells
WASTE RELATED PARAMETERS	
Waste activity	Limited to observations during waste characterization activities

Table 7-7. Preclosure and Postclosure Monitored Parameters

Monitored Parameter	Preclosure	Postclosure
Culebra groundwater composition	X	X
Culebra change in groundwater flow	X	X
Probability of encountering a Castile brine reservoir	X	X
Drilling rate	X	X
Subsidence measurements	X	X
Waste activity	X	
Creep closure and stresses	X	
Extent of deformation	X	
Initiation of brittle deformation	X	
Displacement of deformation features	X	

evaluated. Where applicable, any new information will be incorporated into the performance assessment conducted for recertification. Parameter values outside of expected ranges will also prompt the evaluation of models and their modification, where appropriate, for use in recertification performance assessment activity.

Culebra groundwater composition, Culebra changes in groundwater flow, Castile brine reservoir encounters, Castile brine reservoir pressure, and drilling rate parameters will be evaluated for substantiation that they remain within the range of values assumed in model development and performance assessment. Should there be a significant change outside the assumed range of values used in the performance assessment models, the DOE will evaluate and, where appropriate, modify models for incorporation into the next performance assessment recertification.

In the unlikely event that subsidence values fall significantly outside the range of values predicted and experienced elsewhere in the Delaware Basin, additional evaluation of the potential effects of such deviations will be conducted. If the evaluation requires changes to models used in the performance assessment, these changes will be made and the revised models incorporated into the recertification performance assessment.

The waste activity (see Appendix WCL for a detailed discussion) will be monitored to ensure compliance with the requirements of the LWA and that the values are within the range of values used in performance assessment models. Any significant deviation from expected values will be addressed by the DOE in a timely fashion to avoid any violation of the compliance certification.

Creep closure and stresses, extent of deformation, initiation of brittle deformation, and displacement of deformation features are all parameters that reflect on the geomechanical nature of the repository. Evaluation of these parameters influence the operational aspects of safe operation of the repository. However, should any of these parameters exhibit properties that are significantly outside the experience and expectations of the information baselines developed to date, the DOE will evaluate the impact on the design of the repository and the design of the shaft seal system.

The EPA will be notified of any deviation that the DOE evaluates as significant with respect to complying with the regulations or the certification of the WIPP as a safe repository.

7.2.2.4.2 Direct Measurement

Direct measurement includes current programs such as the underground geomechanical monitoring program and the groundwater surveillance program. In such cases, the monitoring equipment can be inspected, calibrated, and used with high reliability. Malfunctioning equipment can be easily repaired or replaced. Power requirements are met with portable power units such as rechargeable batteries or generators. In some cases, analog measurements can be made mechanically and recorded in notebooks. In other cases, digital logging equipment is available to record large quantities of data and information. Direct measurement allows for changing the measurement parameters as environmental conditions change. Replicate samples can be taken easily if needed. Unusual conditions can be investigated to provide unambiguous interpretation of data.

7.2.2.4.3 *Telemetry Systems*

In the early 1970s to the mid 1980s, the U.S. Bureau of Mines and the Mine Safety and Health Administration demonstrated that reliable communications can be established between underground mines and the surface for the purpose of locating and rescuing trapped miners (see Powell 1976; Murphy and Parkinson 1978, 42). Low frequency radio equipment was demonstrated in numerous mine environments and at many depths. The systems evaluated used low-duty cycle transmitters connected to loop antennae powered by miners' cap lamp batteries. Although through-the-earth transmission of signals is feasible, any system that uses this type of telemetry must deal with the following design problems.

First, because the purpose of the telemetry is to obviate the need for cabling to the surface, all power must be self-contained. For the WIPP, this will require extending battery or portable generators beyond the tens of years that can now be achieved for low-duty cycle systems. Second, issues regarding durability must be addressed since the environmental conditions will be severe. Components will have to withstand the brine and gas environments that are predicted, as well as the effects of creep closure and repressurization. Third, reliability will have to be addressed since failed sensors cannot be replaced nor can calibrations be performed or adjustments made. Finally, in addition to the equipment issues, there are concerns about interpreting results in an environment where interference, such as background electromagnetic noise, can only be, at best, poorly characterized. While these issues and concerns can be addressed with technology development programs, it is doubtful that the high cost is justifiable for the limited amount of data that may be obtained from such systems.

7.2.2.4.4 *Remote Sensing Systems*

The use of remote techniques to determine the characteristics of the earth have been well established. Generally classified as geophysical measurements, these systems look for variations in a parameter within the earth in order to determine geological relationships. Typical parameters that are measured remotely are resistivity, acoustic velocity, magnetism, density, temperature, moisture content, radioactivity, and radiometry (infrared). The general conclusion is that the changes in the repository are too small (in scale), too far from the surface, and too slow to be detectable using remote techniques.

7.2.2.5 Complementary With RCRA Programs

The RCRA, as implemented by both the EPA Office of Solid Waste (OSW) and the NMED, requires that the owner and operator of a hazardous waste management facility prevent releases of hazardous constituents that are harmful to human health and the environment.

Where feasible, credible release pathways must be monitored to demonstrate that no releases above regulatory limits are occurring. In some cases, if monitoring is not feasible or if releases can be shown to be either not measurable or inconsequential, monitoring is not needed.

To satisfy these monitoring requirements, the DOE plans to implement the following programs:

- geomechanical monitoring program,

- VOC confirmatory monitoring program, and

- groundwater surveillance program.

Based on the approach the DOE has taken to monitoring program implementation, the criterion of compatibility with the RCRA program is met.

7.2.3 Monitoring Program Description

Based on the parameter screening described above and the analysis in Appendix MON, the DOE has selected a monitoring program with the following components:

- preclosure monitoring
  - geomechanical monitoring parameters are (25 years or until closure):

    Creep closure and stresses,
    Extent of deformation,
    Initiation of brittle deformation, and
    Displacement of deformation features.

  - VOC confirmatory monitoring parameters are (a minimum of 6 months after closure of first panel):

    1,1-Dichloroethylene,
    Carbon tetrachloride,
    Methylene chloride,
    Chloroform,
    1,1,2,2-Tetrachloroethane,
    1,1,1-Trichloroethane,
    Chlorobenzene,
    1,2-Dichloroethane, and
    Toluene.

- Waste Characterization monitoring parameters (25 years or until last waste shipment is made):

  Waste activity

- preclosure and postclosure monitoring parameters are (30 years after closure and as required by RCRA):[2]
  - groundwater surveillance:

    Culebra brine composition,
    Culebra change in groundwater flow direction, and
    Culebra well water level.

  - observation of drilling activities (100 years after closure):[2]

    Castile brine reservoir encounter,
    Castile brine reservoir pressure, and
    drilling rate.

- postclosure monitoring parameter (100 years after closure):[2]

  - subsidence monitoring.

Each of these programs is described in the following sections. Individual program plans are included in Appendices VCMP, GWMP, SMP and DMP.

7.2.3.1 Geomechanical Monitoring Program

The geomechanical monitoring program at the WIPP facility is an integral part of the DOE's ground control program (see Figure 7-10). Disposal rooms, drifts, and operational area excavations will be monitored to provide confirmation of structural integrity. Geomechanical data on the performance of the repository shafts and excavated areas are currently collected as part of the geotechnical field monitoring program. The results of the geotechnical investigations are reported annually. The report describes monitoring programs and geomechanical data collected during the previous year.

The instrumentation in Table 7-8 is available for use in support of the geomechanical program. The minimum instrumentation for the unexcavated disposal areas designated as Panels 2 through 8 is one borehole extensometer installed in the roof at the center of each disposal room. The roof extensometers will monitor the dilation of the immediate salt roof beam and possible bed separations along clay seams. Additional instrumentation may be

[2] Or until the DOE can demonstrate to the EPA that there are no significant concerns to be addressed by further monitoring.

Table 7-8. Instrumentation Used in Support of the Geomechanical Monitoring System

Instrument Type	Features	Parameter Measured	Range
Borehole extensometer	The extensometer provides for monitoring the deformation parallel to the borehole axis. Units suitable for up to five measurement anchors in addition to the reference head.	Cumulative deformation	0-2 inches
Borehole television camera	Closed circuit television may be used for monitoring areas otherwise inaccessible, such as boreholes or shafts.	Video image	n/a
Convergence points and tape extensometers	Mechanically anchored eyebolts to which a portable tape extensometer is attached.	Cumulative deformation	2-50 feet
Convergence meters	Includes wire and sonic meters. Mounted on rigid plates anchored to the rock surface.	Cumulative deformation	2-50 feet
Inclinometers	Both vertical and horizontal inclinometers are used. Traversing type of system in which a probe is moved periodically through casing located in the borehole whose inclination is being measured.	Cumulative deformation	0-30 degrees
Rock bolt load cells	Spool type units suitable for use with rock bolts. Tensile stress is inferred from strain gauges mounted on the surface of the spool.	Load	0-300 kips
Earth pressure cells	Installed between concrete keys and rock. Preferred type is a hydraulic pressure plate connected to a vibrating wire transmitter.	Lithostatic pressure	0-1,000 pounds per square inch
Piezometer pressure transducers	Located in shafts and of robust design and construction. Periodic checks on operability required.	Fluid pressure	0-500 pounds per square inch
Strain gauges	Installed within the concrete shaft key. Suitably sealed for the environment. Two types used—surface mounted and embedded.	Cumulative deformation	0-3,000 microinches per inch (embedded) 0-2,500 microinches per inch (surface)

installed as conditions warrant. Panel 1 has already been excavated and is heavily instrumented, as shown in Figure 7-10.

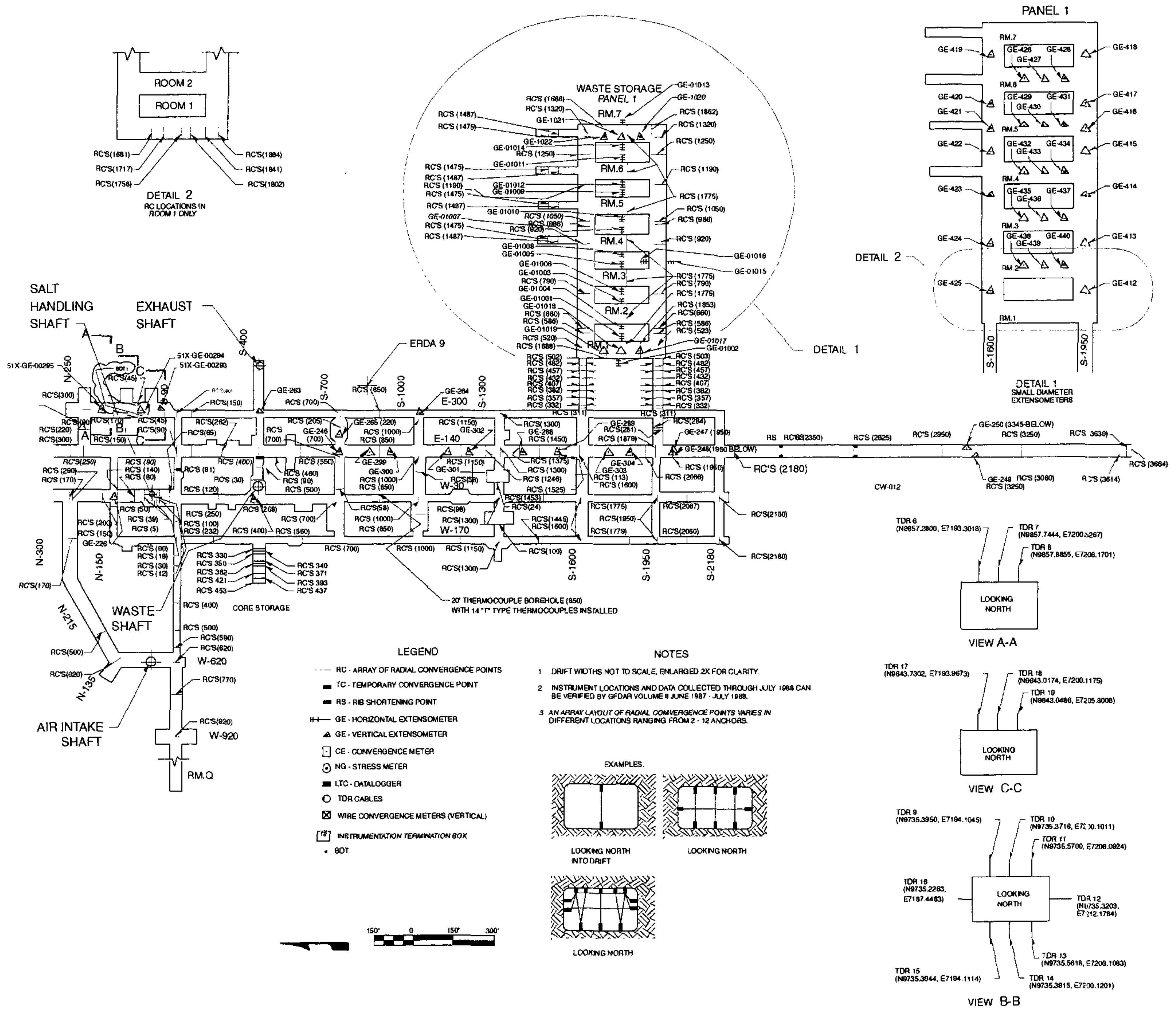
Polling of the geomechanical instrumentation will be performed at least once every month. This frequency may be increased to accommodate any changes that may develop. The results from the remotely read instrumentation will be evaluated after each scheduled polling. Documentation of the results will be provided annually in the Geotechnical Analysis Report.

