Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant

Appendix DEL

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Delaware Basin Study

CONTENTS

ACRONYMS .... DEL-vii

APPENDIX DEL DEL-1

DEL.1 Purpose and Scope DEL-1
DEL.2 Regulatory Context DEL-1
DEL.2.1 EPA Radiation Protection Standards (40 CFR Part 191) DEL-1
DEL.2.2 WIPP Land Withdrawal Act DEL-3
DEL.2.3 EPA WIPP Compliance Certification/Determination Criteria (40 CFR Part 194) DEL-3
DEL.3 Definitions of Key Terms DEL-9
DEL.4 The Delaware Basin and Its Economic Resources DEL-9
DEL.4.1 Delaware Basin Definition and Location DEL-10
DEL.4.2 Resources Within the Delaware Basin DEL-10
DEL.4.2.1 Oil and Natural Gas Resources of the Delaware Basin DEL-10
DEL.4.2.2 Oil and Gas Producing Formations of the Delaware Basin DEL-17
DEL.4.2.3 Oil and Gas Exploration and Production Near the WIPP Site DEL-19
DEL.4.2.4 Potash DEL-25
DEL.4.2.5 Sulfur DEL-25
DEL.4.2.6 Groundwater DEL-25
DEL.5 Well Drilling, Plugging, and Abandonment Practices DEL-26
DEL.5.1 Oil and Gas Well Drilling Technology DEL-26
DEL.5.1.1 Cable Tool Rig DEL-31
DEL.5.1.2 Rotary Drilling Rig DEL-31
DEL.5.1.3 Drilling Fluids DEL-31
DEL.5.1.4 Well Control and Safety DEL-32
DEL.5.1.5 Directional and Horizontal Drilling DEL-32
DEL.5.1.6 Other Recent Drilling Technologies DEL-35
DEL.5.1.7 Developing a Drilling Plan DEL-36
DEL.5.1.8 Drill Site Preparation DEL-39
DEL.5.1.9 Well Completion DEL-40
DEL.5.2 Drilling of Potash Coreholes DEL-41
DEL.5.3 Drilling of Water Wells DEL-41
DEL.5.4 Development of Injection and Secondary Recovery Wells DEL-42
DEL.5.5 Well Plugging and Abandonment Practices DEL-43
DEL.5.5.1 BLM Oil and Gas Plugging and Abandonment DEL-43
DEL.5.5.2 State of New Mexico Oil and Gas Well Plugging and Abandonment DEL-45
DEL.5.5.3 Plugging of Oil and Gas Service Wells DEL-46

CONTENTS (Continued)

DEL.5.5.4 Plugging of Potash Coreholes DEL-46
DEL.5.5.5 Plugging of Water Wells DEL-46
DEL.6 Regulations, Practices, and Problems Associated With Oil and Gas Well and Other Drill Hole Drilling, Plugging, and Abandonment DEL-47
DEL.6.1 Bureau of Land Management (BLM) DEL-47
DEL.6.1.1 Steps Involved in Oil and Gas Resource Development on Federal Lands DEL-48
DEL.6.1.2 BLM Regulation of Onshore Oil and Gas Operations DEL-51
DEL.6.1.3 Agreement Between DOE and BLM on Oil and Gas Activities Affecting WIPP DEL-56
DEL.6.1.4 Protection of Potash Resources DEL-61
DEL.6.1.5 Bonds, Penalties, and Enforcement DEL-63
DEL.6.2 State of New Mexico DEL-64
DEL.6.2.1 Well Drilling Requirements DEL-66
DEL.6.2.2 Well Plugging and Abandonment Requirements DEL-69
DEL.6.2.3 Incidence of Unplugged Oil and Gas Wells DEL-71
DEL.6.2.4 Oil and Gas Development in Potash Areas - NMOCC Order R-111-P DEL-72
DEL.6.2.5 Bonds, Penalties, and Enforcement DEL-73
DEL.6.3 Regulation of Injection Wells DEL-74
DEL.6.3.1 Definitions DEL-74
DEL.6.3.2 Bureau of Land Management DEL-74
DEL.6.3.3 State of New Mexico DEL-76
DEL.7 Inadvertent and Intermittent Intrusion by Drilling DEL-79
DEL.7.1 Regulatory Context DEL-79
DEL.7.2 Shallow Drilling Events DEL-79
DEL.7.2.1 Water Wells DEL-79
DEL.7.2.2 Potash Coreholes DEL-80
DEL.7.2.3 Sulfur Coreholes DEL-80
DEL.7.3 Deep Drilling Events DEL-80
DEL.7.4 Rate of Drilling in the Basin DEL-81
DEL.7.5 Pressurized Brine Encounters Within the Delaware Basin DEL-81
DEL.7.6 Borehole Permeability Assessment DEL-87

REFERENCES DEL-91

BIBLIOGRAPHY DEL-93

GLOSSARY OF TERMS DEL-94

ATTACHMENTS DEL-99

FIGURES

DEL-1. General Location of the WIPP Land Withdrawal Area DEL-5
DEL-2. WIPP Land Withdrawal Area DEL-7
DEL-3. Major Geological Features of the Delaware Basin DEL-11
DEL-4. Oil and Gas Wells Drilled in the Delaware Basin DEL-13
DEL-5. Stratigraphic Nomenclature Chart of the Delaware Basin DEL-15
DEL-6. Oil and Gas Wells in Nine Township Area Surrounding the WIPP Site . . . DEL-21
DEL-7. Oil and Gas Wells Within One Mile of the WIPP Site Boundary DEL-23
DEL-8. Potash Leases Within and Outside the Delaware Basin DEL-27
DEL-9. Extent of Economically Minable Reserves Inside the Site Boundary (Based on NMBMMR Report) DEL-29
DEL-10. Cable Tool and Rotary Drilling Rigs DEL-33
DEL-11. Typical Well Completion DEL-37
DEL-12. Carlsbad Resource Area DEL-49
DEL-13. Minimum Oil and Gas Well Plugging Requirements in the Delaware Basin DEL-57
DEL-14. Standard Oil and Gas Well Plugging Practices in the Potash Resource Area of the Delaware Basin DEL-59
DEL-15. Recent Occurrences of Pressurized Brine in the Castile DEL-89

TABLES

DEL-1. BLM Oil and Gas Well Drilling, Production, and Abandonment Incidents of Noncompliance, FYs 1991 to 1996 According to Violation Code for the Carlsbad Resource Area DEL-65
DEL-2. New Mexico and SE New Mexico Oil and Gas Well Data, 1971 to 1996 . . DEL-75
DEL-3. Boreholes Within the Delaware Basin DEL-82
DEL-4. Number of Shallow and Deep Boreholes Within the Delaware Basin, by Resource or Type DEL-83
DEL-5. Number of Shallow Boreholes Per Square Kilometer in the Delaware Basin, by Resource or Type DEL-83
DEL-6. Number of Deep Boreholes Per Square Kilometer in the Delaware Basin, by Resource or Type DEL-84
DEL-7. Number of Boreholes Per Square Kilometer to be Used in Performance Assessment Calculations DEL-84

ACRONYMS

BLM	Bureau of Land Management
CAD	Computer Aided Drafting
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CRA	Carlsbad Resource Area (BLM)
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EA	environmental assessments
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
FY	Fiscal Year
IIAP	Inadvertent Intrusion Advisory Panel
IM	Instruction Memorandum
INC	Incident(s) of Noncompliance
KPLA	Known Potash Leasing Area
LMR	Life-of-the-Mine Reserves
LWA	Land Withdrawal Act
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NMAC	New Mexico Administrative Code
NMBMMR	New Mexico Bureau of Mines and Mineral Resources
NMOCC	New Mexico Oil Conservation Commission
NMOCD	New Mexico Oil Conservation Division
NMSA	New Mexico Statutes Annotated
NOS	Notice of Staking
NTL	Notice to Lessee
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RMP	Resource Management Plan (BLM)
RRC	Railroad Commission (Texas)
TDS	total dissolved solids
TRU	transuranic
USDW	underground source of drinking water
WIPP	Waste Isolation Pilot Plant

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APPENDIX DEL

This report discusses factors that are pertinent to determining and evaluating inadvertent and intermittent intrusion into the U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) site boundary by oil, gas, and other resource-related drilling. It summarizes the most relevant provisions of the applicable laws and regulations pertaining to compliance by the DOE at the WIPP with U.S. Environmental Protection Agency (EPA) regulations for disposal of radioactive transuranic (TRU) wastes.

DEL.1 Purpose and Scope

The purpose of this investigation is to research and present information relevant to a certification of WIPP compliance with the EPA TRU waste disposal requirements in 40 Code of Federal Regulations (CFR) Part 191 and the relevant certification criteria of 40 CFR Part 194. This information serves as one of several assessments necessary to support the WIPP Compliance Certification Application required by 40 CFR Part 194, Subpart B (61 *Federal Register* [FR] 5224, February 9, 1996). It also supports the performance assessment and compliance assessment required to comply with the EPA environmental standards for disposal in 40 CFR Part 191, Subpart B and the environmental standards for groundwater protection in 40 CFR Part 191, Subpart C.

This report characterizes resource drilling historically accomplished in the Delaware Basin, which is in southeastern New Mexico and southwestern Texas. This report also describes resources in the basin (Section DEL-4), the historic nature, extent, and frequency of drilling for oil, gas, potash, sulfur, and water resources as well as the development and use of the most prevalent oil and gas well drilling technology (Section DEL-5), and federal and state of New Mexico regulations, policies, and problems related to drilling and plugging of oil and gas wells and potash coreholes (Section DEL-6). In addition, the projected rates for potential inadvertent and intermittent intrusion for exploratory oil and gas wells and other types of boreholes over a 10,000-year period are calculated and presented in Section DEL-7.

DEL.2 Regulatory Context

This section provides a context for the inadvertent and intermittent drilling intrusion discussion in the following sections. It summarizes provisions of the EPA radiation protection standards in 40 CFR Part 191, requirements of the WIPP Land Withdrawal Act (LWA), and provisions of the WIPP compliance certification criteria in 40 CFR Part 194 as they pertain to this investigation.

DEL.2.1 EPA Radiation Protection Standards (40 CFR Part 191)

In 1985, the EPA promulgated its radiation protection standards for managing and disposing of spent nuclear fuel, high-level and transuranic wastes,,which apply to management, storage, and disposal of TRU wastes at facilities operated by the DOE, including WIPP (40 CFR Part

191; 50 FR 38084, September 19, 1985). Initially, the standard consisted of two subparts: Subpart A, Environmental Standards for Management and Storage; and Subpart B, Environmental Standards for Disposal. A third subpart was added in 1993: Subpart C, Environmental Standards for Ground-Water Protection (58 FR 66414; December 20, 1993). All three subparts apply to WIPP, although only Subparts B and C are subject to EPA certification, as specified in the WIPP LWA.

Subparts B and C apply to radioactive materials that may be released into the accessible environment resulting from the disposal of TRU wastes; radiation doses received by members of the public as a result of such disposal; and radiation contamination of certain sources of groundwater (40 CFR § 191.11). The containment requirements in 40 CFR § 191.13 provide as follows:

> Disposal systems for . . . transuranic radioactive wastes shall be designed to provide a reasonable expectation, *based upon performance assessments*, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from *all significant processes and events that may affect the disposal system* shall [not exceed certain specified quantities]. (Emphasis added.)

Performance assessments that form the basis for determining compliance with the EPA containment requirements include the following:

(1) identification of processes and events that might affect the disposal system;

(2) examination of the effects of these processes and events on the disposal system; and

(3) estimation of the cumulative releases of radionuclides to the accessible environment over the 10,000-year regulatory period (40 CFR § 191.12).

(The processes and events analyzed in this report are those associated with drilling for resources.) As noted in 40 CFR § 191.13(b), because of the substantial uncertainties involved in projecting how the disposal system will perform in the long-term, performance assessments need not provide absolute proof that containment requirements will be met but only that a reasonable expectation of compliance will be achieved.

Part 191 also includes requirements pertaining to individual (40 CFR § 191.15) and groundwater (Subpart C) protection. Analyses performed to assess compliance with these provisions are called compliance assessments and are limited to the undisturbed performance of the disposal system. Compliance assessment analyses need not include an assumption that someone will intrude into the repository at some future time, but impacts of existing and near future drilling activities must be considered.

TRU waste disposal must also be conducted according to a number of assurance requirements (40 CFR § 191.14). These include but are not limited to the following: maintaining active institutional controls for as long as is practicable (but assuming no more than 100 years in the performance assessment); designating disposal sites with permanent markers, records, and other passive institutional controls; and using the concept of multiple barriers to isolate the wastes. Active institutional controls include disposal site access control, maintenance and remedial action, release control and cleanup, and monitoring. Passive institutional controls include: permanent disposal-site markers; public records and archives; and government ownership and regulations regarding land or resource use (40 CFR § 191.12). No time limit is imposed in 40 CFR § 191.14 on how long passive institutional controls (including government ownership and resource-related regulations) can be expected to endure.

DEL.2.2 WIPP Land Withdrawal Act

The WIPP LWA (Pub. L. 102 – 579) withdrew 16 sections (10,240 acres; 4,144 hectares) of land from operation under public land laws and transferred administrative jurisdiction from the Department of the Interior (DOI), Bureau of Land Management (BLM) to the DOE for operation of the WIPP disposal facility (Figures DEL-1 and DEL-2). Under §7(b) of the Act, the DOE is prohibited from disposing TRU waste in the WIPP repository until EPA certifies that the facility is in compliance with the 40 CFR Part 191 final disposal standards (Subparts B and C) discussed in Section DEL.1.2.1. Under §8(f) of the act, the DOE must document and the EPA must recertify continued compliance with the disposal standards every five years until the end of the decommissioning phase. Section 8(c) of the WIPP LWA requires the EPA to issue criteria for certification of compliance with the disposal standards in 40 CFR Part 191.

DEL.2.3 EPA WIPP Compliance Certification/Determination Criteria (40 CFR Part 194)

In response to the LWA requirements, the EPA issued criteria for certification and recertification of the WIPP's compliance with the 40 CFR Part 191 disposal regulations. These criteria were published on February 9, 1996 as 40 CFR Part 194 (EPA 1996a; 61 FR 5224). All of the terms (for example, active and passive institutional controls) used in the criteria have the same definitions as those found in the Part 191 regulations. In addition to the Part 194 compliance criteria, the EPA issued a report on March 29, 1996, entitled *Compliance Application Guidance Document for 40 CFR Part 194* (EPA 1996[b]).