The instrumentation system provides for data maintenance, retrieval, and presentation. The instrumentation system cognizant engineer first retrieves the data from the instrumentation system and verifies their accuracy by assuring the measurements were taken in accordance with applicable instructions and procedures. Next, the cognizant engineer reviews the data after each polling to assess the performance of the instrument and the excavation. Data that look anomalous are detected during this polling and are investigated to determine the cause (for example, instrumentation problem, error in recording, or changing rock conditions). The data are then processed to calculate various parameters such as the change between successive readings and deformation rates. The results of this assessment are reported to the ground control cognizant engineer and operations personnel. The stability of an open panel excavation is generally determined by the rock deformation rate. Unexpected deformation rates are investigated by Geotechnical Engineering to determine if remediation is needed.

The evaluation of the performance of the excavation is also performed by Geotechnical Engineering. These evaluations will provide an estimate of the stand-up time of the excavation. If the trend is toward adverse (unstable) conditions, then the results of these assessments are reported to the operations manager to determine appropriate operational responses.

Roof conditions are assessed from observation boreholes and extensometer measurements. Measurements of room closure, rock displacements, and observations of fracture development in the immediate roof beam are used to evaluate the performance of a panel. A summary of the Panel 1 monitoring program was presented to the members of the Geotechnical Experts Panel in 1991, who concurred that the monitoring was adequate to determine deterioration within the rooms and could provide early warning of deteriorating conditions.

The assessment and evaluation of the condition of WIPP excavations is an iterative, continuous process using the data from the monitoring programs. Criteria for corrective action are continually reevaluated and reassessed based on total performance to date. Actions taken are based on these analyses and on planned utilization of the excavation. Because WIPP excavations are in a natural geologic medium, there is inherent variability from point to point. The principle adopted is to anticipate potential ground control requirements and implement them in a timely manner rather than to wait until a need arises.



CCA-132-2

Figure 7-10. Layout and Instrumentation of Geomechanical Monitoring System as of January 1996

THIS PAGE INTENTIONALLY LEFT BLANK

Both creep closure of the excavation and the development of the DRZ are included in the conceptual model of disposal system performance. Creep closure is discussed in Section 6.4.3.1 and Appendix PORSURF. The numerical model for predicting creep closure has been developed based on both theoretical considerations and observations. The goal of monitoring is to detect any substantial and detrimental deviations from the expected behavior of Salado halite and to determine the significance of such deviations. Data are analyzed after each round of measurements and results are distributed for use in making ground control decisions. A compilation of data (current and previous) is published annually in the Geotechnical Field Data and Analysis Report. This compilation is useful determining long-term trends in the behavior of underground openings and can be a diagnostic tool for determining substantial and detrimental deviations for expected performance.

The DRZ is modeled as discussed in Section 6.4.5.3. It is assumed that the DRZ maintains its permeability throughout the model period as shown in Table 6-17. Marker bed (MB) 138 and 139 are modeled to be separate geological units with permeabilities lower than those in the DRZ as shown in Table 6-16. Substantial and detrimental deviations from these expectations may impact repository performance. Consequently, as discussed in Section 4.3 of Appendix GTMP, observations of excavation effects, along with the other geotechnical measurements will be useful to detect deviations in expectations for near-term DRZ development.

7.2.3.2 VOC Confirmatory Monitoring Program

As documented in the WIPP Safety Analysis Report (SAR) (DOE 1990, 6.1-34), airborne emission is the only credible contaminant release pathway from the WIPP facility during disposal operations. The panel closure design basis requires this pathway to be controlled during operations and the final facility closure requires that it be eliminated. The panel closure design is described in Appendix PCS. Final facility shaft sealing is described in Appendix SEAL. In order to determine the effectiveness of panel closures, the DOE has targeted the measurement of VOC emissions as diagnostic of repository processes that may be underway within closed panels. The DOE has prepared a VOC confirmatory monitoring plan. The plan has been prepared so that the DOE can show that the assumptions and predictions used to demonstrate compliance to the environmental performance standards are valid. Verification is demonstrated when observed emissions are equal to or less than those predicted. The VOC Confirmatory Monitoring Plan (VCMP) is provided in Appendix VCMP. The VCMP includes monitoring design, sampling and analysis procedures, and quality assurance objectives.

M

In its application to the NMED for a hazardous waste facility operating permit, the DOE demonstrated compliance with the environmental performance standards of 20 NMAC 4.1, Subpart V, § 264.601(c). Appendix VCMP describes a sampling and analysis program to confirm the theoretical calculations. The monitoring program is capable of quantifying VOC concentrations in the ambient mine air at the WIPP. The VCMP addresses the following information requirements:

- rationale for the design of the monitoring program, based on possible pathways, operations, engineered and natural barriers, and monitoring locations optimized for detection, and

- descriptions of the specific elements of the monitoring program, including the type of monitoring, the location of stations, the frequency of sampling, the target analytes, the schedule for implementation, the equipment used, the sampling and analytical techniques, and the data recording and reporting procedures.

While the quantification of VOCs is not of direct relevance to this application, the rate of VOC emission is of direct interest because it is a function of two inter-related repository properties. These are the extent of deformation (creep closure) and gas-producing processes. Both gas generation and creep closure will lead to the pressurization of the closed panel during operations. This pressurization will become the driving force for VOC emissions through and around the closure system. Abnormally high rates of pressurization may indicate a substantial and detrimental deviation from expected conditions requiring further investigation.

The DOE will collect air samples upstream and down stream of Panel 1 beginning just prior to waste emplacement and proceeding until at least six months following completion of panel closure. The DOE will continue monitoring until the criteria for terminating monitoring are met. These criteria are established in Appendix VCMP (Section 3.4). DOE's waste characterization program requires 100 percent measurement of headspace gases. This information will be available to the DOE through the WIPP Waste Information System (WWIS), which is described in Chapter 4.0.

M

7.2.3.3 Groundwater Surveillance Program

In the development of the WIPP monitoring programs, potential pathways for release of hazardous constituents to the environment were evaluated. This evaluation indicated no credible release pathway via surface water. The DOE has prepared a groundwater monitoring plan (GMP), as presented in Appendix GWMP. The appendix describes the basis for the GMP, the organization of the program, the quality assurance for the GMP, and the sampling program description. Sampling locations are shown in Figure 7-11. Sampling frequency will be annual. Analytes of interest for groundwater sampling and other sampling programs[3] are defined in Table 7-9. Analysis of samples is performed by a commercial laboratory that participates in the EPA contract laboratory program. Methods are specified in procurement documents and are selected to be consistent with EPA recommended procedures in SW 846 (EPA 1988). For the GMP, the principal goal of data analyses is the comparison of a data point or data set to equivalent data collected at another location and time (such as preoperational baseline data or data collected at a control location), or to a fixed standard.

[3] Discussion of other sampling programs is provided in Appendix EMP.

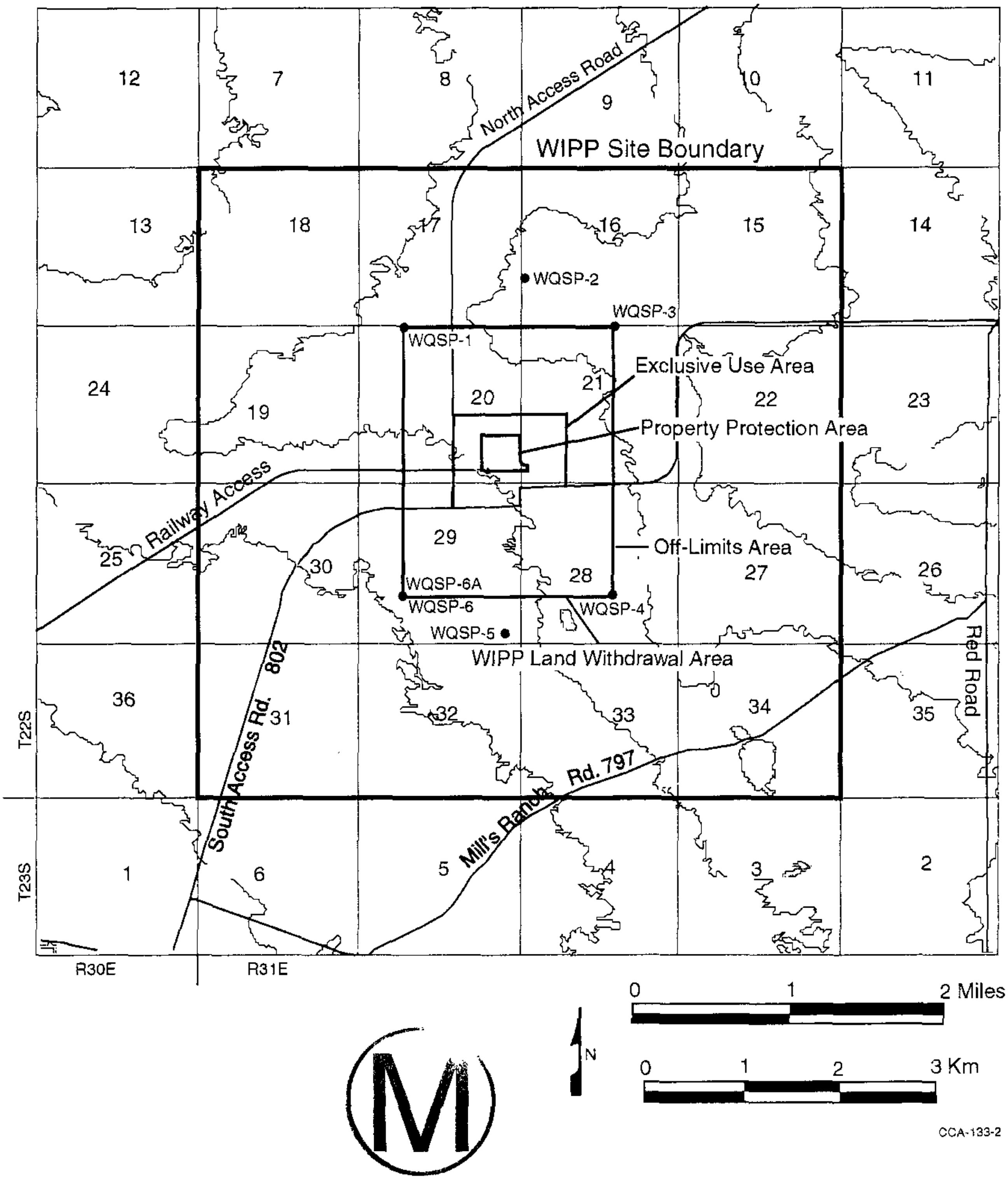


Figure 7-11. Location of the New Water Quality Sampling Wells

THIS PAGE INTENTIONALLY LEFT BLANK

Table 7-9. Typical Environmental Surveillance Analysis Schedule

Type of Sample	Analysis
Liquid influent	Radionuclides
Liquid effluent	Specific radionuclides, chemical constituents
Airborne effluent	Gross β, specific radionuclides
Meteorology	Temperature, wind speed, wind direction, precipitation, dewpoint, barometric pressure
Air quality	Total suspended particulates
Vegetation radionuclides	Specific radionuclides
Beef radioanalysis	Specific radionuclides
Game bird radioanalysis	Specific radionuclides
Rabbit radioanalysis	Specific radionuclides
Fish radioanalysis	Specific radionuclides
Deer radioanalysis	Specific radionuclides
Soil radioanalysis	Specific radionuclides
Surface-water radioanalysis	Specific radionuclides
Groundwater analysis	Specific radionuclides, chemical constituents[a]
Sediments radioanalysis	Specific radionuclides
Aerial photography	Area of land disturbed
Wildlife survey	Bird and small mammal population densities

Legend:

Specific radionuclides = ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{241}Am, ^{243}Am, ^{244}Cm, ^{232}Th, ^{237}Np, ^{226}Ra, ^{137}Cs, ^{90}Sr, ^{60}Co, U_{nat}, and Th_{nat}.

Chemical constituents = chloride; iron; manganese; phenols; sodium; sulfate; pH; specific conductance; total organic carbon; total organic halogen; specified RCRA constituents; antimony; arsenic; barium; beryllium; cadmium; chromium; fluoride; lead; mercury; nickel; nitrate; selenium; silver; thallium zinc; endrin; methoxychlor; toxaphene; 2,4-D; 2,4,5-TP silvex; radium; turbidity; coliform bacteria. Additional analytes may be specified in the WIPP facility hazardous waste permit.

[a] For the purposes of establishing baseline values in wells Water Quality Sampling Program (WQSP) 1-6 and 6a, the analyses will include all 40 CFR 264 Appendix IX constituents.

Comparisons between data sets are performed using standard statistical tests. The selection of the specific test is dependent upon the relative power of the test and the degree to which the underlying requirements of the test are met. In addition to tests comparing data from distinct locations and times, trend analyses are performed on time series where sufficient data exist.

Citation of the source of the test method or the software used to perform the tests will be made when results are reported. Data and subsequent calculated values are reported in the annual site environmental report.

The two parameters of interest from the groundwater surveillance program are the composition of the Culebra groundwater and water levels. Significant and persistent changes in the composition of the Culebra groundwater will be investigated and impacts to the modeling assumptions for long-term performance in Section 6.4.6.2 will be evaluated. Large and rapid water-level fluctuations may be diagnostic of nearby human activity such as potash mining and fluid injection and withdrawal. Water-level changes within the groundwater modeling domain in Section 6.4.6.2 that cannot be explained either based on observed trends or on past experience will be investigated and assessed relative to the assumptions made in the regional groundwater flow model.

7.2.3.4 Observation of Drilling Activities

In preparing this application, the DOE developed a database of drilling activity within the Delaware Basin. In addition, the DOE has an ongoing program of field checking each well that is drilled within one mile of the WIPP site boundary. Field checking includes verifying the location as listed on the Application for Permission to Drill (APD), monitoring drilling and completion activities, and noting abandonment and plugging. Both the maintenance of the database and the field observation program will be continued throughout the operational period to develop additional statistics on the following parameters:

- drilling rates,
- drilling practices,
- Castile brine reservoirs encountered,
- Castile brine characteristics (where available), and
- plugging practices.

Data collected will be addressed as appropriate in the recertification process. Any analyses that indicate that parameter values are changing will be studied to evaluate the impact of the changes.

Significant changes in drilling practices, such as borehole diameters, plug and abandonment practices, mining techniques, Castile brine occurrence, and injection well use will be evaluated for potential impacts on disposal system performance. Any significant deviations noted will be reported to the EPA.

7.2.3.5 Subsidence Monitoring

Subsidence monitoring is accomplished with a Class I leveling survey. The surveys will be performed every ten years during the operational phase and thereafter.

The leveling survey procedures ensure that the data are documented and validated. The data will be included in the baseline database. A procedure will be developed to implement the monitoring program.

The monitoring program includes the following:

- management of the disposal phase monitoring program,
- maintenance of monitoring procedures and quality assurance/quality control documents,
- performance of all necessary field work,
- maintenance of the subsidence network,
- maintenance (and revision as necessary) of the monitoring schedule,
- maintenance and storage of baseline database,
- review of data and evaluation of performance,
- eventual decommissioning of the disposal system monitoring program, and
- archiving of monitoring data.

Subsidence predictions exist of the WIPP. These will be reevaluated at the time of closure. Subsidence measurements will be used to compare actual subsidence with predictions. Significant deviations between expected subsidence and actual subsidence will be investigated to determine if a substantial and detrimental deviation in the expected performance of the repository is indicated.

7.2.4 Reporting

The results of the DOE's monitoring program will be submitted annually. The report will include the results from the previous year, plus any cumulative information that is useful in interpreting the data. The annual report will contain a summary assessment of results to ensure that the performance of the repository can be evaluated on a continuous and consistent basis. *Other reports, such as those stipulated in* 40 CFR § 194.4 (b)(3)*, will be issued when necessary.*

7.3 Passive Institutional Controls

Passive institutional controls, as opposed to active institutional controls, are controls that once established, can be expected to remain effective with no on-site human support. The DOE will implement passive institutional controls that involve multiple types and multiple levels of passive controls to make human intrusion into the disposal site unlikely. To accomplish this, the DOE intends to use several types of monuments and markers, land ownership, and written notations in land records in numerous locations (see Section XVI of Appendix PIC). Written documentation will include information on the location, design, and disposal contents and hazards, as well as stipulations on allowable land uses. Components of the passive controls system will be instituted at the site and at remote locations (see Appendix PIC).

As technology advances, this design concept will be revisited over the operational lifetime of the WIPP. If the DOE believes the design can be enhanced, changes will be proposed during the recertification process for EPA approval. The program described in Appendix PIC will fulfill the requirements of 40 CFR Part 191 and satisfy the certification criteria of 40 CFR Part 194.

7.3.1 Requirements for Passive Institutional Controls

The EPA has specified that "[d]isposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable" (40 CFR § 191.14[c]). The EPA then goes on to define passive institutional controls to mean "(1) permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system" (40 CFR § 191.12[e]). The DOE has interpreted this regulatory language to mandate the development and implementation of a system of passive institutional controls consistent with those components listed in the EPA's definition in order to protect the integrity of the disposal system for as long as practicable after disposal.

Guidance is provided by the EPA in 40 CFR § 194.43 on what subject areas must be addressed in order to demonstrate compliance with the regulation. Three subject areas must be addressed: (a) detailed descriptions of the passive institutional controls must be provided, (b) the period of time that the passive institutional controls are expected to endure and be understood must be estimated, and (c) credit for the passive institutional controls in reducing the likelihood of inadvertent human intrusion in performance assessments must be justified for the proposed time period. Additional guidance is provided in EPA (1996b) indicating what documentation is required in the compliance application to address 40 CFR § 194.43(a), the need for rationales to explain the estimates of how long the passive institutional controls are expected to endure and be understood in 40 CFR § 194.43(b), and the limitations of effectiveness and duration of the effectiveness of the passive institutional controls in performance assessment to address 40 CFR § 194.43(c).

7.3.2 Objectives for Passive Institutional Controls

As prescribed by the standards, the objectives of DOE's passive institutional controls for the WIPP are to convey the following:

- location,
- facility design,
- content, and
- hazard.

The passive institutional controls program described within this application will be effective in accomplishing these objectives (see Appendix EPIC, Section EPIC.6).

7.3.3 Implementation of the Passive Institutional Controls Program

The DOE began addressing the issue of passive institutional controls in the context of the assurance requirements by convening two panels of experts to identify what future societies might be like (Hora et al. 1991). The panels were convened so that the appropriate types of messages, the contents of the messages, and the types of media for transmitting the messages can be selected and to identify design concepts for the system of markers at the repository footprint (Trauth et al. 1993), which is one of the passive institutional controls. The work of the two panels was completed prior to promulgation of 40 CFR Part 194. To address the issues of the passive institutional controls in addition to the markers at the repository footprint and to incorporate the concept of practicable into the design, the DOE developed a conceptual design, which is included as Appendix PIC. With the promulgation of 40 CFR Part 194, the EPA provided guidance on how credit for the passive institutional controls deterring inadvertent human intrusion can be obtained for use in performance assessment. To address the issue of credit for passive institutional controls, the DOE has produced Appendix EPIC.

The timing and duration of the implementation of passive institutional controls is depicted in Figure 7-12.

7.3.3.1 Definition of Passive Institutional Design Appropriate for the WIPP

In deciding which passive institutional controls are appropriate for the WIPP, the DOE was guided by the regulatory language in 40 CFR § 191.14(c) that states that the controls should be practicable. The DOE is expected to address the components of the passive institutional controls listed in the definition of 40 CFR § 191.12(e). The components of the passive institutional controls for the WIPP consist of (1) monuments that define the boundary of the withdrawal area, (2) markers at the footprint of the repository that consist of monuments that identify the outer boundary of the subsurface facility, a berm surrounding the repository footprint, an information center on the surface at the center of the repository footprint, a buried room halfway between the information center and the berm, a buried room halfway between the berm and the hot cell, and randomly spaced buried markers distributed across the repository footprint, (3) sets of records distributed to national and international archives, (4) sets of records distributed to records centers locally, nationally, and internationally (both those of a general nature and those specializing in land and resource use), (5) government control and land-use restrictions, and (6) other means of communication, such as encyclopedias, dictionaries, textbooks, and various maps and road atlases. Appendix PIC contains a detailed description of the designs of each of these components.

Trauth et al. (1993) examined a variety of configurations and materials in concluding that a system comprised of natural materials incorporating massive structures with messages provided in an enduring configuration offered the best system for permanently marking the site. The permanent marker system incorporates these concepts and thus is the best system of passive institutional controls for permanently marking the repository. The use of archives and national publications as described in Appendix PIC is the most extensive means of widespread distribution of the WIPP information. Use of radio or television is transient and will not provide the long-term societal memory.

7.3.3.1.1 _Markers_

Two groups of experts, the Futures Panel and the Markers Panel, were established to examine the issues involved with designing an effective system of permanent markers. Hora et al. (1991) incorporates judgments of the Futures Panel and discusses the underlying physical and societal factors that would influence society and the likely modes of human intrusion at the WIPP site.

The Hora et al. report was an important reference and source of information for the preparation of Trauth et al. (1993). Trauth et al. (1993) reports the results of the Markers Panel, which considered various concepts of marking the site and conveying to future generations information regarding the presence of dangerous waste material and the potential consequence of intrusion into the waste repository. Appendix PIC (Section I) is a modification of the ideas developed by this panel.

Appendix PIC sets forth the permanent markers system for the WIPP facility. This system involves the use of surface monuments, small subsurface warning markers, buried rooms, and large earthen structures marking the WIPP repository footprint on the surface. Appendix EPIC (Section EPIC.6) indicates the period of time during which passive institutional controls will be effective.

The surface monuments are large monuments erected on the surface at both the repository footprint and the controlled area boundaries. To facilitate fabrication and shipping of the monuments, each monument will consist of two separate stones connected by a tendon joint. The large monuments will be engraved with Level II and III messages and Level IV pictographs as described in Appendix PIC (Section IV).[4] Figures 7-12 and 7-13 provide the dimensional characteristics of the large monuments. The monuments intended for marking the controlled area boundaries will differ from the monuments marking the repository footprint. Each footprint monument will be inscribed with the Level II and III messages in seven languages, the six official United Nations languages (English, French, Spanish, Chinese, Russian, and Arabic), and Navajo. The controlled area boundary monuments will be inscribed with warning messages. Trauth et al. (1993, Appendix F) discusses in some detail the selection of these languages by the Markers Panel.

The monuments will be quarried from granite and shipped by rail to the WIPP site. Each monument base will be soundly founded by excavating into the near-surface caliche. After emplacing the base monument, the excavation will be backfilled and the upper monument will be placed over the base tendon.

The small warning marker is shown in Figure 7-14. The Level II messages placed on the small subsurface warning markers will be in the seven languages previously listed. However, each marker will have the message in only one of the seven languages. Warning markers will be placed throughout the repository footprint and within the berm. The warning markers will be made of a diversity of durable materials, such as granite, aluminum oxide, and fired clay, thus improving the likelihood that at least some of the markers will endure for thousands of years.

The small buried warning markers will be randomly spaced in locations and at depths to provide a reasonable expectation of discovery by any organized exploration effort, but to discourage organized efforts at collecting the markers. The current petroleum industry practice in the Delaware Basin is to remove surface soil down to the caliche layer over an area

---

[4] Five levels of messages will be used in the permanent marker system.

- Level I conveys the message that the site is man-made. The message itself is in the physical form of the marker system and the effort expended in constructing it.
- Level II conveys the message that something dangerous is buried here and that no digging or drilling should be conducted. This message is carried in seven languages uniformly distributed among the subsurface warning markers. Each marker has the message in a single language. The Level II message is also engraved on each monument in seven languages.
- Level III conveys basic information that tells what, why, when, where, who, and how. This message is carried by the monument markers.
- Level IV conveys complex information in seven languages and is stored in the permanent structures buried underground and the information center on the surface.
- Level V is archival and involves storing more complete rulemaking records than the messages provided at the WIPP site. These records are not stored at the site, but will be located in various public access facilities at the local, state, federal, and international levels.

sufficiently large to set up a drilling rig and dig a mud pit. Nominally, this area is 50,000 square feet (4,648 square meters). By placing the small warning markers above the caliche at intervals of a few feet, several of the warning markers should be unearthed during any soil clearing operation.

The inclusion of a berm in Figure 7-15 in the permanent marker design is based upon the following criteria (see Appendix PIC, Section VII, for more detail).

- The surface footprint of the repository should be essentially outlined by some enduring structure.

- The structure should be sufficiently massive to provide reasonable expectation that it will endure for thousands of years.

- The structure's profile should minimize the likelihood that it can become buried by shifting sands or that characteristics of the profile may lead to fabrication stresses affecting the ability of the structure to retain its configuration.

- The structure should be constructable without the need for sophisticated equipment or processes.

- The construction materials should be reasonably available to the WIPP site and have little intrinsic value.

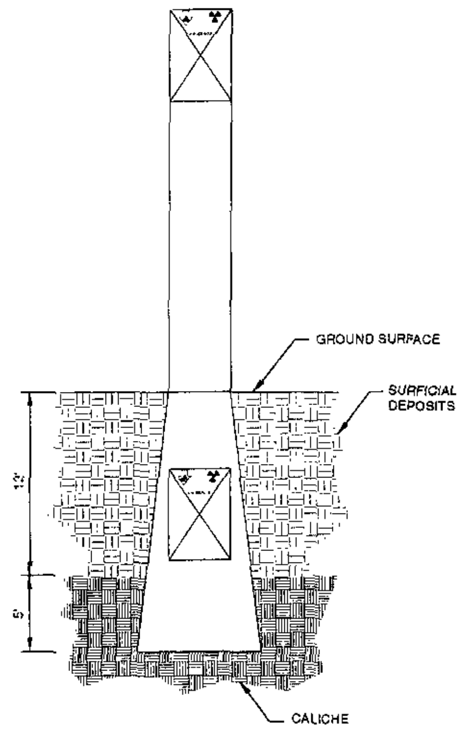
- The cost should not be disproportionately high for the advantages that the alternative provides.