The documentation that must be submitted to the EPA by the DOE is in the form of a compliance certification application, the contents of which are specified in 40 CFR § 194.14. This application must include information on the presence and characteristics of potential pathways for transport of waste from the disposal system to the accessible environment including, but not limited to, existing boreholes and other potentially permeable features (40 CFR § 194.14[a][3]).

The 40 CFR Part 194 rule clarifies, for the purposes of certification, the 40 CFR Part 191 definition of performance assessments by stating that the DOE consider both natural processes and events, mining, deep drilling, and shallow drilling that may affect the disposal system during the regulatory time frame (40 CFR § 194.32[a]). Deep drilling is defined as drilling events in the Delaware Basin that reach or exceed a depth of 2,150 feet (655 meters) (the WIPP disposal horizon) while shallow drilling refers to drilling depths of less than 2,150 feet (655 meters) (40 CFR § 194.2). The following process and assumptions, specified in 40 CFR § 194.33, are to be used in assessing the likelihood and consequences of drilling events.

- Assume that inadvertent and intermittent drilling for resources is the most severe (worst case) human intrusion scenario.

- In the performance assessment, assume that drilling for resources occurs at random intervals in time and space over the 10,000-year time frame.

- Calculate the deep drilling frequency by identifying the drilling that has occurred for each resource in the Delaware Basin over the past 100 years. The total drilling rate is to be derived by summing the drilling rates for each resource.

- Calculate the shallow drilling frequency by identifying the drilling that has occurred for each resource in the Delaware Basin over the past 100 years, considering only the resources of similar type and quality to those in the controlled area. The total drilling rate is to be derived by summing the drilling rates for each resource.

The analysis of the frequency and the consequences of resource-related drilling events over a 10,000-year period is dependent on future state assumptions (40 CFR § 194.25). To foreclose speculation, the EPA requires that compliance applications assume that characteristics of the future remain what they are at the time the compliance application is prepared (40 CFR § 194.25). This assumption applies to human existence and societal conditions and not to geologic, hydrologic, or climatic changes. This means that, for purposes of the 40 CFR Part 194 compliance evaluation, the DOE can assume current drilling technologies, drilling practices, and regulatory requirements will remain consistent with practices in the Delaware Basin at the time this application is prepared (40 CFR § 194.33[c][1]). The assumed future drilling practices include, but are not limited to: types and amounts of drilling fluids; borehole depths, diameters, and seals (plugs); and the fraction of boreholes sealed (plugged) by humans. Although assumptions concerning drilling and plugging regulations are not specified in 40 CFR § 194.33(c)(1), it is apparent that future drilling practices and technologies are in part dependent on and interrelate with federal and state regulations. Regulations are a societal condition under 40 CFR § 194.25(a) and are, therefore, assumed to remain the same.

In addition, provisions applicable to compliance assessment analyses, for the evaluation of compliance with the individual and groundwater protection requirements, are defined in 40 CFR § 194.54. The rule specifies that

> (b) Compliance assessments of undisturbed performance shall include the effects on the disposal system of:

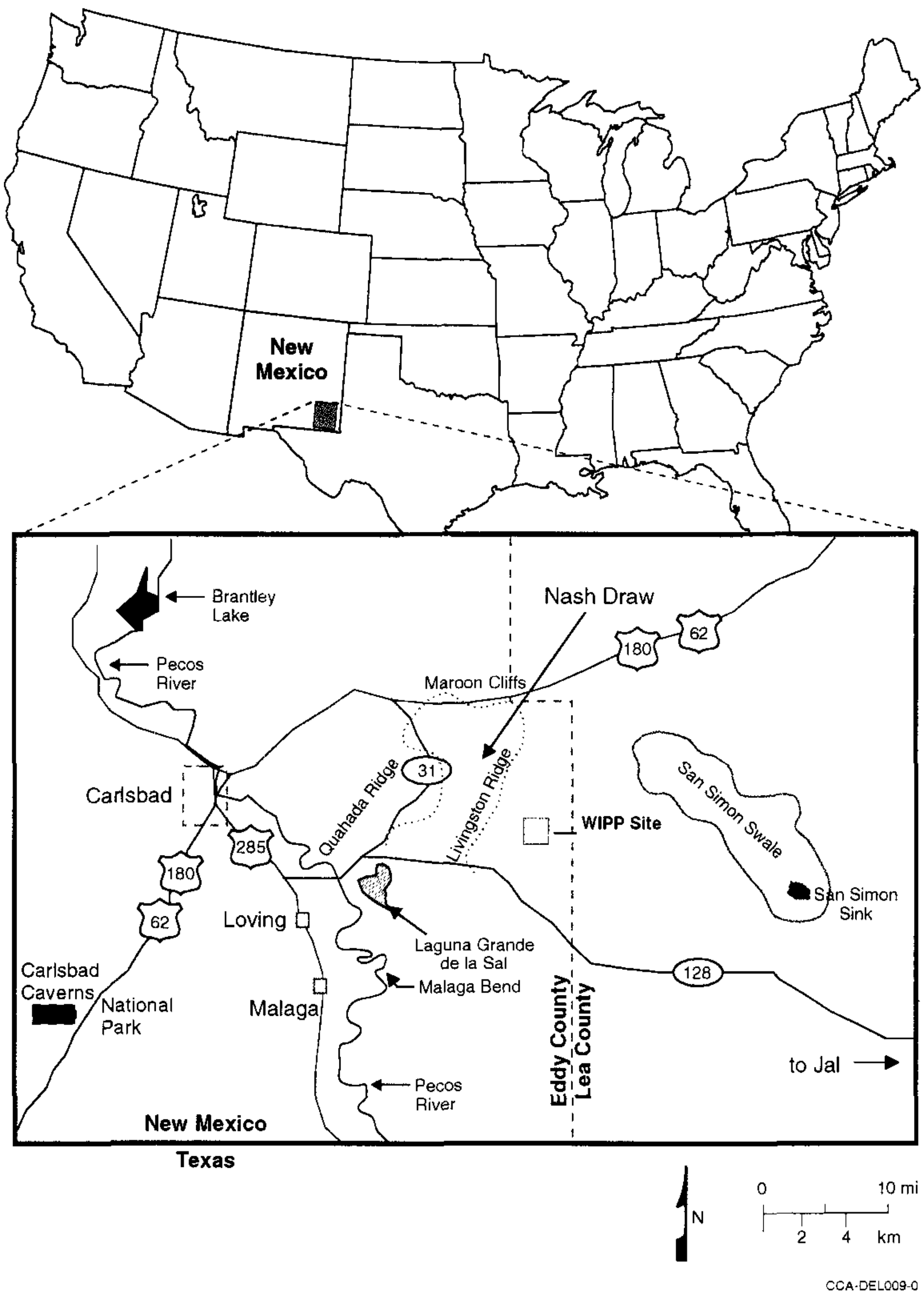

Figure DEL-1. General Location of the WIPP Land Withdrawal Area

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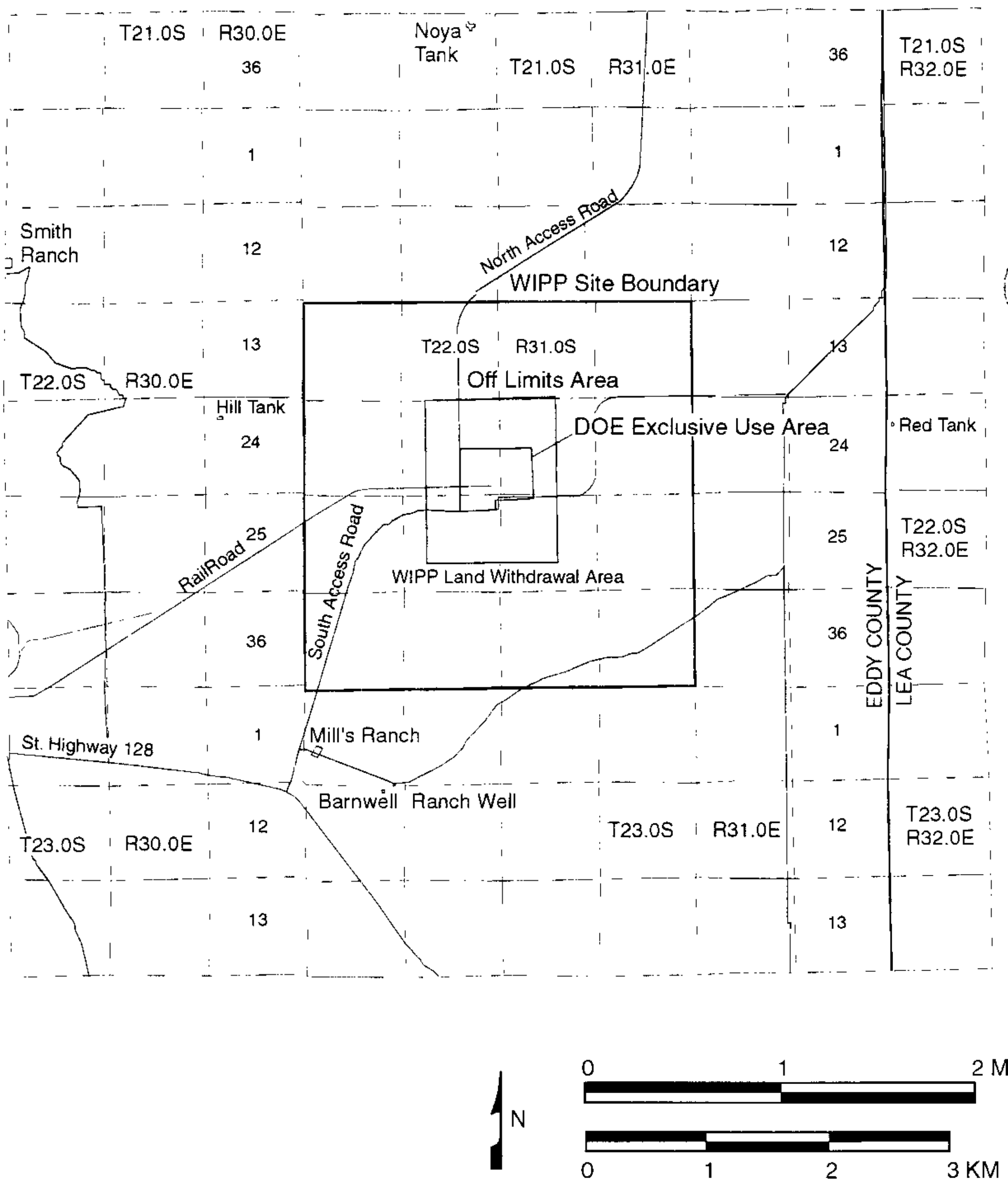

Figure DEL-2. WIPP Land Withdrawal Area

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(1) Existing boreholes in the vicinity of the disposal system, with attention to the pathways they provide for migration of radionuclides from the site; and

(2) Any activities that occur in the vicinity of the disposal system prior to or soon after disposal. Such activities shall include, but shall not be limited to: existing boreholes and the development of any existing leases that can be reasonably expected to be developed in the near future, including boreholes and leases that may be used for fluid injection activities.

The scope of compliance assessments is addressed by the EPA in its preamble to the 40 CFR Part 194 Final Rule:

> Section 194.54 defines the scope of compliance assessments. Compliance assessments should be conducted of the undisturbed performance of the disposal system, which, by the definition in section 12 of 40 CFR Part 191, denotes that the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events.
>
> The Agency recognizes, however, that resource extraction and fluid injection activities which are currently performed in the Delaware Basin can alter the hydrogeologic properties of the initial state of the disposal system. The final rule requires that performance assessments and compliance assessments analyze the effects of all types of fluid-injection and all boreholes which can have an effect on the disposal system and which have been or will have been drilled prior to or soon after disposal. These boreholes shall be assumed to affect the properties of the disposal system for the entire 10,000-year regulatory time frame. Predictions about such future activities shall be strictly limited to the expected use of existing leases.

Compliance assessments of undisturbed conditions for 40 CFR Part 191 Section 15 and Subpart C must consider the effects on the disposal system over the long-term of any borehole drilling activities that are occurring in the vicinity of the disposal system today. Continued occurrence or initiation of new occurrences of the same activities must also be considered, if expected to occur on existing leases given today's conditions, up until the time of shaft sealing. Activities under way at the time of shaft sealing should be assumed to continue to their planned completion. Activities initiated after shaft sealing should not be considered in analyses of undisturbed conditions.

DEL.3 Definitions of Key Terms

The oil and gas industry, and the regulations that govern its activities, have specific terminology which is included as a glossary of terms in this document. Key EPA regulatory terms are also included.

DEL.4 The Delaware Basin and Its Economic Resources

Significant economic resources in the Delaware Basin consist primarily of oil, gas, potash, sulfur, and groundwater. The location of the basin and resources exploration and development activities in the basin are described in this section.

DEL.4.1 Delaware Basin Definition and Location

The Delaware Basin covers 8,920 square miles (23,100 square kilometers). The greatest north-south distance is about 143 miles (231 kilometers) and the east-west distance is about 108 miles (174 kilometers). The basin is shown in Figure DEL-3; it is defined in 40 CFR § 194.2 as follows:

> *Delaware Basin* means those surface and subsurface features which lie inside the boundary formed to the north, east and west of the [WIPP] disposal system, by the innermost edge of the Capitan Reef, and formed, to the south, by a straight line drawn from the southeastern point of the Davis Mountains to the most southwestern point of the Glass Mountains.

The Delaware Basin includes all or part of Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, Ward, and Winkler Counties in Texas, and portions of Eddy and Lea Counties in New Mexico (Figure DEL-3).

DEL.4.2 Resources Within the Delaware Basin

Several natural resources are found within the basin, the most notable of which are oil, natural gas, potash, sulfur, and groundwater. The basin's hydrocarbon resources have been the source of successful exploration for over eighty years. Potash and sulfur are present in quantities large enough to be mined profitably. Caliche, gypsum, and halite are also present within the basin, but of these, only caliche is economically extracted at this time.

The New Mexico Bureau of Mines and Mineral Resources (NMBMMR) in its report, *Evaluation of Mineral Resources at the Waste Isolation Pilot Plant* (NMBMMR 1995), evaluated the resources within the Delaware Basin, with the primary area of focus being the area within one mile of the WIPP-site boundary.

DEL.4.2.1 Oil and Natural Gas Resources of the Delaware Basin

Since the first oil well was drilled in the Delaware Basin in 1909, the basin has been a continual source of oil and natural gas. There have been over 11,000 wells drilled for oil or gas in the Delaware Basin in the last 87 years. Exploration within the basin continues (Figure DEL-4).

The hydrocarbon resources of the Delaware Basin consist mostly of oil and associated gas found in the Permian strata and gas condensate in the Pennsylvanian strata. These strata exist beneath the WIPP site and immediately surrounding areas (Figure DEL-5). The majority of oil and gas production around WIPP has been from the following:

- sandstone reservoirs in the Delaware Mountain Group at 7,000 to 8,000 feet (2,134 to 2,438 meters),

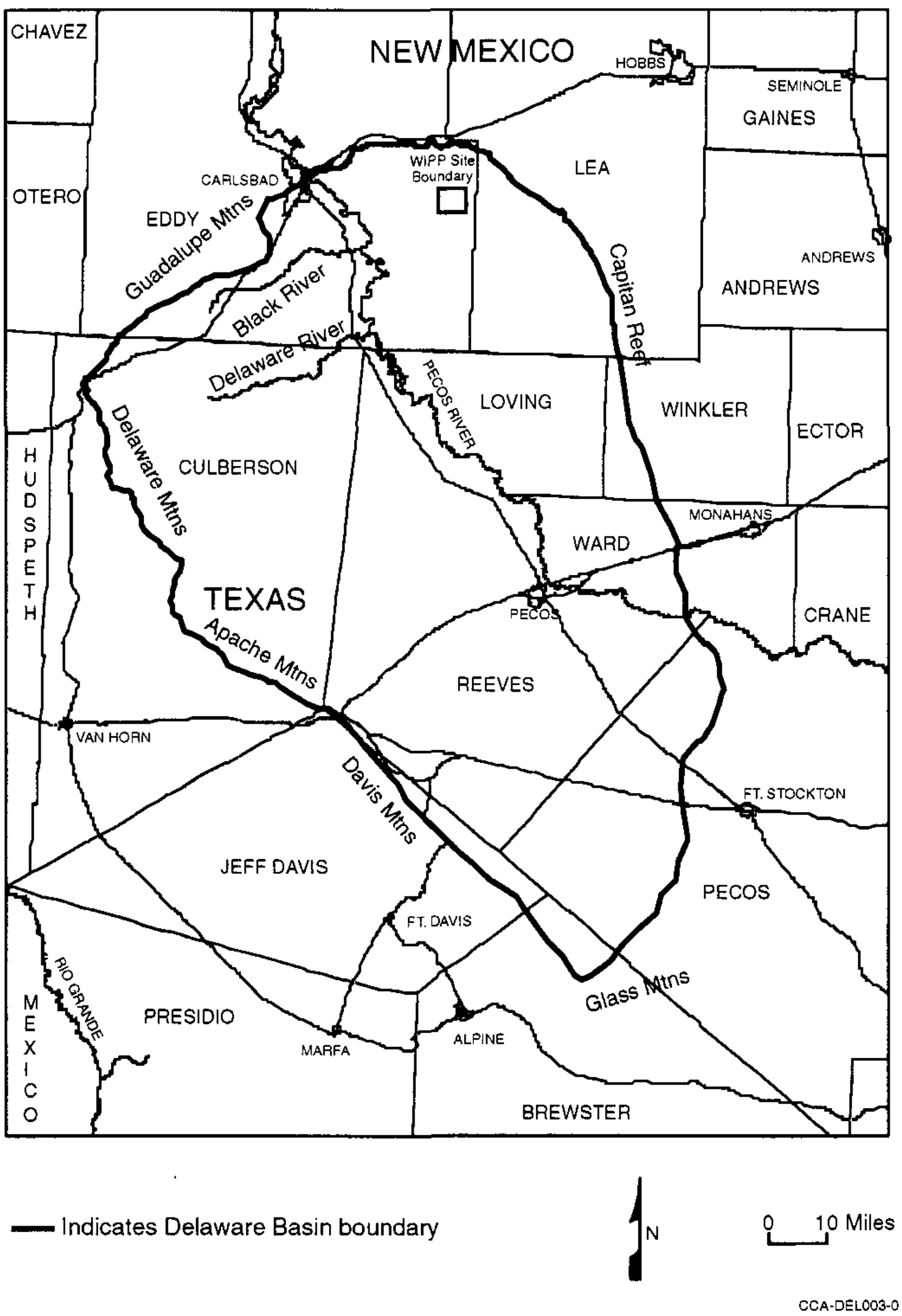

Figure DEL-3. Delaware Basin Boundary

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Figure DEL-4. Oil and Gas Wells Drilled in the Delaware Basin

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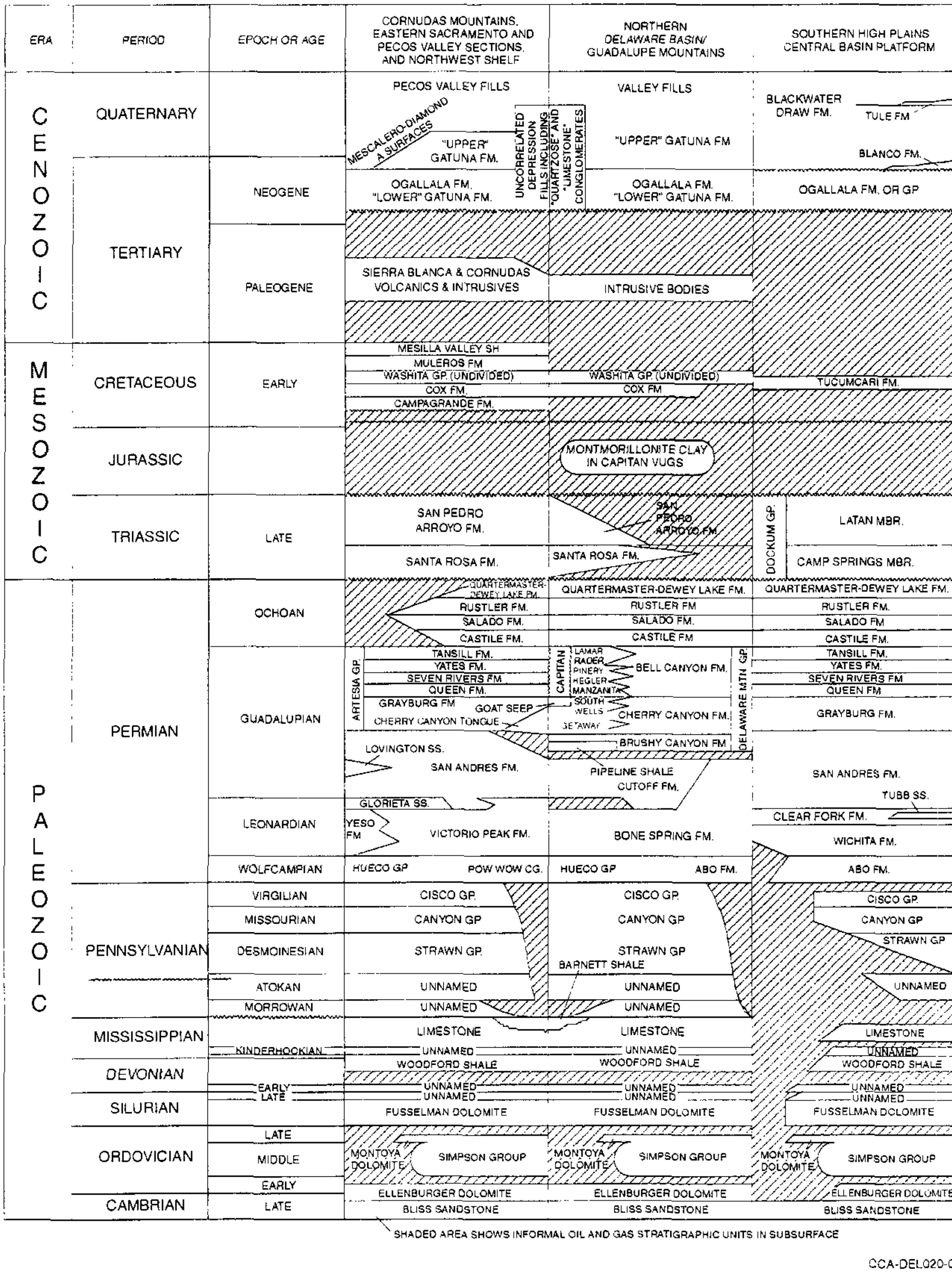

Figure DEL-5. Stratigraphic Nomenclature Chart of the Delaware Basin

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- sandstone and carbonates in the Bone Spring Formation from 8,000 to 11,000 feet (2,438 to 3,353 meters),
- carbonates from the Wolfcamp Group at approximately 12,000 feet (3,658 meters) (secondary oil reservoirs),
- carbonates in the Strawn Group at a depth of approximately 13,000 feet (3,963 meters) (secondary reservoirs of gas and light oil or condensate), and
- sandstone reservoirs of the Atoka and Morrow Groups. These groups are found at 13,000 to 14,000 feet (3,963 to 4,267 meters) and have been the source of most non-associated gas and condensate.

DEL.4.2.2 Oil and Gas Producing Formations of the Delaware Basin

Oil and gas resources occur at various depths within the Delaware Basin. To adequately address these resources and their relationship to the WIPP, it is necessary to discuss each resource as it is found and in which formations each resource is located. Figure DEL-5 provides a generalized stratigraphic cross-section of the oil- and gas-producing formations of the Delaware Basin. The following formation descriptions are from the oldest to the youngest sediments.

DEL.4.2.2.1 The Morrow Group

The Morrow Group is known primarily for production of gas and condensate and is found throughout the Delaware Basin. The Morrow is divided into two sections, the Morrow lime, which is approximately 650 feet (198 meters) thick and the Morrow clastic interval, which is 600 feet (183 meters) to 700 feet (213 meters) thick. Nearly all production in the Delaware Basin comes from the clastic section of the Morrow. Wells within the Morrow, immediately west of the WIPP area, give mixed information regarding the potential for future production of natural gas. The complex nature of Morrow sandstone deposition and trapping mechanisms makes it difficult to determine the probability and quality of any production. It is not uncommon for a Morrow gas well within the Delaware Basin to produce at a relatively high rate for a short period of time and then show dramatically reduced production due to depletion of the gas reservoir. This has been observed in Morrow wells near the WIPP (NMBMMR 1995).

DEL.4.2.2.2 The Atoka Group

The Atoka Group produces both oil and gas. The Atoka is composed of interbedded limestone, sandstone, and shale and is very similar to the Strawn Group in its configuration. Production within the Atoka is well established in the Delaware Basin in both limestone and sandstone reservoirs. All of the productive wells near the WIPP site produce primarily from one narrow and thin sandstone channel. Seven wells located adjacent to WIPP have produced or are currently producing oil and gas. Estimated production from these seven wells is eight billion cubic feet (2.3×10^8 cubic meters) and 70 thousand barrels (11.1 million liters) condensate. Based on subsurface mapping of the reservoir, it appears that there is excellent production potential near the WIPP (NMBMMR 1995).

DEL.4.2.2.3 *The Strawn Group*

The Strawn Group is a gas producer. Four wells have been completed in this group, three of which appear to be economic producers. They have produced significant amounts of gas and condensate. A new well drilled in late 1993 has revealed what appears to be a significant new Strawn reservoir directly adjacent to the west edge of the WIPP land withdrawal area. With only limited exploration of this group, production capability cannot be accurately calculated, but based on drill stem tests it should be capable of producing similarly to other Strawn wells.

DEL.4.2.2.4 *The Canyon, Cisco, and Wolfcamp Groups*

The Wolfcamp Group produces both oil and gas. The Cisco and the Canyon Groups have been included in the Wolfcamp group following the common oil-field usage of the Wolfcamp sequence (Foster 1974). Wolfcamp pools are producers of non-associated gas in the Delaware Basin and oil and associated gas on the Northwest Shelf and Central Basin Platform. Two oil and gas pools have been discovered within the nine-township area surrounding the WIPP site (See Figure DEL-6). Uneconomic volumes of oil and gas have been recorded from three additional wells. Within the Wolfcamp Group, the Bilbrey Wolfcamp gas pool was discovered in 1985, during a re-entry into an abandoned Morrow gas well. At a depth of from 12,100 feet (3,689 meters) to 12,138 feet (3,701 meters), perforation was completed and the well was acidized. As of December 31, 1993, the well had produced 9,884 million cubic feet (2.8×10^8 cubic meters) of gas and 11,683 barrels (1.9 million liters) of condensate. The Diamondtail Wolfcamp pool was discovered in 1981 by a wildcat well during an unsuccessful attempt to drill for gas in the Morrow and Atoka. The well was perforated, acidized, and fractured between 12,181 feet (3,713 meters) and 12,193 feet (3,717 meters). After completion, it was producing 38 barrels (6,041 liters) of oil per day. The true potential of this pool has not been evaluated by further testing.

DEL.4.2.2.5 *Bone Spring Formation*

The Bone Spring Formation is also an oil-producing unit. Numerous Bone Spring pools in the Delaware Basin have been discovered by re-entering old gas wells in which production from the Atoka or Morrow has declined to subeconomic levels. Many of the exploratory wells leading to the discovery of oil in the Bone Spring Formation had originally targeted structural traps in deeper formations. With the exception of the Red Tank pool, development of known pools within the nine-township area surrounding the WIPP has been limited and is incomplete because operators have concentrated on drilling for deeper gas in the Morrow and Atoka or for shallower oil in the Delaware Mountain Group. Therefore, stratigraphic traps and stratigraphic trends have not been fully defined and the Bone Spring remains inadequately explored and developed in the area. It is highly likely that numerous significant commercial accumulations of oil and associated gas remain to be found.

DEL.4.2.2.6 The Delaware Mountain Group

The Delaware Mountain Group is an oil-producing unit near the WIPP site. It is subdivided into three formations: Brushy Canyon, Cherry Canyon, and Bell Canyon. In areas adjacent to the WIPP site, production is obtained from the Cherry Canyon and Brushy Canyon Formations with most production coming from the Brushy Canyon (NMBMMR 1995).