- To the extent practicable, the nature of the structure should lend itself to testing over a period of two to five decades.

The berm is proposed to encompass the repository footprint. Figure 7-15 also depicts the berm cross section.

To provide a distinctive magnetic signature for the berm, large permanent magnets buried at intervals in the berm will be used. These magnets will produce a detectable signal with current airborne detection equipment. The magnetic signal's geometric form will provide strong indication that it could only have been humanly engineered. This magnetic signature should motivate any organization capable of magnetic surveying to further investigate this anomaly prior to initiating drilling activities.

Similarly, to provide a distinctive radar-reflective signature unique from the surrounding terrain, trihedrals fabricated from metal will be buried in the berm. Bellus and Eckeman (1994) provide a description of the trihedrals.



MONUMENT EMPLACEMENT

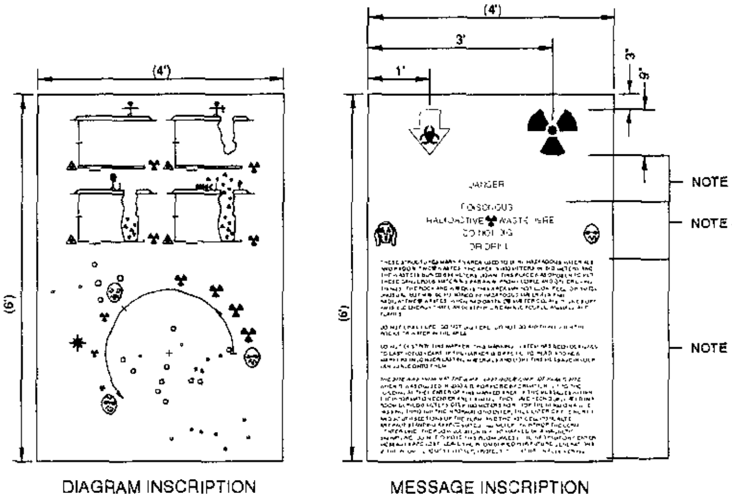
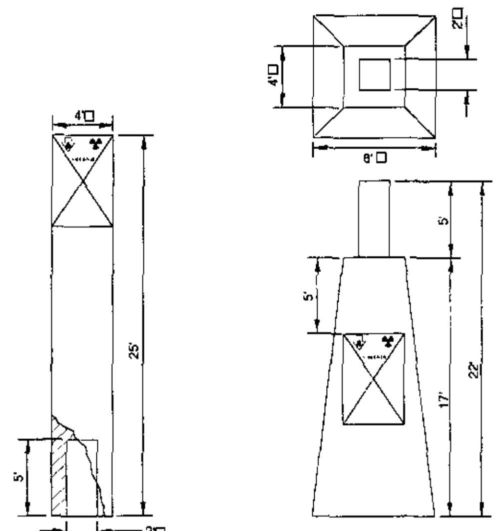


DIAGRAM INSCRIPTION
NOTE 6

MESSAGE INSCRIPTION



MONUMENT FABRICATION

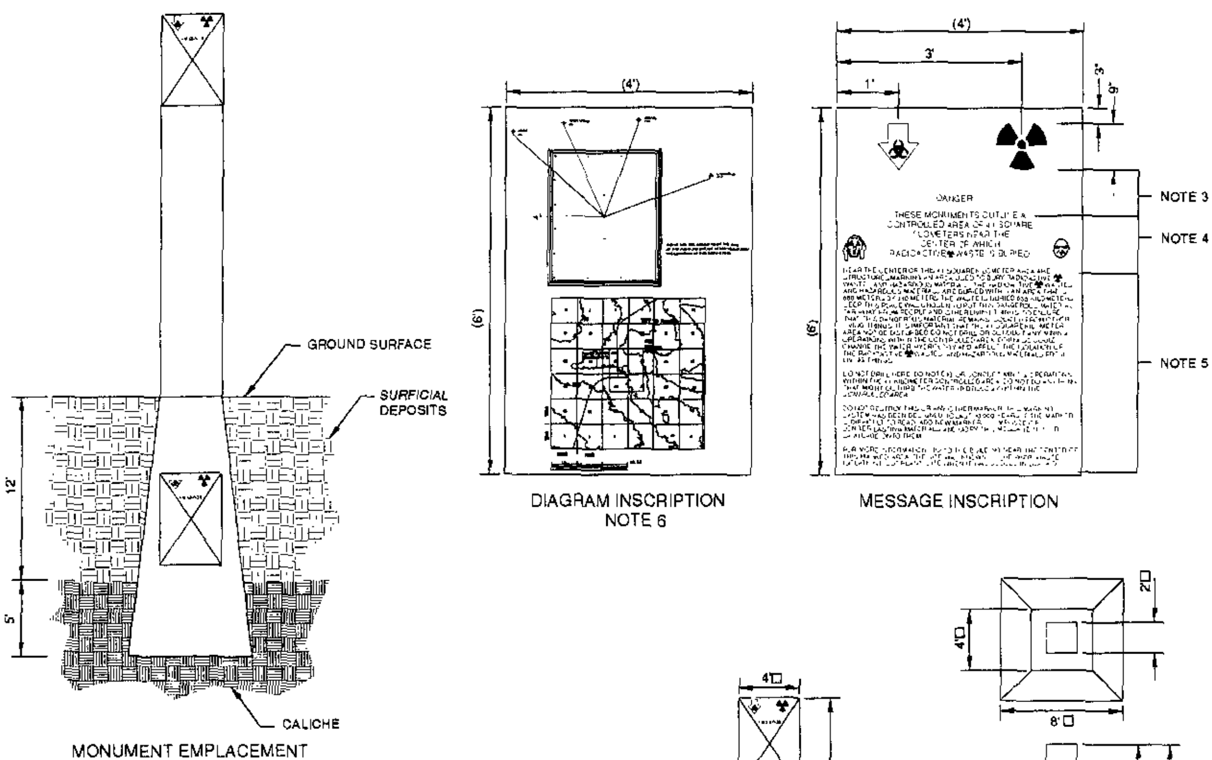
NOTES:

1. MONUMENT TO BE HEWN FROM TWO SOLID PIECES OF GRANITE.
2. MESSAGE TO BE CARVED INTO STONE FACE AND GENERAL LOCATIONS AS SHOWN ON DRAWING. THE MESSAGE WILL APPEAR SEVEN TIMES ON THE MONUMENT, ONCE IN EACH LANGUAGE LISTED BELOW. THE MESSAGE WILL APPEAR AT THE TOP OF THE MONUMENT ON THREE FACES, LEAVING ONE BLANK FACE. IT WILL APPEAR ON FOUR SURFACES AT THE BOTTOM.
   A. ENGLISH
   B. SPANISH
   C. RUSSIAN
   D. FRENCH
   E. CHINESE
   F. ARABIC
   G. NAVAJO
3. THE LEVEL I MESSAGE WILL BE IN 3" HIGH LETTERS WITH A 3" SPACE ABOVE AND A 3" SPACE BELOW.
4. THE LEVEL II MESSAGE WILL BE IN 1 1/2" HIGH LETTERS WITH A 1" SPACE BETWEEN LINES AND A 2" SPACE BELOW THE BOTTOM LINE OF THE MESSAGE.
5. THE LEVEL III MESSAGE WILL BE IN 1" HIGH LETTERS WITH A 5/8" SPACE BETWEEN THE LINES. THERE WILL BE A 1 1/2" SPACE BETWEEN THE PARAGRAPHS OF THE MESSAGE.
6. THE DIAGRAM INSCRIPTION WILL APPEAR ON THE BLANK FACE ON THE TOP OF THE MONUMENT. THE DIAGRAM DESCRIBES THE HAZARDS OF DIGGING HERE AND HOW LONG THAT HAZARD WILL EXIST.

CCA-112-2

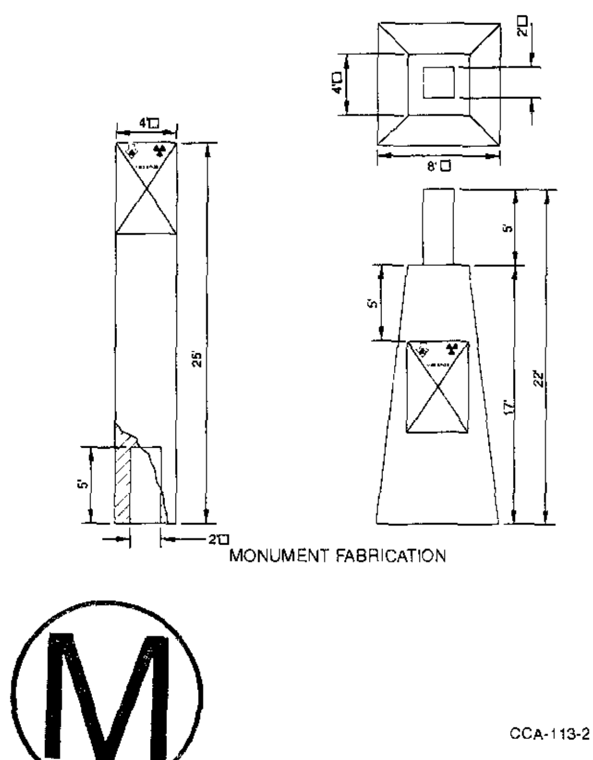
Figure 7-12. Repository Footprint Perimeter Monument Configuration

THIS PAGE INTENTIONALLY LEFT BLANK



NOTES:

1. MONUMENT TO BE HEWN FROM TWO SOLID PIECES OF GRANITE.
2. MESSAGE TO BE CARVED INTO STONE FACE AND GENERAL LOCATIONS AS SHOWN ON DRAWING. THE MESSAGE WILL APPEAR SEVEN TIMES ON THE MONUMENT, ONCE IN EACH LANGUAGE LISTED BELOW. THE MESSAGE WILL APPEAR AT THE TOP OF THE MONUMENT ON THREE FACES, LEAVING ONE BLANK FACE. IT WILL APPEAR ON FOUR SURFACES AT THE BOTTOM.
   A. ENGLISH
   B. SPANISH
   C. RUSSIAN
   D. FRENCH
   E. CHINESE
   F. ARABIC
   G. NAVAJO
3. THE LEVEL I MESSAGE WILL BE IN 3" HIGH LETTERS WITH A 3" SPACE ABOVE AND A 3" SPACE BELOW.
4. THE LEVEL II MESSAGE WILL BE IN 1 1/2" HIGH LETTERS WITH A 1" SPACE BETWEEN LINES AND A 2" SPACE BELOW THE BOTTOM LINE OF THE MESSAGE
5. THE LEVEL III MESSAGE WILL BE IN 1" HIGH LETTERS WITH A 5/8" SPACE BETWEEN THE LINES. THERE WILL BE A 1 1/2" SPACE BETWEEN THE PARAGRAPHS OF THE MESSAGE.
6. THE DIAGRAM INSCRIPTION WILL APPEAR ON THE BLANK FACE ON THE TOP OF THE MONUMENT. THE DIAGRAM DESCRIBES THE LOCATION OF THE BERM AND THE LOCATION OF THE INFORMATION CENTER BY USING THE STARS.



CCA-113-2

Figure 7-13. Controlled Area Perimeter Monument Configuration

THIS PAGE INTENTIONALLY LEFT BLANK

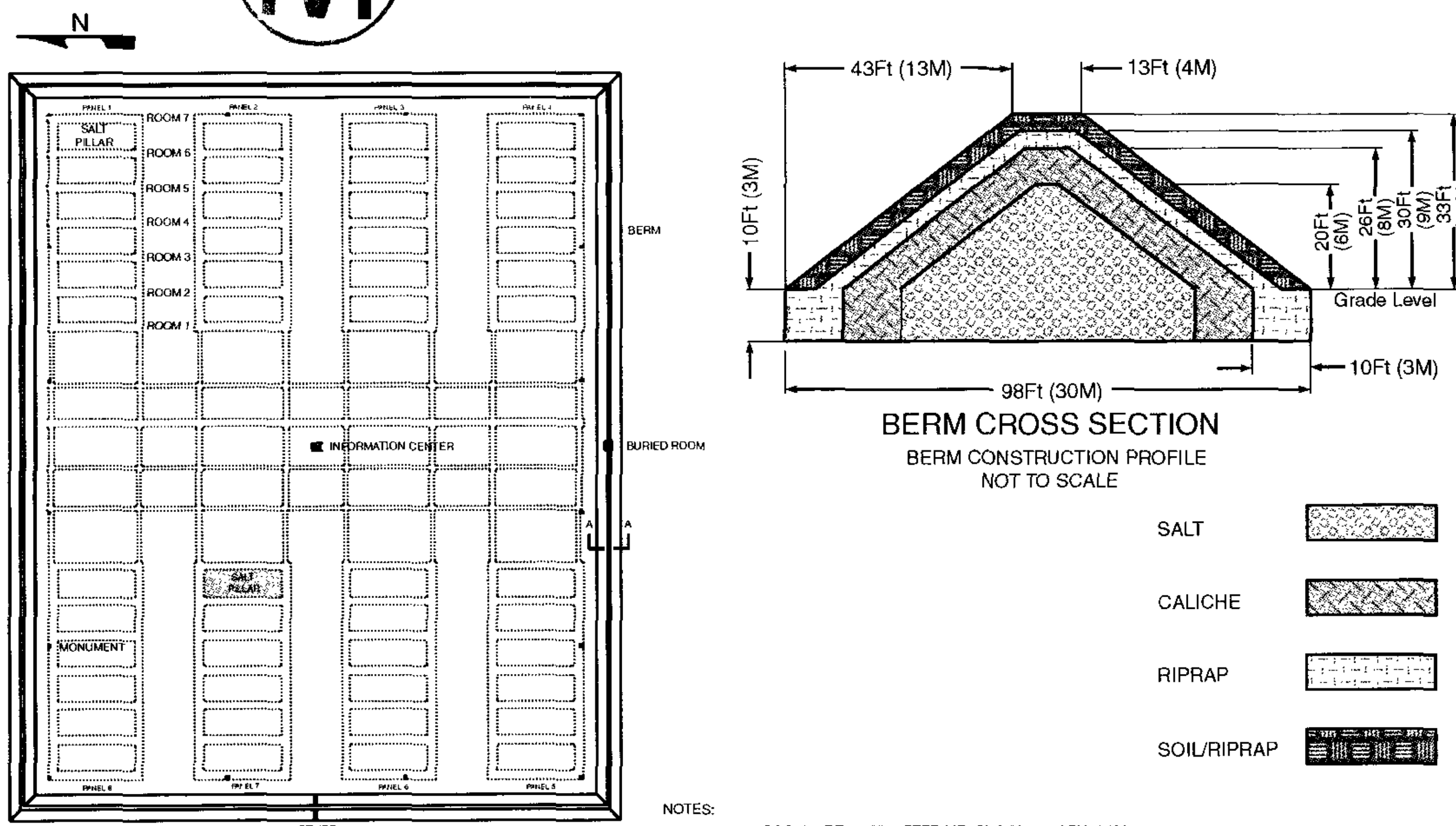
Diameter of Disk is 23 cm. (9 in.)
Not to Scale

CCA-114-2

Figure 7-14. Small Buried Warning Marker

THIS PAGE INTENTIONALLY LEFT BLANK

M



BERM LOCATION

NOTES:

1. THE DISPOSAL AREA PERIMETER MEASURES 629M BY 776M
2. THE INNER PERIMETER OF THE BERM MEASURES 660M BY 814M.
3. THE OUTER PERIMETER OF THE BERM MEASURES 720M BY 874M.
4. PANELS, ROOMS, AND SALT PILLARS REFER TO THE REPOSITORY FOOTPRINT SHOWN AS DOTTED LINES...

CCA-115-2

Figure 7-15. Berm Construction

THIS PAGE INTENTIONALLY LEFT BLANK

Another aspect of the marker system includes on-site buried storage rooms containing the Level IV message and associated diagrams. These rooms will be designed to endure for a similar time period as the permanent marker system and will be buried (see Appendix PIC). The design characteristics contributing to this longevity will be the material and environmental conditions associated with construction and location. The rooms will be made of granite with a minimum number of joints. Individual walls, the floors, and the roofs will comprise single granite slabs joined only at the edges. The configuration minimizes the risk of failure caused by chemical interactions between the construction material and the environment. The message texts contained within the buried storage rooms will be engraved on the walls. To provide redundancy, additional granite slabs engraved with the message text and the diagrams will be held in place against the interior walls. Although some damage could be inflicted by vandals, the granite composition of the message-carrying materials will provide the greatest opportunity for preventing complete destruction of the information contained within the buried rooms.

In addition to the buried storage rooms, an information center, as described in Appendix PIC (Section VII), will be located on the surface providing access to the same information that is contained in the buried rooms. Details regarding the location of one of the buried storage rooms and identical information will be contained in the information center.

7.3.3.1.2 Records

A significant part of the overall system will be the archiving of important information at sites remote to the repository. The archived material will include information that defines the location, design, content, and hazards associated with the WIPP. The amount of information will be more extensive than that available within the permanent marker system at the repository location. Information will be preserved using practicable materials and techniques at record centers and archives throughout the world. Appendix EPIC (Section EPIC.6) provides justification for a period of time that materials placed in archives and records centers are expected to endure and be understood.

Specific documents in the archived information portfolio will include the following. The specific requirements of 40 CFR § 194.43(2)(a) applicable to each document are indicated in parentheses.

- detailed maps describing the exact location of the repository (i),

- the Safety Analysis Report (i – iv),

- the Final Environmental Impact Statement (FEIS) for WIPP and the supplement(s) to the FEIS (i – iv),

- the RCRA Permit (i – v),

- the Compliance Certification Application (i – v),
- environmental and ecological background data collected during the preoperational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of WIPP (iv),
- records of the waste container contents and disposal locations within the WIPP repository (iii),
- drawings defining the construction and configuration of the repository and shafts (ii),
- drawings, procedures, and design reports describing how the waste was emplaced, and how the repository was decommissioned, closed and sealed (v), and
- design information for the passive institutional controls (ii).

The National Archives will be one organization responsible for the permanent storage of this information. As discussed in Appendix PIC, the information will also be distributed to appropriate organizations such as the following for long-term safekeeping:

- federal and state government agencies,
- federal, state, tribal, and local archives and libraries,
- local and state and record repositories (for example, the Eddy County Clerk New Mexico)
- national archives and libraries of nations that possess nuclear weapons and nuclear energy or produce natural gas and oil resources, and
- professional and technical societies.

The archival and record centers identified in Appendix PIC as planned recipients of information were selected based upon one or more of the following criteria:

- representing an international location in a nation which had citizens engaged in the oil and gas exploration and exploitation industry,
- representing an international location in a nation which had the potential to generate radioactive waste,
- representing a local governmental organization frequented by individuals engaged in the oil and gas exploration and exploitation industry,

- representing a National Archival location,
- representing a Regional Library, or
- is a public funded location.

The DOE intends to submit WIPP records to over 100 archives nationally and internationally as identified in Appendix PIC. The initial submittal of these records will occur after closure and decommissioning of the WIPP. Since this time frame is decades into the future and thus significant changes will occur to some or all of the archives as well as some of the governments, the DOE has not attempted to identify the practices employed by each archive and repository for maintaining records and making them accessible to the public. However, the National Archive-Rocky Mountain Region practices are described and are representative of the National Archives and its regional facilities. The state of New Mexico Archive and the Canadian National Archive were also contacted and their practices are similar to those employed by the U.S. National Archives. There are also international standards for the organization and operation of archives that enable the world's archives to function similarly in many aspects of the practices governing maintenance of records and access to the records by members of the public.

To ensure the proper storage and retrievability of archived material, the DOE archivist will develop a filing code system specifically for the WIPP material. This system will be a part of the overall document submittal the DOE will provide to the various archival locations. In the development of the filing code system and communications with worldwide archives, it is expected that differing cultural issues will be addressed in order that the DOE gain acceptance of the information from as many archives as possible.

To reduce the possibility that future archivists may destroy the provided documents, each volume containing documents will be labeled with a warning that the intent of providing the archived material is to ensure its preservation for the 10,000-year regulatory time frame stipulated in the U.S. Government's regulations controlling the disposal of transuranic waste. It is recognized that the federal government may incur some long-term financial obligations to the archival locations to ensure retention. Within two years following the distribution of archival material and at least every 15 years thereafter during the active institutional controls period, the DOE will conduct audits of selected archival locations to verify retention and retrievability of the historical documents.

As an example of how an archive will handle archived information, the National Archive will use the indexing system provided by the DOE in organizing the WIPP material submitted for archiving and public use. Upon receipt of the material in boxes, the archive staff will examine the documents; remove staples, paper clips, rubber bands, and other miscellaneous materials that may damage or are otherwise incompatible with the records over an extended period of time; enclose any damaged material in individual protective covers; place the records in acid-free boxes; and store those boxes in an environmentally controlled vault. The individual boxes are labeled with coded alpha-numeric designations that tie the contents back to the agency submitting the documents, the year in which the documents were received, and the general content of the documents. Finding aids, content indices, or significant word lists are developed to aid researchers in identifying the material desired. The coded number will also provide information relative to whether or not the documents may be destroyed after a given amount of time. Many government documents are scheduled to be destroyed after 30 years. Other documents are preserved indefinitely.

Title 36 CFR Part 1254, Availability of Records and Donated Historical Materials, regulates the manner in which archival material within the National Archive system is made available to members of the public. In general, researchers must register each day that they enter a research facility and may be required to provide identification. The researcher must sign for the documents received and again may be required to show identification. The researcher is not permitted to leave the room without notifying the room attendant and placing all documents in their proper containers. Documents must be returned to the research room attendant prior to the room closing. Documents may not be used where there is food, drink, or the presence of ink. Only pencils may be used in the room containing original documents. If the researcher requires copies of documents, the appropriate document must be marked with a paper tab provided by the archive. No paper clips or rubber bands may be used on the documents. The room attendant will provide the copying services for the researcher. Documents must be maintained in order by the researcher, however if the documents become disordered, the room attendant must perform the re-ordering function and not the researcher. Upon exiting a research room, the researcher must present for examination any article that could contain documents.

In addition to the national and state archives, Indian tribes and pueblos (for example, Navajo, Mescalero Apache, and Zuni) were contacted to determine the extent of any archival activity. Only the Zuni were establishing a limited internal archive. Other groups forward archive worthy materials to federal storage facilities. The DOE will continue to work with key nations, tribes, and pueblos to establish pertinent agreements and to ensure that appropriate WIPP records are distributed for archiving and reference purposes.

Finally, the International Atomic Energy Agency (IAEA), with the DOE as a current participatory through the agency of its Scientific Advisor, is developing a procedure for the archiving of records pertinent to the disposal of radioactive waste in deep geological repositories. The procedure, published in final draft May 31, 1996, is titled *Maintenance of Records for Deep Geological Repositories*. The DOE embraces this effort and intends to continue to pursue final publication of this comprehensive document with the IAEA.

7.3.3.2 <u>Implementation of Programs to Collect Information</u>

Prior to implementing the passive institutional controls, a testing program will determine whether the specific messages proposed can be expected to convey the intended warnings and information across cultures and whether the proposed media for transmitting the messages will endure to the degree anticipated in the development of the conceptual model. The testing to be conducted will address the refinement of the messages, diagrams, and the method of presentation. As recommended in Trauth et al. (1993), the translated versions of the message text should be evaluated by presentations to groups indigenous to the countries whose language is represented in the message. This process should provide input into how comprehensible the messages are and provide information regarding any idiom changes that may be necessary in the translated versions. When considering that the messages were developed by educated individuals residing in the U.S., it is prudent that the effectiveness of the messages to convey their intended content to a broader cross-section of individuals be thoroughly tested. The testing therefore should include cross-cultural groups in evaluating the effectiveness of conveying the intended messages through diagrams and pictures as well as script. The DOE will continue to develop and review the details of a testing program to ensure that a comprehensive effort is made to test the final written and pictograph message comprehensibility. For those components that include either large volumes of various materials (for example, the berm) or the movement of heavy objects (for example, the sections of granite in the monuments), procedures will be tested for transporting the material and constructing the specified designs. The testing programs are described in Appendix PIC. See Appendix EPIC for a discussion of the durability of materials to be used to construct passive institutional controls.

7.3.3.3 Passive Institutional Controls Timelines

The DOE has prepared a tentative schedule of the implementation of the passive controls program. The schedule is shown in Figure 7-16. The following is provided as a brief expansion of the timelines provided in Figure 7-16.

- 1996-2083 Design and Test Permanent Marker Concepts and Materials. During this period the testing and monitoring described in Appendix PIC related to the permanent marker components, materials, and communication concepts are conducted.

    - 1998 – 2005 Construct Test Berm. During this period, the DOE will install test monuments, buried test markers, and construct a section of berm for testing. The berm section will include magnets and radar reflectors for testing.

    - 2005 – 2083 Monitor Performance of Test Markers and Test Berm. During this period, the DOE will monitor the performance of the test structures to develop information for use in the final design.

    - 2018 – 2023 Test Message Comprehension. The DOE will gain operational experience for any information that may affect the composition of the intended messages, both narrative and pictogram, and then conduct testing for comprehension by populations indigenous to the countries represented by the languages used in the messages.

- 2083 – 2090 Final Design. During this period, the DOE will complete the final design of the permanent marker system.

- 2090 – 2093 Construct Permanent Marker System. During the period, the permanent marker system will be constructed including installation of messages.

- 1999-2093 Implement Information Collection and Establish Archival and Record Center Agreements. During this period the actions required to implement record keeping and record storage aspects of passive institutional controls are conducted. Individual actions and associated timelines are:

  - 2003 Establish Filing System. The DOE will establish the filing system under which the record center and archival information will be assembled. Completion of the system by 2003 will support the information collection program.