The Brushy Canyon Formation has also been a producer of oil and associated gas in oil pools adjacent to the WIPP land withdrawal area. The oil traps are largely stratigraphic sandstones that are the major producers of all the Delaware oil pools adjacent to the WIPP site. The Cherry Canyon Formation wells have been drilled since 1970 and several producing fields exist within the Delaware Basin. The more productive Cherry Canyon wells have estimated recoveries of more than 180,000 barrels (2.86×10^5 hectoliters) of oil per well. The Bell Canyon Formation has been the zone most frequently drilled near the WIPP site. The majority of exploratory oil and gas wells were drilled before 1965 and were in the upper or middle part of the Bell Canyon Formation. Although a large number of these wells had positive oil shows through drill stem or core testing, they were never completed as production wells.

DEL.4.2.2.7 Brushy Canyon Formation

The Brushy Canyon is considered to have five main areas of deposition of oil and gas. The units of this formation have been carefully correlated and mapped. The Livingston Ridge Delaware was discovered in 1988 and the Lost Tank Delaware in 1992. Resources in these pools have been developed rapidly, averaging 25 wells per year since 1991. The Los Medanos Complex was discovered in 1991. Since its discovery, 99 wells have been drilled at depths ranging from 7,900 feet (2,409 meters) to 8,100 feet (2,470 meters). The Cabin Lake Pool was discovered in 1986 and has been developed at an average rate of seven wells per year. The Quahada Ridge Southeast Pool, the most recently discovered, began development in 1993. Development of this pool has been relatively slow with only three wells drilled in 1993 and two more in 1994.

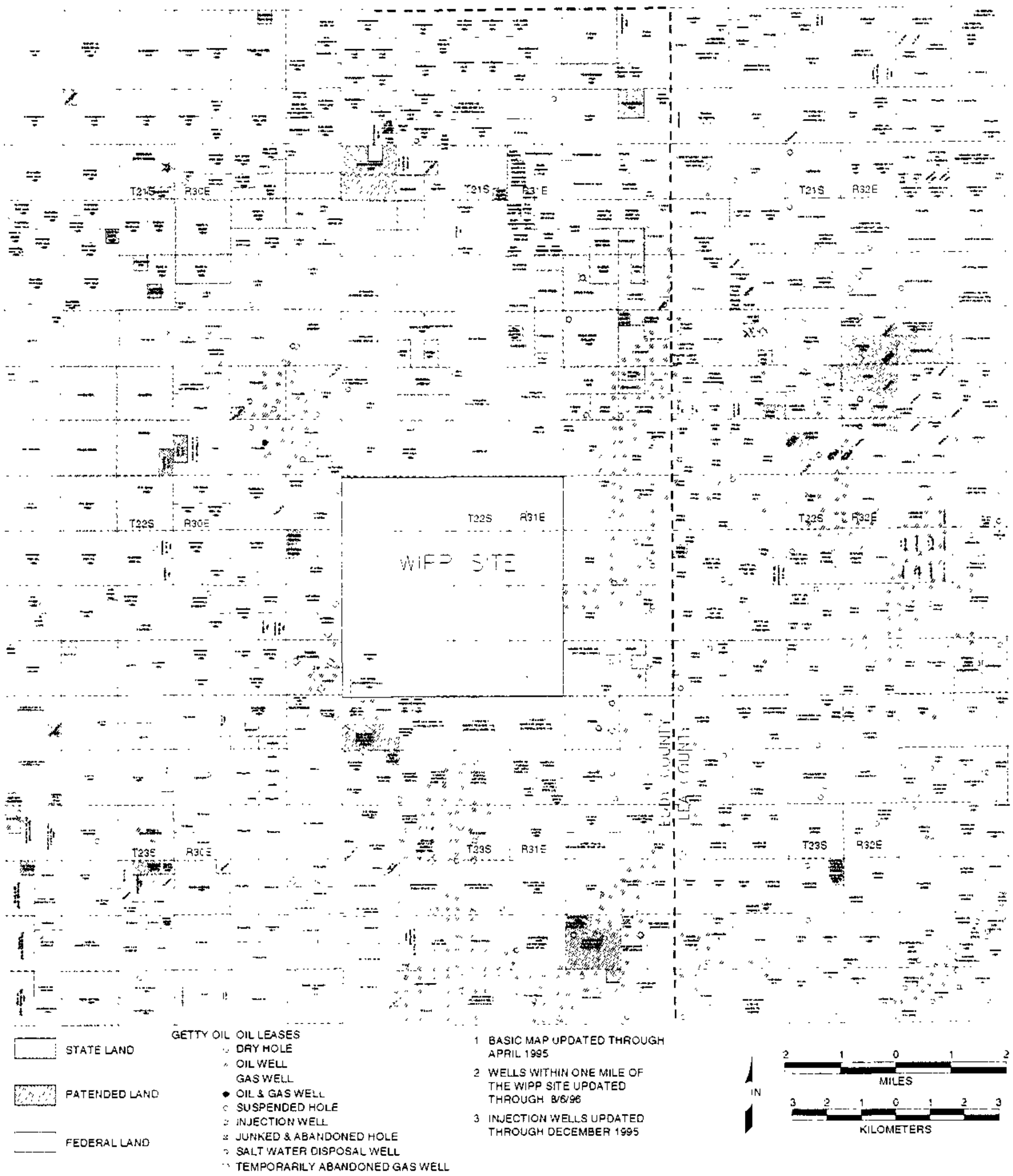
DEL.4.2.3 Oil and Gas Exploration and Production Near the WIPP Site

As late as 1974, the WIPP site and the area within one mile (1.6 kilometers) of the site boundary was not thought to have large petroleum resources located within its boundaries. However, since 1974, successful completion of exploratory wells has demonstrated that profitable quantities of resources are present beneath the WIPP site. Comprehensive well records on file at the New Mexico Oil Conservation Division (NMOCD) show that 532 wells have been drilled in the nine-township area centered around the WIPP site as of 1993, with a large number of these completed after 1974 (Figure DEL-6). Few wells were drilled in the area before 1960. From 1960 to 1989, drilling activity increased but was sporadic, although it exceeded 20 wells per year. In 1990, however, drilling increased markedly. Annual totals increased to a maximum of 140 wells per year during 1993. Increases in well completions during the 1990s can partially be attributed to the opening to drilling of previously restricted potash areas. The status of oil and gas wells within the WIPP withdrawal area and within 1 mile (1.6 kilometers) of the WIPP site boundary as of April 6, 1994, is shown in Figure DEL-7.

Lower parts of the Delaware Mountain Group were not generally recognized as exploratory and development targets until the late 1980s and early 1990s. Prior to that time, they were bypassed during drilling with little or no thought that they might contain economic oil reservoirs. In the years prior to 1970, the majority of wells drilled near the WIPP were for shallow oil 4,000 feet (1,220 meters) to 4,500 feet (1,372 meters) in the Bell Canyon Formation (NMBMMR 1995). Although these wells were considered exploratory and most were plugged and abandoned, there were many indications of oil in cores and drill-stem tests. Interest in gas wells was limited due to a lack of accessible pipelines and low well head prices. There was some limited success in the Bell Canyon area at Triste Draw, although none of the wells was drilled deep enough to reach either the Cherry Canyon or Brushy Canyon reservoirs which are now productive. Wells drilled after the 1970s and into the early 1980s were for natural gas from the much deeper Morrow and Atoka formations.

Drilling within the 10,240-acre (4,147-hectare) WIPP land withdrawal area has been extremely limited. Only three wells have been drilled for oil and gas within or below the area that was withdrawn for the WIPP site (Figure DEL-7). Two of the three wells drilled during the 1970s were abandoned without ever establishing production. The third well, drilled in 1982, reached the Atoka sandstone reservoir and gas production was established. This well, the Perry R. Bass No. 13 James Ranch Unit, remains productive and to date has produced 4.664 billion cubic feet (1.3×10^8 cubic meters) of natural gas and 27,500 barrels (4.4 million liters) of condensate from a total depth of 13,466 feet (4,105 meters). This well was directionally drilled from a surface location outside the WIPP land withdrawal area to a bottom hole location within the WIPP land withdrawal area. The drilling of this well was allowed as the result of the final judgement on the condemnation of land within Township 22 South, Range 31 East, Section 31.

In 1977, the United States, at the request of the Acting Administrator of the Energy Research and Development Administration, entered into condemnation actions (77-071-B and 77-776-B) for the acquisition of land within Township 22 South, Range 31 East, Section 31, Eddy County, New Mexico. The final judgment of the condemnation hearing allowed the U.S. to acquire the mineral rights for the surface and the underlying 6,000 feet (1,829 meters). The mineral rights below 6,000 feet (1,829 meters) were retained by the leaseholders. The mineral rights to the upper 6,000 feet (1,829 meters) were acquired to ensure that the bedded salt would remain intact and undisturbed by drilling.



Note: A full-sized map of this figure is in a pocket at the end of this volume.

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Figure DEL-6. Oil and Gas Wells in the Nine-Townships Study Area Surrounding the WIPP Site

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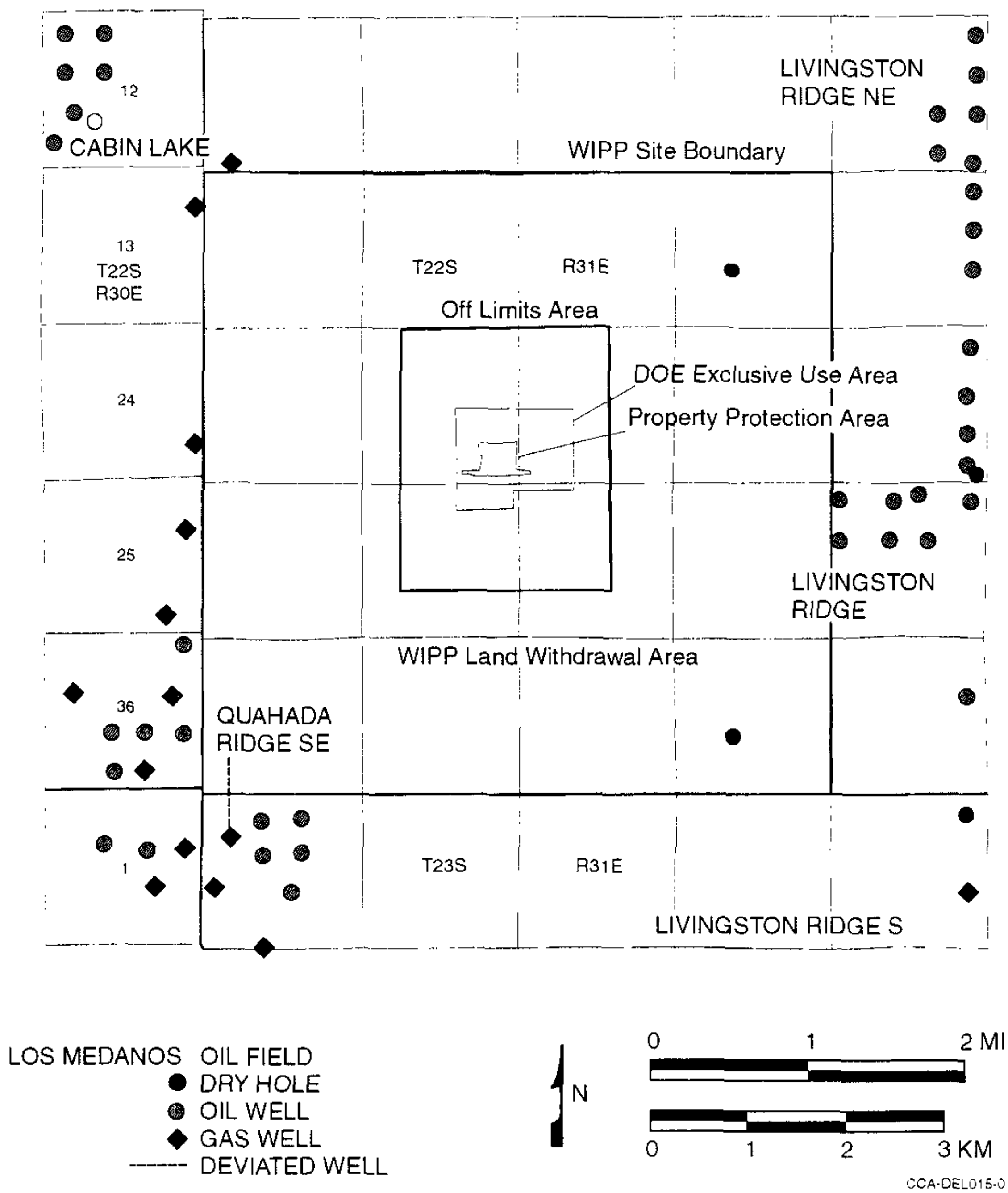

Figure DEL-7. Oil and Gas Wells Within One Mile of the WIPP Site Boundary

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DEL.4.2.4 Potash

Potash was discovered in Eddy County, New Mexico, in 1925 in the Snowden McSweeney Well No. 1 near the center of what is now called the Know Potash Lease Area (KPLA) (Figure DEL-8). The first potash coreholes were drilled in 1926. Potash is second in economic importance among the resources found in the Delaware Basin. It is found primarily in Eddy and Lea Counties of New Mexico which produced 83 percent of the nation's domestic potash in 1992. The BLM Carlsbad Mining District in southeastern New Mexico contains the largest domestic potash reserves (Figure DEL-8). The potash industry of New Mexico produces sylvite and langbeinite.

In March 1995, the NMBMMR completed a comprehensive reevaluation of potash resources within the WIPP land withdrawal area and the area within one mile (1.6 kilometer) of the land withdrawal area. The re-evaluation was based on an examination of 40 existing boreholes in the 36-square-mile (93-square-kilometer) area. This investigation indicated that economically attractive potash reserves are contained within the study area. However, of the 11 recognized potash zones, only the 4th and 10th zones within the area investigated contain economically attractive potash reserves (see Figure DEL-9). Even though these potash reserves have been identified as being present in the WIPP land withdrawal area, the repository itself is located in an area that is either barren of potash or has only minor potash mineralization (BLM 1993). Figure DEL-8 shows the distribution of potash leases within and outside of the Delaware Basin.

DEL.4.2.5 Sulfur

Sulfur appears in the Delaware Basin approximately 50 miles (81 kilometers) south of the WIPP in significant quantities and is considered an economically important resource at that location. There is no sulfur mining activity in the BLM Carlsbad Mining District or in NMOCD Districts 1 and 2.