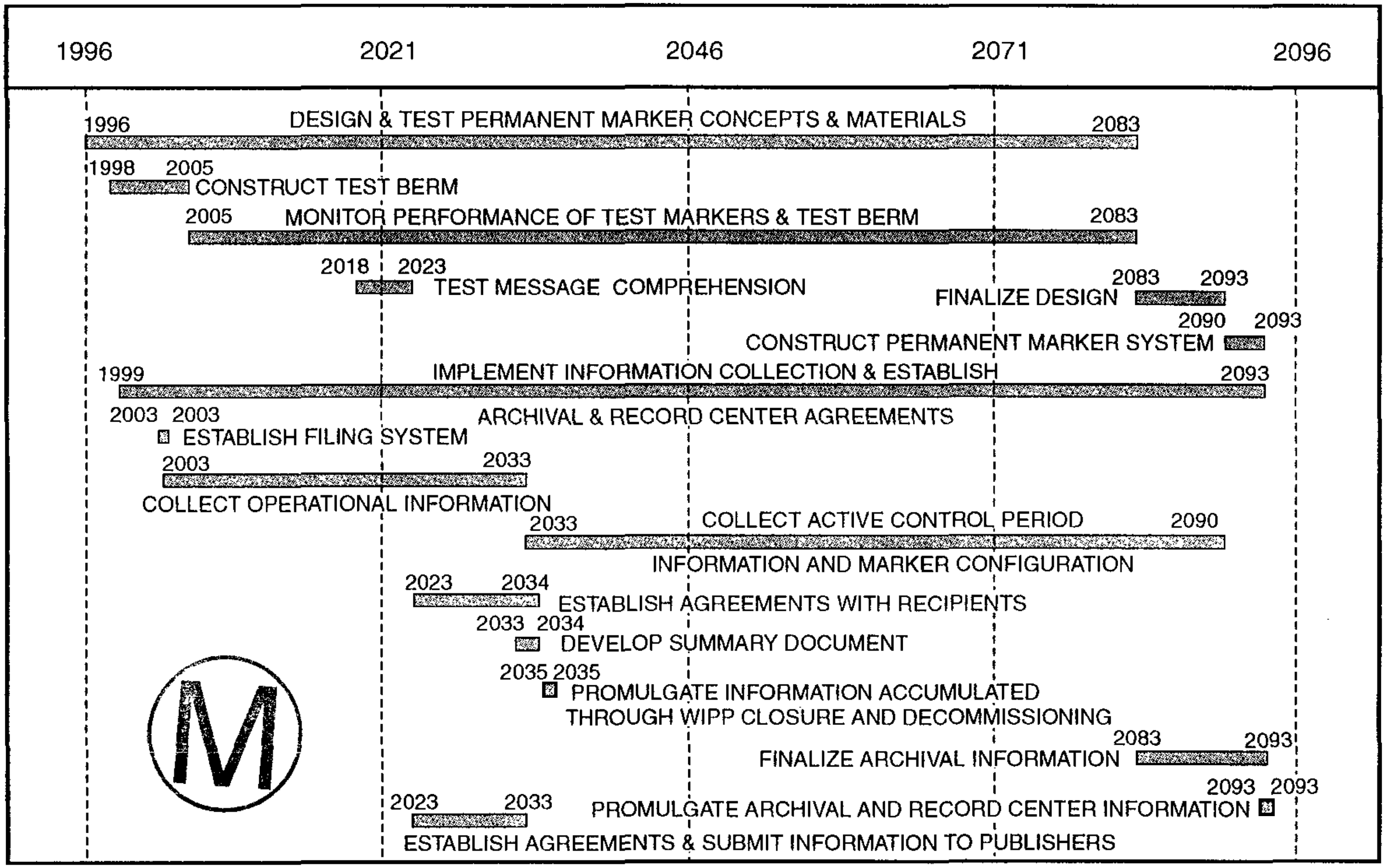
  - 2003 – 2033 Collect Operational Information. Collect the information relative to WIPP operation, including decommissioning, which will be included in the promulgated documentation.

  - 2033 – 2090 Collect Active Control Period Information and Marker Configuration. Collect the information relative to WIPP active controls and the results of testing of the permanent marker system components and communication concepts.

  - 2023 – 2034 Establish Agreements with Recipients. During this period the DOE will communicate with the planned document recipients to develop general agreements with respect to language translation, scope of translated material, format in which the material will be provided, and any financial support required to achieve acceptance by each recipient. Beginning about 2023 when most of the documentation should have been developed, this effort should start. The DOE expects two to three years to establish the agreements and another five to eight years for translation with completion about the time that decommissioning and decontamination are finished. This provides for the incorporation of information related to decommissioning and decontamination.

  - 2033 – 2034 Develop Summary Document. The DOE will develop the WIPP summary document to be provided for ease of public access and understanding of the WIPP.

  - 2035 Promulgate Information Accumulated Through WIPP Closure and Decommissioning. The DOE will make a distribution of documents accumulated through the final closure, decontamination, and decommissioning of the WIPP.



CCA-175-0

Figure 7-16. Passive Institutional Controls Timeline

THIS PAGE INTENTIONALLY LEFT BLANK

- 2023 – 2033 Establish Agreements and Submit Information to Publishers. During this period, the DOE will establish agreements with map makers and text publishers including financial support and provide hazard, history, and location information to be included on maps and various text materials.

- 2083-2093 Finalize Archival Information. During this period, the DOE will develop the final additions to the planned submittal, which include information describing the WIPP history during the first 50 to 60 years following closure and the final configuration of the permanent marker system.

- 2093 Promulgate Archival & Records Center Information. The DOE will make the distribution of the final portion of the archived information nationally and internationally.

7.3.4 Effectiveness of Passive Controls in Reducing the Rate of Human Intrusion

The EPA raises the issue of the expected ability of the passive institutional controls to convey information to future societies in two areas. In the context of the assurance requirement in which no assumptions can be made to limit the uncertainty of the future states of societies, the EPA states

> Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood. (40 CFR § 194.43[b])

In the context of credit for passive institutional controls in deterring inadvertent human intrusion for use in performance assessments, the EPA goes on to state that

> The Administrator may allow the Department to assume passive institutional controls credit, in the form of reduced likelihood of human intrusion, if the Department demonstrates in the compliance application that such credit is justified because the passive institutional controls are expected to endure and be understood by potential intruders for the time period approved by the Administrator. Such credit, or a smaller credit as determined by the Administrator, cannot be used for more than several hundred years and may decrease over time. In no case, however, shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely (40 CFR § 194.43 [c]).

To limit the speculation about the state of future society, the EPA has provided additional guidance by stating that "EPA expects that the DOE will establish a framework of assumptions for passive institutional controls that is a prudent extrapolation of the future state assumptions established in § 194.25" (EPA 1996b, 61) and by providing for the existence of certain societal "common denominators" based on "patterns of human behavior that may be detected throughout history and around the world" (EPA 1996b, 61).

Section 7.3.4.1 addresses the issue of how long the passive institutional controls are expected to endure and be understood in the context of the Assurance Requirement (40 CFR § 194.43[b]), and Section 7.3.4.2 addresses the issues of how long these controls are expected to endure and be understood and the resulting credit in deterring inadvertent human intrusion in performance assessment calculations (40 CFR § 194.43[c]).

7.3.4.1 Expected Effectiveness

The passive institutional controls in the Conceptual Design Report (DOE 1994) were developed from the recommendations of the Markers Panel convened in 1991, modifying them for reasons such as constructability or resource requirements. The Markers Panel developed fundamental principles of long-term communication making only the most minimal assumptions about what future societies would be like (for example, they will be human beings similar to what we are today). No assumptions were made about what languages they might be speaking or how technologically sophisticated they might be. Because no assumptions were made about language or technology, the Markers Panel developed strategies that attempt to communicate with individuals in a variety of means and in a systems approach whereby the various components reinforce and supplement the other messages.

Without assumptions about technological sophistication, messages will be provided in various levels of complexity, ranging from the most basic marker of human construction rather than a natural phenomenon, to the entire written record of information about the repository and its certification. Because it is not known what languages will be spoken in the future, the markers will include non-linguistic means of communication, such as pictures of humans, star charts, and the periodic table of the elements. In this way, the design of the markers responds to the EPA's requirement for the "most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location" (40 CFR § 191.14[c]). While the Markers Panel focused its efforts on the repository footprint, based on the 40 CFR Part 191 definition of human intrusion, the entire withdrawal area will be identified by on-site passive institutional controls to satisfy criteria in 40 CFR § 194.43. Because of the requirement for records and archives, plans have been made to place materials within the existing governmental and scientific systems of recordkeeping.

In addressing the issue of credit for passive institutional controls in performance assessment calculations, the DOE examined historical analogues for the controls components (see Appendix EPIC, Chapter 5). Certain design characteristics of these historical analogues have survived destruction from both societal turmoil and natural processes. By designing the passive institutional controls to mimic and enhance these design characteristics, the DOE believes that the passive institutional controls for the WIPP will be capable of surviving at least as long as the historical analogues. Based on the characteristics of the markers, these components have the capability of lasting in excess of several thousand years. This conclusion is consistent with the conclusions of both teams of the Markers Panel whose estimates were based on basically the same design characteristics for the markers and on a wide variety of future states of society. The multiple copies of the records in the records centers and archives, the selection of highly durable materials (that is, archival paper and carbon-black ink), and the fact that the records will have value in the economic and health areas suggest that at least some copies of the records have a high probability of surviving for many hundreds to thousands of years.

The Markers Panel concluded that the messages proposed have a high probability (greater than 0.70) of being understood by all potential levels of technology for at least 2,000 years (Team A estimated at least 5,000 years). Although the Markers Panel considered only the messages on the markers, the same information, both text and pictographs, will be included in the records in records centers and archives. As a result, the DOE concludes that these records will be interpretable for as long as the documents survive.

7.3.4.2 Credit Taken in Performance Assessment Calculations

In addition to their use for compliance with the assurance requirements, the passive institutional controls have a separate function in deterring human intrusion into the disposal system for performance assessment calculations. While only minimal assumptions were made about future society for the purposes of designing the passive institutional controls, more detailed assumptions need to be made to provide actual numbers for performance assessment calculations. The Preamble to 40 CFR Part 194 limits any credit for passive institutional controls in deterring inadvertent human intrusion to 700 years after disposal. This shorter time period is an important factor in the development of numbers to evaluate the effectiveness of passive institutional controls for performance assessment. The effectiveness of passive institutional controls is further described in Appendix EPIC.

Active institutional controls will be implemented at the WIPP after closure to control access to the site and will ensure that only those activities allowed by the LWA take place at the site. The existence of active institutional controls will preclude human intrusion in the withdrawal area, although there is a regulatory prohibition against taking credit for the effectiveness of active institutional controls in performance assessment calculations beyond 100 years after disposal. Because of the nature of the system of active institutional controls, the effectiveness of the active institutional controls would be the controlling factor for performance assessment calculations up to 100 years. Thus, the effectiveness of passive institutional controls for use in performance assessment is focused on the time period from year 100 to year 700 after disposal. See Appendix EPIC for discussion and analysis.

The Markers Panel developed its recommendations for the longevity of marker materials and configuration based, in part, on historical analogues. When the passive institutional controls task force (PTF) assessed the effectiveness of the passive institutional controls, as described in Appendix PIC, additional historical analogues were considered, and a one-to-one comparison was developed between individual passive institutional controls components and individual historical analogues. This one-to-one comparison allowed the PTF to identify general periods of time for endurance for each passive institutional control. At the same time, the PTF identified potential failure mechanisms of the markers components, the records and archives system, and governmental control components. Because the passive institutional controls were designed to address failure mechanisms based on historical analogues that endured and those for which there is a record of failure, the PTF believes that physical failure of the passive institutional controls components over the entire withdrawal area will not occur in the time frame of interest for performance assessment. This belief is supported by the fact that no failure mode applies to all passive institutional controls and failure of the marker system requires failure of all components of the marker system.

After physical durability was evaluated, the PTF studied the ability of messages to be understood. Building upon assumptions listed by the EPA in the Compliance Application Guidance as common denominators of human behavior, the PTF developed a list of assumptions about how future societies would operate, focusing on potential intrusions to explore for and exploit natural resources. One of the PTF's assumptions is that English will be understandable to the resource exploration and exploitation community for at least 1,000 years. This assumption is made based on (1) 1,000-year-old English literature can be understood by scholars today, (2) English is a world language with a concomitant inertia against radical and rapid change, and (3) the valuable nature of the resources in the area means that resource-seeking individuals and corporations will make the effort to decipher past records dealing with resource availability. The PTF believes that for the time frame of interest for performance assessment, the ability of potential drillers to interpret past records is virtually certain.

Other assumptions made by the PTF are discussed in Appendix EPIC. The PTF provides the basis for assumptions relating to basic human attributes, government, language, natural resources, and estimating passive institutional controls effectiveness. The PTF established this framework of assumptions through a "prudent extrapolation" of the future state (that is, present-day) assumptions established in 40 CFR § 194.25.

The failure mode that remained after these PTF evaluations were performed was human error either in obtaining and documenting a lease or a permit to drill, or in actually setting up a drill rig and drilling a borehole in the wrong location. When a search of the New Mexico portion of the Delaware Basin resource records did not yield any documentation of wells drilled in the wrong location, the PTF queried individuals who had many years of experience with drilling in both the Delaware Basin and the encompassing Permian Basin. These individuals were able to provide five instances of wells drilled in the wrong location, although none was in the Delaware Basin. Based on 429,000 wells drilled in the area in question, these five instances resulted in a failure rate of 0.00001 for the Permian Basin and 0.00 for the Delaware Basin. There may be other wells drilled in the wrong location that were not identified in the recent search. In addition, there may be additional failure modes that were not identified in the passive institutional controls effectiveness report. Because of these possibilities, the PTF increased the calculated failure rate by three orders of magnitude to 0.01 to provide a bounding value for performance assessment calculations.