DEL.4.2.6 Groundwater

The northern portion of the Delaware Basin, where the WIPP site is located, is surrounded by the Capitan Reef Complex which is of Permian age. The inner margin of the Capitan Reef serves as the boundary of the Delaware Basin (Section DEL.4.1 and Figure DEL-3). Within the Basin, a thick sequence of Permian rocks and a thin layer of Triassic rock contain six units that are important to the hydrogeology of the area: Bell Canyon, Castile, Salado, Rustler, Dewey Lake, and Santa Rosa (Figure DEL-5). Of these six units, only the Rustler, Dewey Lake, and Santa Rosa contain groundwaters that can be characterized as an economic resource. A discussion of the occurrence of underground sources of drinking water near the WIPP is provided in Appendix USDW.

DEL.4.2.6.1 Rustler Formation

The Rustler contains the most significant water-bearing zone in the northern Delaware Basin in the Culebra and Magenta Dolomite Members (Figure DEL-5). The groundwater chemistry of the Culebra is extremely variable with total dissolved solids (TDS) concentrations ranging from less than 5,000 milligrams per liter to greater than 200,000 milligrams per liter east of the WIPP site. The use of water from the Culebra is limited due to its varying yields and salinity. Useable water from the Culebra occurs several miles southwest of the WIPP site where the salinity is low enough to provide water for livestock.

The groundwater chemistry of the Magenta is also highly variable, ranging in TDS concentrations from 5,460 milligrams per liter to 270,000 milligrams per liter. Although, within the WIPP land withdrawal area, the general water quality of the Magenta is better than that of the Culebra, its use is very limited near the WIPP site.

DEL.4.2.6.2 Dewey Lake Formation

The Dewey Lake Redbeds overlie the Rustler Formation and underlies the Triassic Dockum Group (Figure DEL-5). Although the Dewey Lake has not normally been found to yield water, there are wells that will produce water in the southwestern to south-central portion of the WIPP site. Wells on the J.C. Mills and Twin Wells ranches south of the site produce water for both domestic and livestock use.

DEL.4.2.6.3 Santa Rosa Formation

The Santa Rosa Formation, which is present over the eastern half of the WIPP site, ranges in thickness from 0 to 300 feet (91 meters) (Figure DEL-5). Water occurrences in the Santa Rosa are very limited (DOE 1991 and DOE 1993).

DEL.5 Well Drilling, Plugging, and Abandonment Practices

This section discusses the current state of drilling technology for oil, gas, potash, and water, with primary emphasis directed at oil and gas well drilling technology. New and evolving drilling technologies are described where they apply. The intent of this section is to describe the current practices within the industry, within the Delaware Basin.

DEL.5.1 Oil and Gas Well Drilling Technology

Various types of drilling rigs, drill bits, and drilling fluids are discussed in this section. New drilling technologies, a typical drilling plan, and drill site preparation are also addressed. A typical oil and gas drilling sequence that might potentially occur in the New Mexico portion of the Delaware Basin is included in Attachment 1.

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contained in a pocket at the end of this volume.

Figure DEL-8. Potash Leases Within and Outside the Delaware Basin

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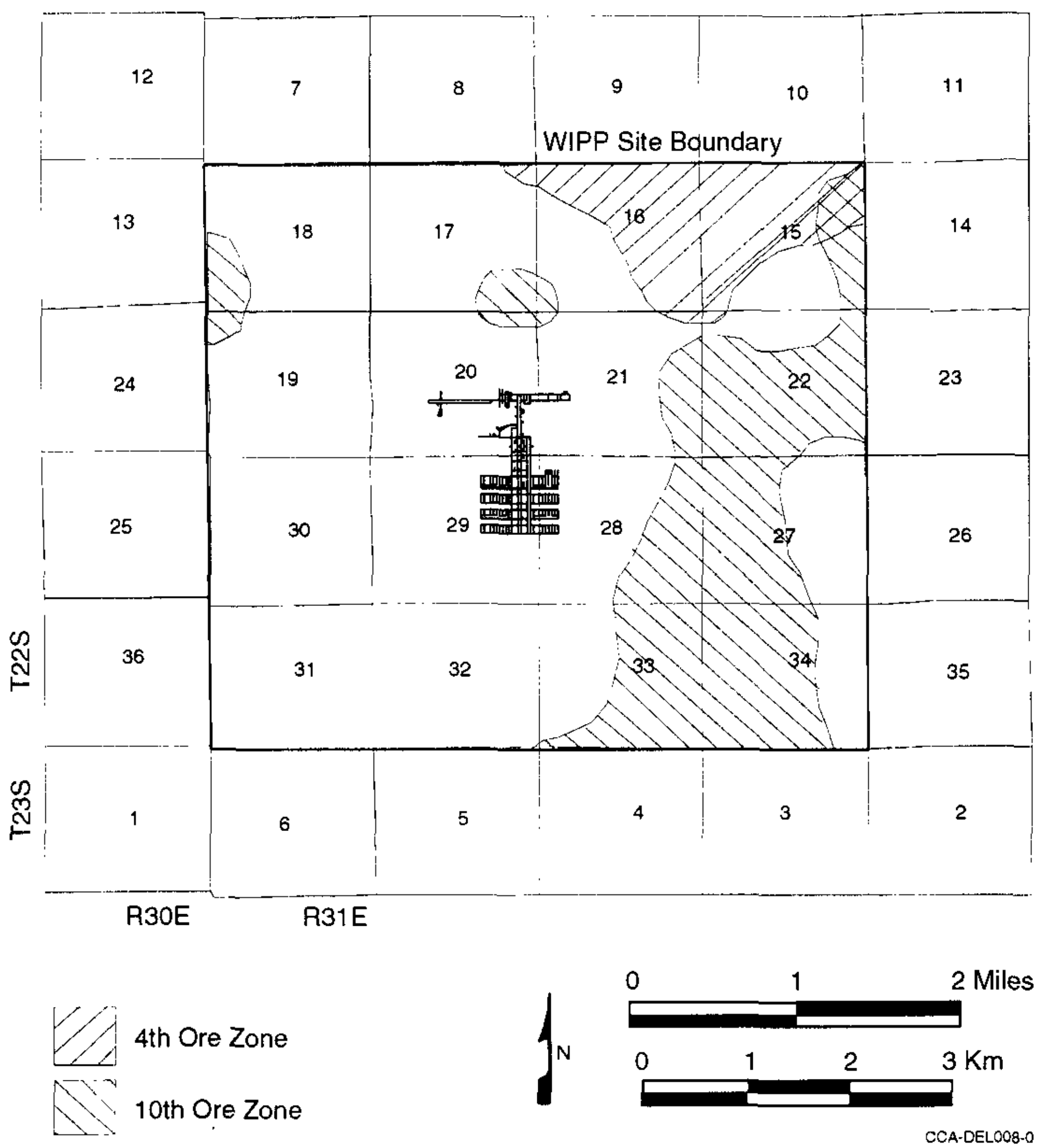

Figure DEL-9. Extent of Economically Minable Reserves of Potash Inside the Site Boundary (Based on NMBMMR Report)

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DEL.5.1.1 Cable Tool Rig

Cable tool rigs were used in early exploration for oil and gas in the Delaware Basin and were the workhorses of the industry in the early years. Cable tool drilling operates on a combination hammer-suction principle. A heavy, sharp-pointed bit is raised and dropped continuously into the hole, so that it chips and breaks the rock away. The bottom of the hole is kept full of mud and water, and the motion of the bit is regulated so that the moment it hits bottom it starts up again, adding the effect of suction to the pounding. Cable tool drilling has been substantially replaced by rotary drilling rigs. Diagrams of both types of rigs are provided in Figure DEL-10.

DEL.5.1.2 Rotary Drilling Rig

The cable tool rig was replaced in the early 1900s by the rotary drilling rig. Rotary rigs make a hole with a boring action rather than punching a hole, as is the case with the cable tool rig. The bit rotates while in constant contact with the rock at the bottom of the hole. Part of the weight of the drill pipe above the bit rests on the rotating bit. This pressure forces the bit into the rock as it turns. Fluid is pumped down the drill pipe and back to the surface to remove rock cuttings produced by the drill bit (Kennedy 1983).

The basic idea of rotary drilling has not changed significantly in more than 75 years, although there have been many improvements in the equipment comprising these rigs. Improvements have brought greater efficiency, greater depth capability, increased safety, and more control over hole conditions and reservoir fluids. The dual-speed top drive drilling rigs were introduced in the early 1980s. Demand for this type of rig has increased worldwide. One of the new dual-speed top drives is rated at 650 tons (590 metric tons). It can handle larger bit sizes and larger drill-string diameters, and reach greater drilling depths. This type of drilling rig offers greater personnel safety because it eliminates the rotary table. Other new tools have been developed to supplement the basic rotary drilling machinery.

DEL.5.1.3 Drilling Fluids

Drilling fluids are an integral part of every drilling program. Rotary drilling rigs and drill bits would not be able to function without drilling fluids, or mud as it is most commonly referred to in the oil and gas industry. The drilling fluids are circulated continuously through the drill pipe, down hole to the bit nozzles, and back up the annulus to the mud tanks on the surface. The drilling fluids pumped through the bit nozzles cause the bit cutters to turn and cut the hole. As the fluid moves out through the drill bit, it carries the cuttings made by the bit to the surface.

Drilling fluids serve several other functions as well. They lubricate and cool the bit, assist in bringing heavier cuttings to the surface, aid in controlling pressures that may exist in formations that are penetrated by the bit, and serve as a source of downhole information.

There are a variety of drilling fluids used in Delaware Basin drilling. Most rotary drilling operations use saturated brine (10 to 10.5 pounds per gallon) as a drilling fluid until reaching the Bell Canyon Formation, where intermediate casing is set. The brine has most often been manufactured by injecting fresh water into the Salado Formation and then pumping the water back to the surface. This process enables drillers to have a constant source of quality brine water. Saturated brine is used heavily in drilling because the intermediate string passes through the Salado Formation, which is salt. Fresh water will cause washout of the salt. Once drilling is continued in harder rock formations, such as the Bell Canyon Formation, materials such as bentonite, barite, or attapulgite are often added to the drilling fluid. All of these materials will increase viscosity and add weight to the drilling fluid column.

In recent years, the increased capacities of circulating systems and improvements in pumping technology have resulted in greater precision in controlling mud flow. Present day drilling fluids have been formulated using complex chemistry to combat specific downhole problems. These additions to fluid technology allow the driller to vary chemical and physical properties of the drilling fluid many times if necessary while drilling an oil or gas well.

DEL.5.1.4 Well Control and Safety

Well control and safety are two of the major concerns related to drilling. Because they are so closely interrelated, one cannot exist without the other. Maintaining a constant downhole pressure during drilling operations is a key factor in controlling an oil or gas well. Detailed well planning is the first step in preventing well control problems. Constant monitoring of drilling variables, use of appropriate equipment, and employment of well-trained drilling crews can significantly reduce the chances of losing control of a well.

Failure to control well pressures can cause major impediments to drilling progress. Loss of control over formation pressures can lead to loss of life, destruction of equipment, and abandonment of the well. Also, a well that has blown out may cause damage to the surrounding environment. These potential consequences have resulted in great emphasis being placed on the design and use of blowout control equipment, personnel training in well control, and regulations aimed at reducing the probability of well blowouts. (Note: A well blowout occurs when an uncontrolled flow of gas, oil, or other well fluids escapes into the atmosphere or an underground formation which is not the source of the pressurized fluid. It occurs when the pressure in an underground formation exceeds the pressure being applied by the column of drilling fluid. [The University of Texas 1991])

DEL.5.1.5 Directional and Horizontal Drilling

Directional, or deviated, drilling has been practiced in the petroleum industry for many years, however, the vast majority of wells are drilled vertically. Drilling rig personnel almost continually monitor drilling activity to maintain a vertical borehole. Occasions arise that call for the borehole to deviate in a direction that may be controlled by the driller. Methods to change direction of the borehole while drilling have changed from the conventional

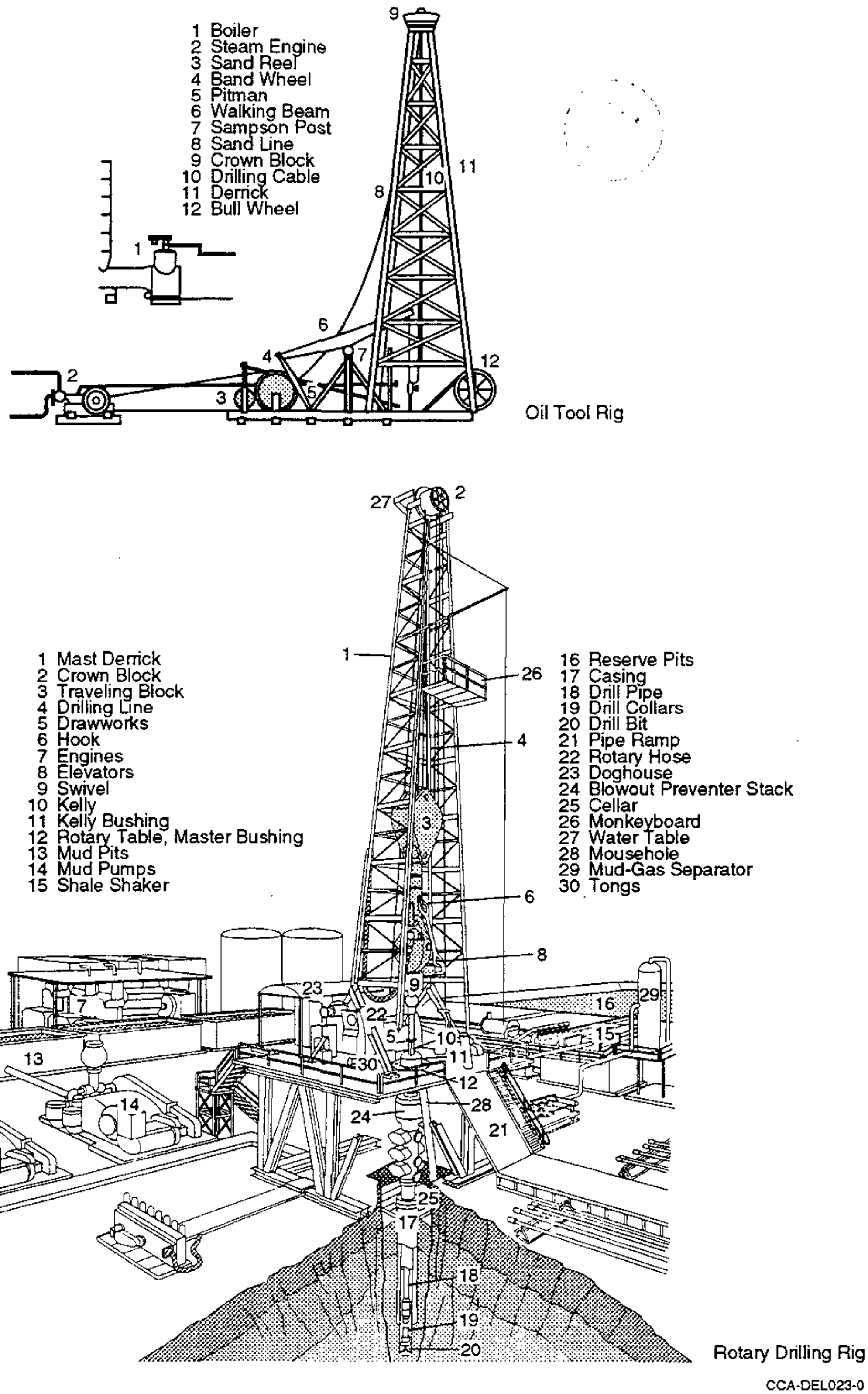

Figure DEL-10. Cable Tool and Rotary Drilling Rigs

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whipstocking of the 1960s and 1970s to new and more efficient methods. Technical developments since the mid-1980s have made it possible to complete wells that could not have been completed earlier, either for technical or economic reasons. The petroleum industry has placed much emphasis on the drilling, completion, and stimulation of wells through directional drilling. Directional drilling has improved as the result of the development of downhole motors with improved control capabilities that may be steered from the surface. Communication between the downhole and the surface using telemetry allows the driller to know exactly where the bit is and how drilling is progressing. This information is available almost immediately to the driller, whereas before, drilling was delayed until drilled materials were circulated to the surface. This technology makes it possible for the driller to make more accurate adjustments in order to follow the planned pathway to the drilling target.