A one percent failure rate would mean that out of every 100 permit requests, one involved an unlawful permit, or one involved a location error on the permit itself, or the drillers set up in the wrong location (that is, in the wrong lease). Such a high failure rate, however, would be widely known within the drilling community and the failure rate would have caused the implementation of stronger controls over drilling.

Thus, for performance assessment calculations, the passive institutional controls are considered to be 0.99 (that is, 1 to 0.01) effective in deterring inadvertent human intrusion over the entire withdrawal area.

7.4 Multiple Barriers

The WIPP facility has incorporated multiple natural and engineered barriers, including plugs, seals, and backfill into its design. As a part of the DOE's program to evaluate multiple barriers, an Engineered Alternatives Task Force (EATF) evaluated optional additional engineering measures for the WIPP facility. The findings of the task force are summarized in the *Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives* (DOE 1991). A more recent study, the Engineered Alternatives Cost/Benefit Study, updated the 1991 EATF activity and augmented it with more in-depth and comprehensive analyses of the relative benefits and detriments of the alternatives. Benefits and detriments at the waste generation and storage sites were evaluated in this study as well as those at the WIPP. (This study is included as Appendix EBS.)

Beyond the requirements contained in 40 CFR § 191.14(d) relating to multiple barriers, 40 CFR § 194.44 has imposed certification criteria upon the DOE with regard to engineered barriers. The following sections provide a discussion of the manner in which the DOE has complied with the multiple barrier requirement of 40 CFR § 191.14(d) and an overview of the manner in which the engineered barrier criteria of 40 CFR § 194.44 have been met. A detailed discussion of the cost and benefit analysis dictated in 40 CFR § 194.44 is provided in Appendix EBS.

7.4.1 Requirements for Multiple Barriers

By requiring the use of both natural and engineered barrier types as the assurance requirement, the EPA intends to ensure that the impacts of the failure of any single barrier type will be minimized.

In the LWA, Congress mandated that the Secretary will use both natural and engineered barriers. Waste form modifications may be used at the WIPP to isolate waste after disposal to the extent necessary to comply with the final disposal regulations. Therefore, the disposal system design involving the Salado as a natural barrier and the shaft seals as engineered barriers complies with this assurance requirement as indicated by the compliant complementary cumulative distribution functions (CCDFs) shown in Section 6.5.

7.4.2 Objectives for Multiple Barriers

The primary objective for the implementation and the use of multiple barriers at the WIPP facility is to help guard against unexpectedly poor performance from one type of barrier. This is accomplished by a design that includes multiple types of barriers.

7.4.3 Implementation of Multiple Barriers

The baseline design for the WIPP facility includes the concept of multiple barriers for isolation and containment of waste. Barriers that are part of the design include natural barriers (for example, hydrological, geological, and geochemical conditions) and engineered barriers (for example, borehole plugs, shaft seals, panel closures, and backfill). The effectiveness of these barriers is modeled in the performance assessment to demonstrate the ability of the disposal system to meet EPA standards.

Section 194.44(a) provides a criterion for certification for the analysis of the costs and benefits of various engineered barrier options. The text in the following subsections describes the DOE program that meets the engineered barrier requirements.

7.4.3.1 Engineered Alternatives Cost and Benefit Study

To fulfill the benefit and detriment evaluation criterion contained in 40 CFR § 194.44(b), the DOE published *Engineered Alternatives Cost/Benefit Study; Final Report* (DOE 1995) (see Appendix EBS). The EPA's criterion for this cost and benefit study is as follows:

> In selecting any engineered barrier(s) for the disposal system, the Department shall evaluate the benefit and detriment of engineered barrier alternatives, including but not limited to: cementation, shredding, supercompaction, incineration, vitrification, improved waste canisters, grout and bentonite backfill, melting of metals, alternative configurations of waste placements in the disposal system, and alternative disposal system dimensions. The results of this evaluation shall be included in any compliance application and shall be used to justify the selection and rejection of each engineered barrier evaluated. (40 CFR § 194.44[b])

The primary purpose of this cost and benefit study was to provide the DOE with information for use in selection or rejection of additional engineered barriers to provide assurance in the performance calculations. The current facility baseline, as represented in performance assessment, provides sufficient multiple barriers to obtain compliance with the requirements of 40 CFR § 191.14(d) as described in Sections 6.4.4 (Shaft Seal Engineered Barriers), 6.4.5 (The Salado Formation Natural Barrier), and 6.5 (Performance Assessment Results).

The approach used in the study was to screen potential engineered alternatives compiled from previous studies, the ten technologies specified in 40 CFR § 194.44(b), and input elicited from stakeholders. The screening process used a working group composed of technical professionals from various related fields to compare the proposed engineered alternatives to the established definition of an engineered alternative and then to determine if those alternatives that meet the definition also meet regulatory and technological feasibility criteria. The outputs of the screening process were

- a list of engineered alternatives that did not meet the definition or screening criteria, along with the justification for their rejection, and

- a list of engineered alternatives retained for further consideration.

The screening process evaluated 111 proposed engineered alternatives and screened out all but 54 (see Appendix EBS, Section 2.2.2). The 54 alternatives retained were then subjected to a DOE management-level assessment to determine the set of alternatives that would be retained for full analysis through the study. The basis for this assessment was to:

- develop a set of alternatives that address important WIPP performance issues, such as reducing the solubility of actinides in brine and improving the strength of the waste,

- analyze those alternatives that have high technical feasibility (that is, those alternatives that have been subjected to bench-scale testing at the least), and

- assess those alternatives that have a high likelihood of being permitted in a reasonable amount of time.

This assessment resulted in the selection of 18 alternatives for full analysis through the study. The screening process, including this DOE management-level assessment, was included in the scope of an independent peer review done on the study to address the requirements of 40 CFR § 194.27(a)(3). The peer review panel concluded that the entire screening process was reasonable and acceptable. Details of the peer review are found in Appendix PEER (Section 3.2).

The 18 alternatives finally selected for further study consisted of nine basic alternatives and nine variations. The 18 alternatives were compared to the criteria in 40 CFR § 194.44(c):

> (i) The ability of the engineered barrier to prevent or substantially delay the movement of water or waste toward the accessible environment;
> (ii) The impact on worker exposure to radiation both during and after incorporation of engineered barriers;
> (iii) The increased ease or difficulty of removing the waste from the disposal system;
> (iv) The increased or reduced risk of transporting the waste to the disposal system;
> (v) The increased or reduced uncertainty in compliance assessment;
> (vi) Public comments requesting specific engineered barriers;
> (vii) The increased or reduced total system costs;
> (viii) The impact, if any, on other waste disposal programs from the incorporation of engineered barriers (for example, the extent to which the incorporation of engineered barriers affects the volume of waste);
> (ix) The effects on mitigating the consequences of human intrusion. (40 CFR § 194.44[c][1])

In addition to the criteria listed above, Appendix EBS includes analyses that evaluated

- existing waste that is already packaged,
- existing waste that is not yet packaged,
- existing waste that is in need of repackaging, and
- to-be-generated waste.

All 18 alternatives met the intent of these criteria. This process is further described in Section 2 and Appendix O of Appendix EBS. The variations originated in the screening process, details of which can be found in Sections 2.2 and 2.3.1 of Appendix EBS.

For comparison, the baseline was considered to be the WIPP facility with no additional engineered barriers beyond shaft seals and panel closures. The 18 final engineered alternatives, along with a brief description of each, are listed below.

- **Supercompact Organics and Inorganics.** Solid organic and inorganic wastes are sorted to remove items that cannot be compacted. Sorted waste is precompacted in 35-gallon (132.6-liter) drums and then supercompacted. Usually, the contents of four supercompacted drums are placed in a 55-gallon (208-liter) drum. Sludges are not processed.

- **Shred and Compact Organics and Inorganics.** Solid organics and inorganics are shredded and compacted in 55-gallon (208-liter) drums using a mechanical shredder and a low-pressure compactor. Sludges are not processed.

- **Plasma Processing of All Wastes.** All wastes are processed through a mechanical shredder and the input waste stream is controlled to ensure a suitable metal to nonmetal ratio. The waste is processed through a plasma arc centrifugal treatment system and placed into 55-gallon (208-liter) drums.

- **Sand Plus Clay Backfill.** A mixture of medium-grained sand and granulated clay is used as backfill. The mixture is placed around the waste stack and between the drums filling the void space between drums and unmined host salt in waste emplacement panels. A 50-percent void space is assumed.

- **Salt-Aggregate (Grout) Backfill.** A salt-aggregate grout mixture is used as backfill to fill the void spaces between drums and unmined host salt in waste emplacement panels. This backfill consists of a cementitious-based, salt-aggregate grout with crushed salt aggregate and is pumped around the waste stack and between the drums filling the void spaces. A 20-percent void space is assumed.

- **Cementitious Grout Backfill.** A cementitious grout backfill consisting of ordinary Portland cement, sand, and fresh water is pumped around the waste stack and between the drums filling the void space. A 20-percent void space is assumed.

- **Supercompact Organics and Inorganics, Salt-Aggregate and Grout Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.6 meters) wide, and 300 feet (91.4 meters) long.

- **Supercompact Organics and Inorganics, Clay-Based Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.6 meters) wide, and 300 feet (91.44 meters) long.

- **Supercompact Organics and Inorganics, Sand and Clay Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.6 meters) wide, and 300 feet (91.44) meters long.

- **Supercompact Organics and Inorganics, CaO Backfill.** Monolayer of 2,000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long.

- **Salt Backfill with CaO.** A backfill of commercially available granulated lime and crushed salt is placed around the waste stacks and between the drums filling the void space. A 50-percent void space is assumed.

- **Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, No Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Sand and Clay Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A mixture of medium-grained sand and granulated clay is used as backfill. The mixture is placed around the waste stack and between the drums filling the void space between drums and unmined host salt in waste emplacement panels. A 50-percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Cementitious Grout Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A cementitious grout backfill consisting of ordinary Portland cement, sand, and fresh water is pumped around the waste stack and between the drums filling the void space. A 20-percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Salt Aggregate Grout Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A salt-aggregate grout mixture is used as backfill to fill the void spaces between drums and unmined host salt in waste emplacement panels. This backfill consists of a cementitious-based, salt-aggregate grout with crushed salt aggregate and is pumped around the waste stack and between the drums filling the void spaces. A 20-percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Clay-Based Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A backfill consisting of commercially available pelletized clay is placed around the waste stack and between the drums, filling the void space. A 50-percent void space is assumed.

- **Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, CaO and Salt Backfill.** This alternative includes two processes to treat the waste. The first is an enhanced cementation process of previously solidified and as-generated sludge. Existing sludges are fed into a mechanical crusher and shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly-generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums. A backfill of commercially available granulated lime and crushed salt is placed around the waste stacks and between the drums filling the void space. A 50-percent void space is assumed.

- **Clay-Based Backfill.** A backfill consisting of commercially available pelletized clay is placed around the waste stack and between the drums, filling the void space. A 50-percent void space is assumed.

The product from the evaluation of each factor was integrated into a quantifiable result called a performance vector. This vector expresses the performance of each engineered alternative relative to the baseline. The results of the factor analyses are presented in detail in Appendix EBS (Section 5.4).

The Engineered Alternatives Cost/Benefit Study (Appendix EBS) was useful to the DOE as it identified engineered barriers that could be used to improve long-term repository performance. Specifically, the advantages of a backfill that chemically altered the pH of brine in the disposal room were identified in Appendix EBS (Section 3.1) as providing significant benefit in reducing the quantity of mobile actinides. Alkaline earth oxides (such as calcium oxide [CaO]) are known to readily react with water to form hydroxides. These hydroxides are free to react with carbonic acid that may form in the disposal room. The reaction buffers the brines to a pH that reduces the amount of actinide in solution. After further analysis, which is documented in Appendix BACK and discussed in Appendix SOTERM, the DOE selected magnesium oxide (MgO) as the backfill material that provided the desired long-term benefit while minimizing the operational impacts associated with the more caustic CaO. The beneficial effects of MgO backfill are now included in the WIPP performance assessment calculation. Relevant discussions can be found in Sections 3.3.3 and 6.4.3.4.

7.4.3.2 <u>Incorporation into Repository Design</u>

In its guidance to implementation of the certification criteria in 40 CFR § 194.44(d), the EPA requested that the DOE describe how engineered barriers are incorporated into the repository. The purpose of this section is to identify the location of these descriptions and the location of the analysis that evaluates the performance of the engineered barriers.