Horizontal drilling is a new technology that allows a driller to not only directionally drill a well but also to be able to drill horizontally into the chosen drilling horizon thereby exposing more of the formation to production. This technique evolved in the 1980s and has been improved upon since. The ability to open more of the paying zones of a formation allows the producing company to bring more oil or gas to the surface and do so more quickly. Directional and horizontal drilling is not widely practiced, however, as directional drilling may increase the cost of drilling by 50 to 60 percent, while horizontal drilling could double the cost of the well (NMBMMR 1995).

DEL.5.1.6 Other Recent Drilling Technologies

Recent innovations in drilling technologies are important to the understanding of the future states concept in the compliance evaluations; the same drilling techniques used today will be assumed to be used in the future. Several recent developments are summarized below.

- **Measurement and Logging While Drilling.** Measurement while drilling and logging while drilling are two of the fastest growing new technologies and are currently used in the Delaware Basin. These new technologies are capable of providing continuous sampling of data through downhole sensors positioned close to or at the bit. The data collected downhole are then transmitted to the surface through the drilling fluid, inside the drill string, using pressure impulses. Impulses are analyzed at the surface. Recorded parameters can be monitored at the surface for better control of operating conditions and wellbore direction as well as lithological information. Measurement while drilling data are collected to ensure continuous surveying, monitoring, and control. Logging while drilling collects data on porosity, resistivity, gamma ray, and caliper measurements to ensure better control of the drilling zone and wellbore status. This information can be combined into an excellent guiding tool.

- **Oil and Gas Well Cementing.** Improvements have been implemented in recent years in well cementing, particularly with regard to the use of cement additives. The use of additives has reduced the permeability of the cement behind the well casing. Gas migration in the annulus between the casing and the formation has been eliminated as a result of the addition of four new cement additives: ironite sponge, XC-polymer, synthetic rubber, and Anchorage clay. Ironite sponge eliminates the micro-annulus between the casing and cement body by magnetically bonding the casing with the sponge. XC-polymer is a filtrate control agent. Anchorage clay reduces the permeability of cement by blocking pores. The addition of synthetic rubber compensates for the expansion and contraction cycles that are set in motion during the setting of the cement.

These improvements in cementing technology have a positive impact on wells completed in the Delaware Basin. The use of impermeable cement minimizes the threat of gas leaks. Cement with low permeability eliminates the formation of both micro-cracks and a micro-annulus. When used with dual-wall casing, it significantly reduces gas migration.

Drill pipe metallurgy has also improved, effectively combating corrosion and enabling the pipe to withstand the stresses resulting from extreme temperatures, pressures, and depths. Pipe handling tools and downhole equipment have been developed to meet specific needs.

Several changes in rotary drilling have been studied and some have been field tested. Currently, none of these new ideas has been competitive with conventional drilling techniques. Two new techniques that have been tested, high-pressure water jetting and abrasive jetting, still use mechanical energy to remove rock from the bottom of the hole. These new methods are significant departures from the conventional rotary method because of the need for specially-designed equipment. Successful field testing of these new techniques has been conducted but neither method is used routinely.

DEL.5.1.7 <u>Developing a Drilling Plan</u>

A typical scenario for an oil or gas well in the WIPP area would begin with a well planning process that would forecast the potential production zones encountered along with their expected depths (see Section DEL.6.1.1 for additional details). The forecast would be prepared using the results of gravity, magnetic or seismic surveys, or data obtained from offset wells. Commercial companies as well as the NMOCD and BLM would be consulted for information. Records maintained by drilling companies would be reviewed for information on hole and casing size, setting depth, formation pressures, mud types and weights, general characteristics, and any drilling problems that had been observed at previous wells in the area.

Once this stage of well planning was completed, the selection of hole and casing sizes and setting depths would be determined. A typical well completion is shown in Figure DEL-11. A well drilled in the Delaware Basin would have the first casing string set and cemented above the projected top of the salt section. Surface casing would typically be set and cemented from the surface to a depth of 400 feet (122 meters) to 800 feet (244 meters). The second (intermediate) casing string would be set and cemented below the base of the salt. Near the WIPP, this interval would be from the surface down to between 3,800 feet

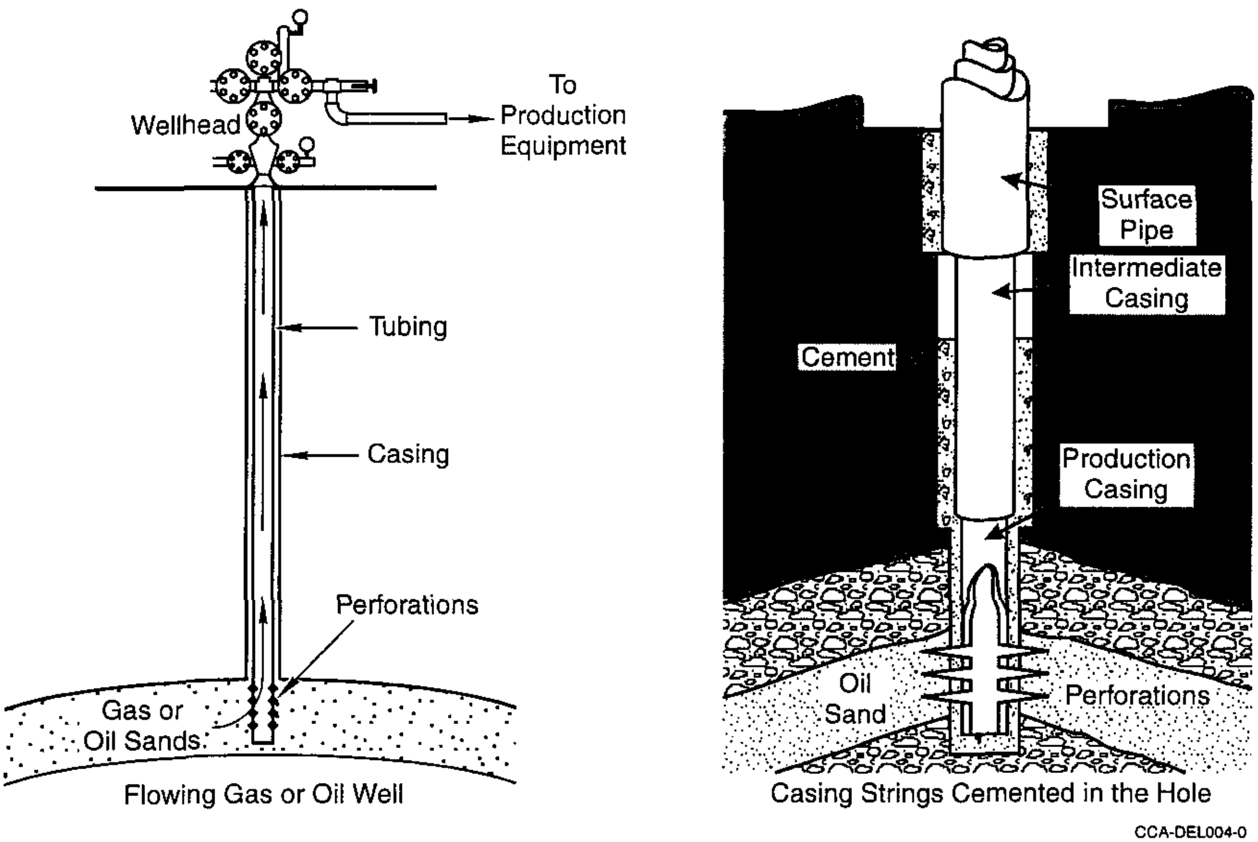

Figure DEL-11. Typical Well Completion

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(1,159 meters) and 4,200 feet (1,280 meters). The production casing string would be run from the surface to the total depth once drilling was completed.

Selection of the proper well casing weights and grades for the well is based on several considerations. The casing pipe must have sufficient wall thickness and steel strength to support the weight of the pipe as it is run into the hole. A safety factor must be added to both pipe and the pipe connections because of the possibility of the pipe sticking while it is being run into the hole. Pressure burst and collapse ratings must be calculated for the hole as they bear on the selection of casing weight and grade.

The type of cement, additives, and volumes must be selected for each casing string. Each casing string must be considered separately. The volume of cement for the intermediate and production string would be based upon bonding to the cement of the preceding casing string. The well plan would also include a cement bond log to indicate the effectiveness of the cementing of the casing strings.

The selection of a drilling mud system is critical to the drilling plan. Factors that must be considered include

(1) counterbalancing formation fluid pressures;

(2) efficient removal of rock fragments from the hole, including suspension of rock fragments when circulation stops;

(3) cooling, lubrication, and prevention of corrosion of the drill pipe and bit; and

(4) minimizing formation damage during the drilling process so that maximum information may be obtained from the formations as they are penetrated.

DEL.5.1.8 Drill Site Preparation

Following the completion of a drilling plan, a drilling site is selected by the operator. Upon final approval to drill, the location is surveyed and staked, and the drilling contractor is authorized to initiate construction. Information critical to construction of the drilling site (for example, location, dimensions, placement of the cellar, locations of the mouse and rat holes, and the layout of the reserve pit) is collected.

The size of a typical oil or gas well drilling pad is 300 feet by 260 feet (91 meters by 79 meters) with an additional 150 feet by 150 feet (46 meters by 46 meters) area for the reserve pit. Once the location of the pad is established, it is excavated to the underlying caliche layer and leveled. Caliche is hauled to the site by truck and compacted as necessary to establish a stable base. When the drilling pad is completed, a cellar is constructed over the intended wellbore. The cellar is excavated with final dimensions of about 8 feet by 8 feet by 6 feet (2.4 meters by 2.4 meters by 1.8 meters) and lined with either concrete or heavy wooden timbers. An auger contractor then drills a starter hole to a depth of 40 to 80 feet (12 to 24 meters). A conductor pipe ranging in diameter from 20 to 30 inches (50.8 to 76.2 centimeters) is then set and cemented in place. The diameter of the conductor pipe is determined by the casing size selected for the well.

Reserve pits are then constructed at a point adjacent to the cellar. The reserve pits are excavated to a depth of from 4 to 6 feet (1.2 to 1.8 meters) with a berm constructed around the outside of the pit. The reserve pits are lined with 0.2 to 0.5 mil (0.005 to 0.0127 millimeters) plastic. The plastic liner is required by the NMOCD to prevent possible contamination of groundwater by drilling fluids that are circulated into the pit during the drilling operations.

At this stage, the location is ready for the drilling rig to arrive and be set up for drilling operations. The rig size and type selected to drill the well is determined based on hole size and anticipated total depth of the well. Factors considered in the selection of the appropriate rig are horsepower, hoisting capability, derrick and substructure capacity and height, pumps, and well control equipment. The rig size normally selected for drilling in the WIPP area is one with a drilling depth capacity of 7,000 to 15,400 feet (2,134 to 4,695 meters). After selection of the proper drilling rig, the drilling contractor moves onto the location and begins drilling operations. A typical oil or gas drilling sequence for drilling that might occur in the Delaware Basin in the future is included as Appendix A.

DEL.5.1.9 Well Completion

The final stage of the oil or gas drilling process is completion of the well (Figure DEL-11). A pulling-unit is moved onto the location and set up over the wellbore. An engineering completion company runs a cased hole log of the well. This log is compared to the open hole log and areas within the selected formation are selected for perforation. In most instances, standard 4-inch (10-centimeter) perforation guns are loaded at a shot-density determined by the completion engineer. The perforation guns are then run into the hole to the depth selected for perforation. (Note: Perforation involves puncturing or piercing the casing wall and cement in a wellbore to provide holes through which formation fluids may enter the wellbore. It is accomplished by lowering a perforating gun into the well which fires electrically detonated bullets or shaped charges.)

When the completion company is confident that the perforation guns are at the correct depth, casing perforation is completed. After perforation of the casing, the well could receive further stimulation by fracturing or acidizing the wellbore at the site of the perforations to begin or improve production. During these operations, sand and acid are pumped under high pressures through the perforations into the formation. Sand pumping and acidizing cause fracturing of the formation and can increase porosity and permeability, thereby enhancing the production of oil or gas.

DEL.5.2 Drilling of Potash Coreholes

Potash coreholes are drilled for the purpose of locating potash reserves. Diesel-powered wireline and conventional core drill rigs are used for potash exploration. With this equipment, conventional rotary drilling procedures are used to bore to the top of the potash-bearing section. Cores are then cut with a face-discharge bit that is set with diamonds. Cores are typically 2.25 inches (6 centimeters) in diameter. A double-tube core barrel through which drilling fluid is circulated between the inner and outer tubes is used to core the desired areas. The drilling fluid is usually composed of saturated sodium and potassium chloride brine to which starch, gel, and diesel fuel is added. Cores are usually cut in 10 or 20 feet (3 or 6 meter) lengths. These cores provide the potash industry with valuable data in determining the presence of mineable potash as well as the type and grade of the potash.

Before potash coreholes are drilled, the mining company must contact the State Land Office and secure a right-of-way if the cores are to be taken from land currently held by the mining company through a lease. If the land that the mining company plans to core drill is not held by lease, a prospecting permit must be obtained from the State Land Office. Once the permit is obtained, the mining company must then submit a sundry notice of intent to drill to the State Engineer's Office. This notice is usually accompanied by a second notice of intent to plug or abandon. Both of these notices are required by the State Engineer. The mining company submits both forms before drilling any coreholes.

When the corehole has been drilled and all cores removed, the corehole is usually filled with cement before the drilling rig is moved to the next coring site. As a result of this, potash coreholes are expected to have no effect on the performance of the WIPP.

DEL.5.3 Drilling of Water Wells

Water wells must be drilled by a company or individual licensed by the State Engineer's Office. The driller is required to post a bond.

The typical sequence of activities for drilling a water well is initiated with the construction of a drilling pad with two pits, a mud pit, and a settling pit. A truck-mounted rotary drilling rig or a cable tool rig is then moved in and set up over the selected drilling site, after which drilling with mud or air is initiated.

When mud is selected as the drilling medium, the mud pit is filled with the appropriate drilling fluid. The mud is then pumped from the mud pit through the bit. The mud serves to drive the drill bit rotary cutters, cool the drilling bit, and circulate cuttings through the annulus to the surface and into the settling pit. Upon hitting water, the mud is used to flush cuttings from the hole. The well is then completed.

In drilling with air, the air performs the same function as mud. Air cools the bit and moves cuttings to the settling pit. The mud pit, however, is left dry until water is hit. Once water has been encountered, the mud pit is filled and the mud is used to flush cuttings from the hole. The well is then completed.

Well completion typically consists of placing a 25-foot (8-meter) length of steel well screen casing at the base of the well within the area where water is found. The steel screen is slotted, with the slots usually being 0.02 inch (0.05 centimeter) wide. This size is used because the casing is packed internally with gravel; the slots must not be large enough to allow the gravel to pass through. The remaining wellbore is cased and cemented to the surface with 3 feet (1-meter) of casing above ground level. A 10-foot (3-meter) layer of sand is deposited on top of the gravel inside the casing; this sand filters water as it rises in the well. Depending upon the depth of the water well, either polyvinyl chloride (PVC) or steel casing is installed to the surface.

Water wells that exceed 500 feet (152 meters) must be cased with steel because PVC is not sufficiently strong to withstand the weight of the casing. Also, the pressures become too great at that depth. Further, the bottom hole temperatures at that depth, combined with heat generated through hydration of cement used in casing the well, may actually melt the PVC. After cementing and packing, a submersible pump is installed in the well to allow water to be pumped to the surface for its intended use. When water wells are abandoned, the State Engineer's Office designates how the well will be plugged and witnesses the plugging activities.

DEL.5.4 Development of Injection and Secondary Recovery Wells

A permit is required from the NMOCD for any well used to inject gas, air, or water for secondary recovery or for water disposal. The regulation of injection wells is discussed in Section DEL.6.3. When injection well permits are granted, the NMOCD maintains close control over each well by requiring that annual casing-integrity testing be conducted and tracer surveys run to ensure that injected fluids are being pumped into the proper formations and they are not endangering any underground source of drinking water.

The most common type of injection well is for brine produced from the producing formation in oil and gas wells. Salt water disposal wells have become necessary as a result of the EPA's ruling that formation water may no longer be disposed of on the surface. All producing oil and gas wells produce water along with oil or gas. This water is now disposed of by injecting it into approved salt water disposal wells.

Waterflooding is the most common form of secondary recovery. This method involves the pumping of water through the existing perforations in a well in which production has decreased sufficiently to merit stimulation. As the water is pumped into a formation, it stimulates production of oil or gas in other nearby wells. This is a proven method of recovering hydrocarbons that otherwise would be unretrievable.

Waterflooding has been a popular form of secondary recovery for over 40 years. In its early stages, there was little or no monitoring of this process. More recently, it has been determined that waterflooding is responsible for a number of environmental problems related to groundwater. Since the late 1970s, strict control of waterflooding has been enforced. Section DEL.6.3.3.4 provides information on the regulation of waterflooding in the Delaware Basin.

DEL.5.5 Well Plugging and Abandonment Practices

This section addresses the technology associated with well plugging and abandonment. While the focus is on oil and gas wells, the plugging of potash coreholes and water wells is also described.

DEL.5.5.1 BLM Oil and Gas Plugging and Abandonment

The BLM regulations on oil and gas plugging and abandonment in 43 CFR § 3162.3-4 and Oil and Gas Order No. 2 are discussed in detail in Section DEL.4.1.2.2. This section serves as a supplement to that discussion.

DEL.5.5.1.1 Oil and Gas Well Plugging Sequence

The first step in plugging and abandoning a well is the submission of the Sundry Notice (Form 3160-5, Attachment 2) that informs the BLM of the operator's intent to abandon the well. This form must include a plan by the operator detailing exactly how the well will be plugged. BLM inspectors will review and approve the plan as presented or make modifications which the operator must follow.

The operator must provide a 24-hour notice to the BLM before beginning abandonment operations in order to allow BLM personnel an opportunity to witness the operation. BLM does not consider the plugging and abandonment procedure completed until a surface cap has been welded on the opening to the casing, a 4-inch (10 centimeter)-diameter pipe, 10 feet (3 meters) long, has been embedded in cement and extended 4 feet (1 meter) above ground level, and the cellars have been filled to the surface. When all phases of the abandonment are complete and have been inspected, the well plugging bond may be released (see Section DEL.6.1.5).

Plugging operations are typically carried out using a pulling unit (a truck with a large mounted derrick). The pulling unit sets up over the wellbore and is used to complete the plug and abandonment operation. The first step in the plugging process is to set the required cast iron bridge plug at the depth shown in the plugging plan as approved by the BLM. The point of placement for the bridge plug is just above the uppermost production perforations in the casing. Once the bridge plug is in place, the pulling unit operator will tag the bridge plug (touch the top of the plug with the tubing) to make certain that it is set at the correct depth as specified on the plugging plan contained in Form 3160-5 (Attachment 2).

When the proper depth is confirmed, a minimum of 25 feet (8 meters) of cement is placed on top of the bridge plug. The operator will then fill the borehole with at least nine-pound mud or brine water, filling the borehole to the site of the next plug location. The viscosity of the mud allows the operator to then pump a type C or H cement through the tubing to its correct depth on top of the mud. The mud column will support the weight of the cement until it sets up. The operator, if required by the BLM, will again tag the top of the cement to verify both the position and length of the plug.

While the NMOCD has inspection personnel on site in every instance to verify this process, the BLM elects to witness only selected plugging operations. The process of setting plugs will continue in the same manner until each of the plugs identified on the plugging plan has been properly placed. At this point, plugging operations are complete. The only remaining requirement to complete the plug and abandonment operation is that of returning the drill pad to a near-original state. This process may be completed in only a few days or possibly up to several months after plugging has been completed.

DEL.5.5.1.2 Plugging of Temporarily Abandoned Wells

Wells may be temporarily abandoned for up to five one-year periods with BLM approval (see Section DEL.6.1.2.3). A Sundry Notice must be submitted requesting temporary abandonment (Form 3160-5, Attachment 2). The notice must include a description of the abandonment procedure, a complete wellbore diagram, and the anticipated date the operations will occur. As with plugging and abandonment, this plan must be reviewed and approved by BLM inspectors. Once approved, a 48-hour notice must be given to BLM to allow an opportunity for the plugging inspection. Operators must install a bridge plug or a cement plug 50 to 100 feet (15 to 30 meters) above the perforations. If a cement plug is chosen, it must be tagged to make certain it is at the proper depth. Bridge plugs are set using a wireline with the proper depth being verified before the plug is set.

The integrity of the casing must be also be verified. If testing indicates problems with the casing, repairs must be made before the well may be temporarily abandoned.

DEL.5.5.1.3 Plugging in the Potash Resource Area

BLM requirements for plugging and abandonment in the potash areas are the same as in non-potash areas. Although the BLM has not overseen the plugging of any oil or gas wells in the potash area in a number of years, the requirements of the New Mexico Oil Conservation Commission (NMOCC) Order R-111-P (see Section DEL.6.2.4) will be considered at the appropriate time (Personal Communication 1996a). According to the Secretary of the Interior Order of October 28, 1986 (51 FR 39425), on oil, gas, and potash leasing, the BLM will cooperate with the NMOCD in implementing state rules and regulations although the BLM will make the final decision.

DEL.5.5.1.4 Most Common Technical Violations

Large national oil companies and large independent companies normally comply strictly with the oil and gas well plugging requirements. Large businesses, which have the necessary resources to properly plug and abandon their wells, typically contract with other large businesses to perform their plugging operations. It has been BLM's experience that these companies follow sound business practices and wish to remain in good standing with the BLM. Smaller independent operators are more likely to lack resources to respond as quickly to the BLM and may not plug a well with the same expertise that a larger established company might have. The BLM is aware of situations that pose a potential for improper plugging. If the agency has a concern regarding a contractor's methods, BLM personnel are present during the entire plugging operation (Personal Communication 1996b).

Plugging bonds are required to ensure that wells are plugged and abandoned properly and within a reasonable time frame (see Sections DEL.6.1.5 and DEL.6.2.1). Both NMOCD and BLM have experienced higher rates recently of what they refer to as orphan wells. These are wells that should be plugged and abandoned, but owners of these wells cannot be located. When this occurs, plugging of these wells becomes the responsibility of the agency upon whose land they are located. Both agencies have orphan well plugging funds that are funded partially through plugging bonds that have not been returned and money from their operating budgets. These orphaned wells are a matter of concern to both agencies and they are working to conserve financial resources for plugging.

DEL.5.5.2 State of New Mexico Oil and Gas Well Plugging and Abandonment

The NMOCD regulations on well plugging and abandonment are discussed in Sections DEL.6.2.2 and DEL.6.2.3. They are similar in many respects to the BLM requirements.

DEL.5.5.2.1 Plugging Outside the Potash Resource Area

The major distinction between NMOCD and BLM practices is that NMOCD witnesses every well plugging and abandonment operation on state and private land, whereas the BLM is only able to witness approximately 50 percent of the plugging operations on federal leases. Both agencies require sundry notices to be filed with an abandonment plan and both agencies review and approve or modify those plans.

DEL.5.5.2.2 Plugging Within the Potash Resource Area (R-111-P)

Operators must follow the same procedures within the potash enclave as they do in other areas, with the exception that the NMOCD requires the operator to run a solid cement plug through the entire salt section and water bearing zones in addition to installing a bridge plug above the perforations. Installing a solid cement plug through the salt provides additional assurance that no fluids or gases escape through the casing into potash mining areas or fresh water formations. (See Section DEL.6.2.3 on NMOCC Order R-111-P.)

DEL.5.5.2.3 Most Common Technical Violations

Because NMOCD inspectors are able to witness 100 percent of the plugging and abandonment operations, technical violations are very rare. NMOCD inspectors are present for each step in the plugging operation. Operators are informed that plugging operations are not to begin before NMOCD inspectors are on site. If NMOCD inspectors are not present when plugging operations begin, the operator may be required to remove everything from the well and start over. The NMOCD also requires plugging bonds to be secured by the operator before plugging and abandonment are carried out (see Section DEL.6.2.1). The bond is not released until all requirements for plug and abandonment have been properly completed (Personal Communication 1996c).

DEL.5.5.3 Plugging of Oil and Gas Service Wells

Oil and gas operators are required to follow NMOCD Rule 705 on commencement, discontinuance, and abandonment of injection operations when plugging an injection well. This rule requires operators to file a Notice of Discontinuance when a decision has been made to cease injection operations. The rule forbids temporary abandonment of service wells. Plugging requirements are the same as when plugging oil and gas wells or dry holes.

DEL.5.5.4 Plugging of Potash Coreholes

In June 1975, the land that is now the WIPP land withdrawal area became part of the Carlsbad Underground Water Basin. This placed potash coreholes under the jurisdiction of the State Engineer. A review of the records maintained by BLM on commercial potash coreholes indicates that, since 1975, 155 coreholes have been drilled and plugged in the New Mexico portion of the Delaware Basin. Of the 155 coreholes, 151 were plugged from bottom to top with solid cement while four were plugged with a mixture of mud and cement. As indicated by this review, the current plugging practice is to fill potash coreholes with a cement slurry from the bottom of the hole to the surface.

DEL.5.5.5 Plugging of Water Wells

The State Engineer has authority for all water wells. The State Engineer must be notified when a well is to be plugged and he designates how it is to be plugged. The method typically used in the Carlsbad Underground Water Basin is to remove all casing from the hole, clean the hole to the bottom using a sand pump or a cable tool drilling rig with a bailer, and fill the hole with red clay. The red clay is compacted as the hole is filled. Another method of filling the hole is to circulate the hole full of cement. This method is more expensive and is not typically used.

DEL.6 Regulations, Practices, and Problems Associated With Oil and Gas Well and Other Drill Hole Drilling, Plugging, and Abandonment

This section describes BLM (Section DEL.6.1) and NMOCD (Section DEL.6.2) regulatory requirements pertaining to the drilling and plugging of oil and gas wells. Requirements related to drilling and plugging of drill holes (coreholes) associated with exploration for potash resources are also briefly discussed. While the emphasis is on plugging of oil and gas or other types of boreholes, drilling requirements are discussed insofar as they may relate to inadvertent intrusion at the WIPP site. Enforcement actions, incidents of non-compliance with regulations, and other problems associated with drilling or plugging as they may relate to the integrity of the WIPP site are also identified.

The entire 10,240-acre (4,144-hectare) WIPP site (Figure DEL-2) is withdrawn from all forms of oil and gas, potash, and other mineral leasing and appropriation under §3(a)(1) of the Waste Isolation Pilot Plant Land Withdrawal Act of 1992 (U.S. Congress 1992). WIPP activities related to the management and disposal of TRU wastes are given priority although the WIPP site may continue to be used for wildlife habitat, livestock grazing, and hunting subject to conditions imposed by the DOI and applicable grazing laws and policies (LWA § 4[b]). With the exception of two existing oil and gas leases (which can be acquired by the DOE if deemed necessary), the LWA prohibits all surface and subsurface mining or oil and gas production on land on or under the WIPP site (LWA § 4[b][5]). Slant drilling from outside the boundaries of the WIPP site that would intrude into the withdrawal is also prohibited.