Shaft seals delay the movements of radionuclides toward the accessible environment through the shafts. These shaft seals are described in detail in Appendix SEAL and are summarized in Section 3.3.1. Analysis of the effectiveness of shaft seals is included in Appendix SEAL (Section 8) and Section 6.4.4. Panel closures prevent the movement of radionuclides toward the accessible environment by limiting the magnitude of releases that can occur during certain human intrusion events. The design of panel closures is described in Appendix PCS, summarized in Section 3.3.2, and their role in the repository model is discussed in Section 6.4.3. Backfill substantially delays the movement of radionuclides toward the accessible environment by limiting, through chemical means, the amount of actinides that can be dissolved in brines that enter the repository. The placement of backfill is described in Section 3.3.3, and its design and functions are described in Appendix SOTERM. Actinide mobility is discussed in Section 6.4.3. Borehole plugs are used to limit the volume of water that could be introduced to the repository from overlying water-bearing zones and to limit the volume of contaminated brine that could be released to the accessible environment. Borehole plug design is addressed in Section 3.3.4. In addition, parameter values selected to implement the various engineered components into the performance assessment model are described in Appendix PAR. Borehole plugs, as described in Section 3.3.4, are also included to mitigate the potential for contaminant migration.

7.5 Resource Characteristics Evaluations

The EPA discourages the location of repositories in areas in which valuable natural resources are present, through the assurance requirements in 40 CFR § 191.14(e). This assurance requirement states that

> Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive ecosystems. Such places shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future (40 CFR § 191.14[e]).

The purpose of the requirement is to provide assurance that site selection actions further reduce the likelihood of future intrusion into the repository by giving preference to those sites without currently recognized resources.

In promulgating 40 CFR Part 194, the EPA provided for a clear manner in which to assess compliance with this requirement, stating that

> If performance assessments predict that the disposal system meets the containment requirements of § 191.13 of this chapter, then the Agency will assume that the requirements of this section and § 191.14(e) of this chapter have been fulfilled (40 CFR § 194.45).

Section 6.5 demonstrates compliance with 40 CFR § 191.13, including resource considerations, and hence compliance with 40 CFR § 194.14(e). The EPA further provides, in its guidance to 40 CFR Part 194, that the DOE

- document that the effects of mining and drilling over the regulatory time frame have been incorporated into performance assessments according to the requirements of § 194.32, § 194.33, and § 194.43;

- document that performance assessments incorporate the effects on the disposal system of any activities that occur in the vicinity of the disposal system or are expected to occur in the vicinity of the disposal system soon after disposal, according to the requirements of § 194.32; and

- document whether the results of performance assessments demonstrate compliance with the containment requirements of § 191.13.

The DOE has satisfied the EPA guidance concerning resource evaluation. This information is documented in Chapter 6.0. The DOE has satisfied the EPA criteria concerning resource evaluation. This information is documented in Section 6.5.2. The mean CCDFs in Figure 6-38 incorporates both the effects of mining inside the controlled area (see Section 6.4.6.2.3 for a description of the mining conceptual model) and the effects of intermittent and inadvertent drilling (see Section 6.4.7 for a discussion of the drilling conceptual model). In addition, the impacts of resource development outside the controlled area were considered in the development of disposal system conceptual models.

7.5.1 Resource Considerations Prior to 40 CFR Parts 191 and 194

The WIPP site selection occurred prior to promulgation of 40 CFR Parts 191 and 194. Resource considerations were included in the site selection process for the WIPP and are documented in the WIPP FEIS (DOE 1980) and Appendices GCR and IRD. The objective of the program for demonstrating compliance with the resource considerations requirement is to document the rationale used in the decision-making process.

7.5.2 Implementation of Resource Considerations

Resource considerations were included in the site selection process for the WIPP and are documented in the WIPP FEIS (DOE 1980, Section 7.3.7). The FEIS describes a four-step decision-making process that was applied to siting the repository. This process is summarized below:

- Step 1 - Bedded salt was selected as the most promising geologic medium, and geographic regions that contain extensive bedded salt formations were identified. This was accomplished by gathering and evaluating existing information concerning rock types and their geographic distribution. Desirable criteria were identified and the most favorable regions were identified.

- Step 2 - A literature review was performed to narrow the number of regions identified in Step 1. Once a region was selected, candidate sites within the region were chosen. Selection criteria were used to compare the sites. Those sites that satisfied the most criteria were selected for further evaluation. Resource-conflict considerations were applied on a broad scale at this stage of the process.

- Step 3 - The candidate sites identified in Step 2 were subjected to further investigations covering geology, hydrology, archaeology, demography, and biological resources. The results of all the site evaluations were compared, and the site that best met the selection criteria was selected for additional site characterization. At this stage, the types and quantities of natural resources present at the site were considered in detail.

- Step 4 - In this final step, a detailed system analysis was performed. This analysis addressed the specific geologic environment, the waste forms, the disposal facility design, and the potential failure modes with respect to radiation safety and environmental impact.

Based upon the above process, the DOE concluded that the favorable characteristics of the WIPP site (good hydrological characteristics, salt medium, moderate depth, salt thickness, low population density, lack of significant economic conflicts, and others) uniquely qualified it for a repository for defense waste. These characteristics also compensate for any increased likelihood of future disturbance. Appendix IRD provides further analysis of compliance with the resource disincentive requirement. Section 2.3.1 provides a summary of known and inferred resources in the vicinity of the WIPP. Appendix DEL contains resource-development-related information used in the conceptual model of disposal system performance.

7.6 Waste Removal

Removal of the waste any time after emplacement is possible. Because the repository was initially mined to provide access to the repository rooms, access to the waste can be accomplished using similar mining technologies. Location and removal are also possible using similar equipment modified to operate remotely. A remote retrieval demonstration was conducted at the WIPP in April 1992.

7.6.1 Requirements for Waste Removal

With the promulgation of 40 CFR Part 194, and in particular 40 CFR § 194.46, the EPA specifies the criteria for demonstrating compliance with this requirement. Specifically, the EPA mandates that "any compliance application shall include documentation which demonstrates that removal of waste is feasible for a reasonable period of time after disposal." The EPA states that this documentation should "include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared."

In promulgating its disposal regulations, the EPA stated that "any current concept for a mined geologic repository meets this requirement without any additional procedures or design features" (EPA 1985, 50 FR 38082).

Because the WIPP facility is a mined repository, no additional actions other than documentation to meet this assurance requirement are necessary. The rationale for this assurance requirement is to preclude use of some disposal technologies that would not allow future generations to recover the wastes should they decide to do so. According to the EPA, recovery need not be easy or inexpensive but only possible (EPA 1985). Appendix WRAC describes a feasible system for waste removal using available mining technologies.

7.6.2 Implementation of Waste Removal

After determining the existing repository condition, the mining and waste removal operations will be designed to minimize the amount of contamination and exposure to allow limited human access for assessments, equipment retrieval, and repairs. Any radiological work will be performed using standard industry practices and approved procedures.

Radiological sampling activities will be planned and implemented so that recovered wastes can be handled. Packaging the removed waste and any decontamination of containers can be accomplished with standard automation techniques. Plans and procedures will ensure that the amount of additional contaminated material produced during the actual waste removal is minimized.

The removal concept is composed of the following five phases.

Phase 1 — Planning and permitting.
Phase 2 — Initial above ground setup and shaft sinking.
Phase 3 — Underground excavation and facility setup of underground ventilation, radiation control, packaging areas, decontamination areas, maintenance, remote control center, and personnel support rooms.
Phase 4 — Waste location and removal operations, including mining waste removal, packaging, package surveying and decontamination, transportation to surface, staging for off-site transportation, and off-site transportation.
Phase 5 — Closure and D&D of the facility.

Each of the five phases is summarized below and described in detail in Appendix WRAC (Section 5).

7.6.2.1 Planning and Permitting

A decision to remove waste will initiate the planning and permitting phase. Permitting requirements will be based on governing regulations at the time removal is authorized. The planning and permitting program will identify all permits and research the available technologies at that time to determine available removal techniques and the condition of the repository. After initial research is completed, a plan will be drafted to itemize and schedule all removal activities.

7.6.2.2 Initial Above Ground Setup and Shaft Sinking

Above ground support buildings will house the exhaust fans and filters, administration, operations and maintenance facilities, control center waste staging and decontamination areas, the warehouse (containers), and others as deemed necessary.

7.6.2.3 Underground Excavation and Facility Setup

After the shafts are completed, drifts will be run and ventilation paths will be established using air control regulators. Support rooms will be excavated for maintenance, control rooms, and packaging areas. Air locks will be constructed to provide the necessary level of control and separation. All equipment required for removal, packaging, and related support equipment will be installed.

Excavation will be in two stages. Initial excavation will not contact waste but will mine support rooms and haulage drifts that provide ventilation and access to the waste. The second stage will remove the waste.

7.6.2.4 Waste Location and Removal Operations

The waste removal will be performed in separate operations. The waste will be removed by mining the area where the waste was emplaced. The mined waste will be transported to the packaging areas. The waste can be removed many ways using standard equipment. Appendix WRAC (Sections 6 and 7) contains a brief description and feasibility of using various mining techniques for waste removal. An appropriate level of radiological controls will be used depending upon the radioactivity of the mined waste.

7.6.2.5 Closure and D&D of the Facility

After waste is removed from the repository, the facility will be decommissioned according to the current regulations at that time.

REFERENCES

Bellus, P.A., and Eckerman, J. 1994. *Airborne or Spaceborne Surveillance Radar Detection of WIPP Site*. Westinghouse Electric Corporation, 10950, Minnetonka, MN.

DOE (U.S. Department of Energy). 1980. *Final Environmental Impact Statement, Waste Isolation Pilot Plant*. DOE/EIS-0026. Vols. 1 and 2. Assistant Secretary for Defense Programs. Washington, D.C. WPO 38835, WPO 38838, WPO 38839.

DOE (U.S. Department of Energy). 1990. *Final Safety Analysis Report*. WP 02-9, Rev. 0, May 1990. Westinghouse Electric Corporation, Waste Isolation Pilot Plant, Carlsbad, NM.

DOE (U.S. Department of Energy). 1991. *Draft Report: Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force*. DOE/WIPP 91-007, Rev. 0. Westinghouse Electric Corporation, Carlsbad, NM.

DOE (U.S. Department of Energy). 1994. *Permanent Marker Conceptual Design Report* Draft. Rev. 2, November 1994. U.S. Department of Energy, Carlsbad, NM.

DOE (U.S. Department of Energy). 1995. *Engineered Alternatives Cost/Benefit Study; Final Report*. DOE/WIPP 95-2135. U.S. Department of Energy, Carlsbad, NM. Included in this application as Appendix EBS.

EPA (U.S. Environmental Protection Agency). 1985. "40 CFR Part 191: Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule." *Federal Register*, Vol. 50, No. 182, pp. 38066 – 38089, September 19, 1985. Office of Radiation and Air, Washington, D.C. WPO 39132.

EPA (U.S. Environmental Protection Agency). 1988. Test Methods for Evaluating Solid Waste. Volume 1A through 1C and Volume 2. Field Manual Physical Chemical Methods (3rd Edition). Report EPA/SW-846, September 1988, National Technical Information Service, Springfield, VA.

EPA (U.S. Environmental Protection Agency). 1996a. "40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule." *Federal Register,* Vol. 61, No. 28, pp. 5224 – 5245, February 9, 1996. Office of Radiation and Indoor Air, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1996b. *Compliance Application Guidance for 40 CFR Part 194*. EPA 402-R-95-014, March 29, 1996. Office of Radiation and Indoor Air, Washington, D.C. WPO 39159.

Hora, S.C., von Winterfeldt, D., and Trauth, K.M. 1991. *Expert Judgment on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant.* SAND90-3063. Sandia National Laboratories, Albuquerque, NM.

Murphy, J.N., and Parkinson, H.F. 1978. "Underground Mine Communications," Proceedings of the IEEE, Vol. 66, No. 1, pp. 26 – 50.

NMBMMR (New Mexico Bureau of Mines and Mineral Resources). 1995. *Final Report Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site.* Vol. I, Ch. I-III, December 22, 1994.

Powell, J.A. 1976. *An Electromagnetic System for Detecting and Locating Trapped Miners,* U.S. Bureau of Mines Report of Investigations, RI 8159, U.S.B.M, Pittsburgh, PA.
Murphy, John N. and H.F. Parkinson. 1978. *Underground Mine Communications,* Proceedings of the IEEE, Vol. 66, No. 1, January 1978.

Trauth, K.M., Hora, S.C., and Guzowski, R.V. 1993. *Expert Judgment on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant.* SAND92-1382. Sandia National Laboratories, Albuquerque, NM. WPO 23389.

BIBLIOGRAPHY

DOE (U.S. Department of Energy). 1990. *Radionuclide Emission Data Package for the Waste Isolation Pilot Plant.* U.S. Department of Energy, Carlsbad, NM.

DOE (U.S. Department of Energy). 1992. *Statistical Summary of the Radiological Baseline Program for the Waste Isolation Pilot Plant.* DOE/WIPP 92-037. U.S. Department of Energy, Carlsbad, NM.

DOE (U.S. Department of Energy). 1993. *Waste Isolation Pilot Plant Land Management Plan.* DOE/WIPP 93-004. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.

DOE (U.S. Department of Energy). 1994. *WIPP Active Access Controls After Disposal Design Concept Description* (Draft). Rev. 1, December 1994. U.S. Department of Energy, Carlsbad, NM.

U.S. Congress. 1992. Waste Isolation Pilot Plant Land Withdrawal Act. Public Law 102-579.

THIS PAGE INTENTIONALLY LEFT BLANK