DEL.6.1 Bureau of Land Management (BLM)

Leasing of oil and gas resources under federal ownership in the WIPP area is conducted for the Carlsbad Resource Area (CRA) (Figure DEL-12) by the BLM Roswell District Office. Leasing has most recently been conducted under the 1988 Carlsbad Resource Management Plan and site-specific environmental assessments prepared to meet the requirements of the National Environmental Policy Act (NEPA). Leasing of oil and gas is authorized by the Mineral Leasing Act of 1920 and subsequent federal legislation.

The CRA encompasses approximately 6.4 million surface acres (2.6 million hectares) in Eddy and Lea Counties and the southwest portion of Chaves County (Figure DEL-12). The federal government owns both the surface estate and subsurface oil and gas resources on approximately 2.2 million acres (0.9 million hectares). On another 1.9 million acres (0.8 million hectares), the subsurface oil and gas is under federal ownership while the surface is either owned by non-federal surface owners or not administered by the BLM. Thus, federal oil and gas resources underlie approximately 4.1 million surface acres (1.7 million hectares) of the CRA. The CRA, within which the WIPP site is located, occupies only a small portion of the northern part of the Delaware Basin (Figure DEL-3).

DEL.6.1.1 Steps Involved in Oil and Gas Resource Development on Federal Lands

The steps involved in exploration, development, and production of oil and gas, as well as eventual plugging and abandonment, are similar on federal and State-regulated lands although BLM and NMOCD regulatory requirements differ. The major steps on BLM lands are as follows.

1. **Screening of Parcels Proposed for Leasing.** Screening is conducted according to a number of primarily environmental criteria and leasing requirements of other surface management agencies.

2. **Leasing of Parcels.** Leasing is authorized by the Mineral Leasing Act of 1920 (and subsequent legislation) and conducted according to BLM regulations in 43 CFR Part 3100, Subpart 3101. A lessee has the right to use as much of the leased land as is necessary for exploratory drilling and development of the oil or gas resources. Leasing applies to the federal mineral estate whether the surface is administered by the BLM, a private individual or company, or some other government agency.

3. **Geophysical Exploration.** Prospecting using seismic reflection surveys is the prevalent method used in the Roswell BLM District. Operators are required to file with the BLM Area Manager a notice of intent to conduct oil and gas exploration operations (Sundry Notice Form 3160-5; Attachment 2) accompanied by evidence of adequate bonding. When exploration activities are completed, the operator must file with the BLM a notice of completion of oil and gas exploration operations (Sundry Notice Form 3160-5; Attachment 2). The BLM may impose certain terms and conditions on exploration activities and notify the operator, following an inspection, if the terms and conditions have been met. If they have not been met, the surety bond required cannot be released. During the period of 1986 through 1992, the BLM approved 369 geophysical exploration notices of intent for the CRA.

4. **Drilling Permitting.** The lessee or operator must submit to BLM either a notice of staking (NOS) or an application for a permit to drill (Form 3160-3; Attachment 2). This is followed by a BLM field inspection to assess possible surface and subsurface impacts and specify, as necessary, site-specific mitigation measures. Before approving the application for a permit to drill, the BLM must prepare the required NEPA documentation. A number of environmental and other conditions and stipulations are attached to all drilling permits.

5. **Drilling Operations.** Applications for a permit to drill are approved for a one-year period and may receive a one year extension if drilling is not started during the first year. Drilling methods and technology are discussed in Section DEL.5.0. BLM drilling regulations are discussed in Section DEL.6.1.2.1.

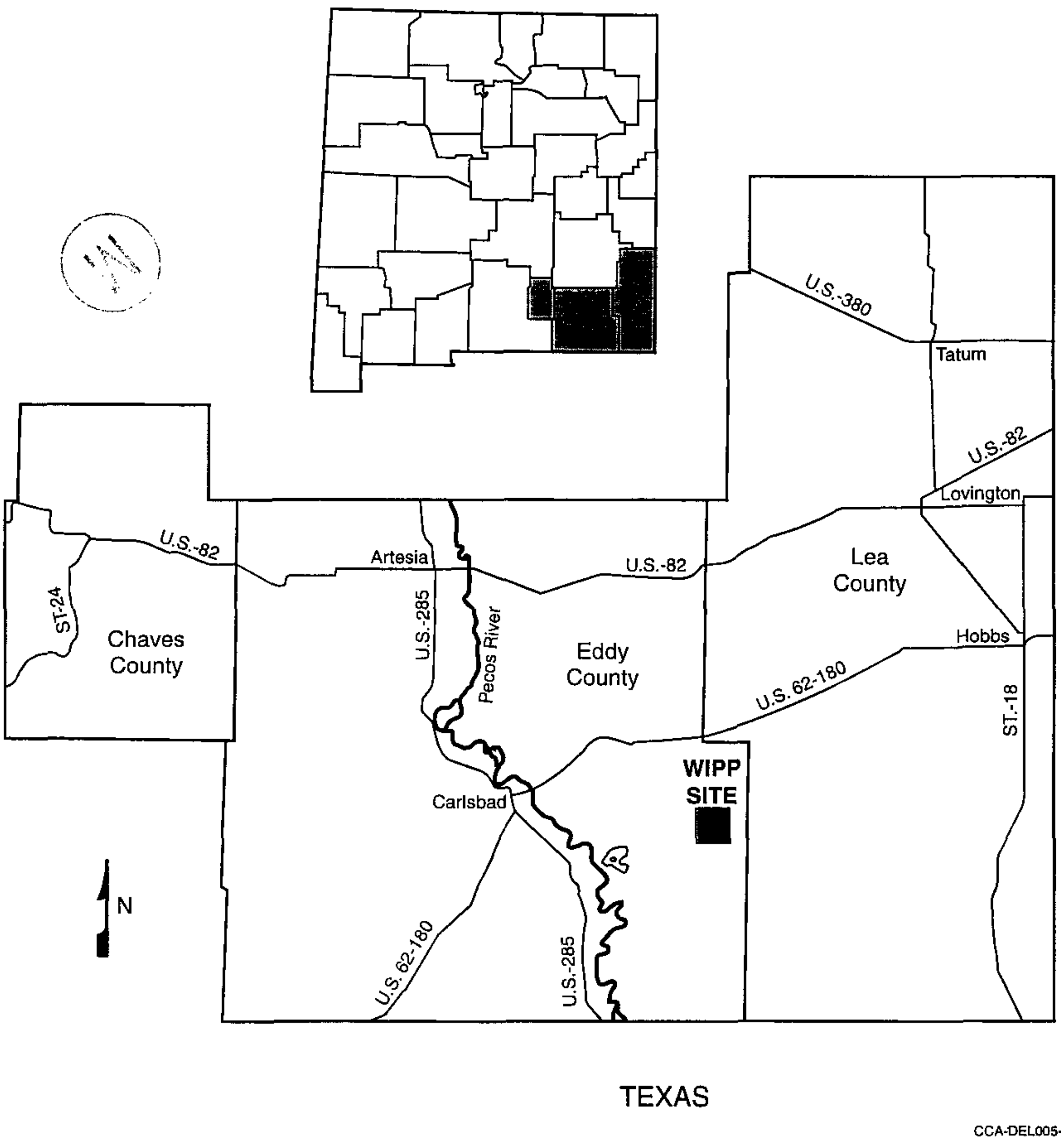

Figure DEL-12. Carlsbad Resource Area

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6. **Development and Production.** Wells are completed and production equipment installed only when it is determined that oil or gas can be recovered in commercial quantities. A well completion or recompletion report and log, BLM Form 3160-4, is included in Attachment 2.

7. **Well Plugging and Abandonment.** BLM regulatory requirements governing well plugging and abandonment are discussed in Section DEL.6.1.2.2. Plugging of an abandoned well is required to prevent migration of fluids between underground zones, protect other resources (for example, potash and useable water), and reclaim the surface. A correlative purpose of plugging is to prevent waste of oil and gas resources.

DEL.6.1.2 BLM Regulation of Onshore Oil and Gas Operations

Exploration, development, and production of oil and gas from federal leases administered by the BLM are governed by comprehensive regulations for onshore oil and gas operations in 43 CFR Part 3160. Under the regulations, the term federal lands means all lands and interests in lands owned by the United States which are subject to the mineral leasing laws, including mineral resources or mineral estates reserved to the United States in the conveyance of a surface or nonmineral estate (§ 3160.0-5[c]). Thus, the regulations are not limited to oil and gas recovered from lands where the surface is administered by the BLM.

The BLM is authorized to require that

> [All] operations be conducted in a manner which protects other natural resources and the environmental quality, protects life and property and results in the maximum ultimate recovery of oil and gas with a minimum of waste and with minimum adverse effect on the ultimate recovery of other mineral resources (43 CFR § 3161.2).

The BLM regulations in 43 CFR are implemented and supplemented by various onshore oil and gas orders which are periodically issued under Subpart 3164 of the regulations. Onshore Oil and Gas Order No.1 (48 FR 48916) was issued on October 21, 1983, and covers many of the same topics as the regulations, some in more detail. Onshore Oil and Gas Order No. 2 (53 FR 46798, November 18, 1988) applies particularly to drilling operations including well abandonment and plugging requirements, and it expands on the 43 CFR regulations. BLM inspections and enforcement activities rely more on the oil and gas orders than on the regulations (Personal Communication 1996a).

DEL.6.1.2.1 Well Drilling

The BLM has authority to approve and monitor drilling and production, impose assessments or penalties, issue notices to lessees (NTLs), and suspend operations. No drilling operations or related surface disturbances can be commenced without approval of an application for a permit to drill (43 CFR § 3162.3-1[c]). The application for a permit to drill (Form 3160-3; Attachment 2) must include a drilling plan for a single well or several wells, a surface use plan, and evidence of bond coverage. A proposal to conduct well operations other than drilling (for example, redrill, deepen, perform casing repairs, plug-back, and alter casing) must also be submitted to BLM for approval on Form 3160-3 (Attachment 2). Before approving an application for a permit to drill, the BLM must prepare an environmental review or an environmental assessment. These documents are used to determine if an environmental impact statement is required and to identify drilling approval terms and conditions (43 CFR § 3162.5-1[a]).

During the drilling and completion of a well, the operator is required to conduct tests, run logs, and make other necessary surveys (43 CFR § 3162.4-2). The operator is also required to determine the amount and direction of any deviation of the well from vertical. Results of such tests and surveys must be made available to the BLM.

Onshore Oil and Gas Order No. 2 details BLM's uniform national standards for minimum levels of performance for conducting drilling operations as well as for plugging and abandonment (53 FR 46798, November 18, 1988). Highly technical requirements are included for well control, well casing and cementing, drilling mud and related drilling procedures, drill stem testing, and special drilling operations. Casing and cementing programs are to be conducted to protect and isolate usable water zones, potentially productive zones, lost circulation zones, abnormally pressured zones, and any prospectively valuable mineral deposits. Drilling mud characteristics, use, and testing and implementation of related drilling procedures must be designed to prevent loss of well control.

DEL.6.1.2.2 Well Abandonment and Plugging

The BLM requirements pertaining to plugging and abandonment of oil and gas wells are contained in 43 CFR § 3162.3-4 and Section III.G of Onshore Oil and Gas Order No. 2. The regulations in 43 CFR Part 3160 provide as follows:

> The operator shall promptly plug and abandon, in accordance with a plan first approved in writing or prescribed by the authorized officer, each newly completed or recompleted well in which oil or gas is not encountered in paying quantities or which, after being completed as a producing well, is demonstrated to the satisfaction of the authorized officer to be no longer capable of producing oil or gas in paying quantities (43 CFR § 3162.3-4[a]).

There is an exception to this requirement if the BLM approves the use of the well as an injection well to recover additional oil or gas (enhanced recovery) or for subsurface disposal of produced water. Also, completion of a well as plugged or abandoned may include using the well as a water supply source, provided that the party using the well accepts responsibility for all costs over and above the normal plugging and abandonment expenses.

No well can be temporarily abandoned for more than 30 days without approval of the BLM, although permanent abandonment may be delayed for a period of up to 24 months. A temporarily abandoned well is defined as a completed well that is not capable of production in paying quantities but which may be used as a service well. Drilling or production equipment must be removed from a well site that is to be permanently abandoned and the land surface reclaimed in accordance with an approved plan.

Oil and Gas Order No. 2 provides as follows:

> All formations bearing useable-quality water, oil, gas, or geothermal resources, and/or a prospectively valuable deposit of minerals shall be protected . . . . Failure to obtain approval [following an oral request and a written notice of intent] prior to commencement of abandonment operations shall result in immediate assessment of [$500] . . . . Within 30 days of completion of abandonment, a subsequent report of abandonment shall be filed (53 CFR at 46810).

Oil and Gas Order No. 2 prescribes the following method of plugging either open holes (that is, those holes in which no casing has been emplaced) or cased holes.

Open Hole:

- For an open hole, a cement plug must be placed to extend at least 50 feet (15 meters) below the bottom (except as limited by total depth or plugged back total depth) to 50 feet (15 meters) above the top of any zone encountered during drilling that contains fluid or gas with a potential to migrate or any prospectively valuable mineral deposits.

- All cement plugs, except the surface plug, must have sufficient slurry volume to fill 100 feet (30 meters) of hole plus an additional 10 percent of slurry for each 1,000 feet (305 meters) of depth.

- No plug, except the surface plug, can consist of less than 25 sacks of cement without approval from the BLM. (A sack of cement weighs 94 pounds [43 kilograms] and produces between 1 and 2 cubic feet [0.03 and 0.06 cubic meters] of slurry volume, depending on the quantity of additives used.)

- Extremely thick sections of a single formation (for example, salt sections) may be secured by placing 100-foot (30-meter) plugs across the top and bottom of the formation.

- Unless there are zones containing fluids or gas with the potential to migrate or potentially valuable mineral deposits (which require their own plugs 50 feet [15 meters] above and 50 feet [15 meters] below), long sections of open hole must be plugged at least every 3,000 feet (915 meters).

Cased Hole:

- For a cased hole, a cement plug must be placed opposite all perforations (holes made in the casing to allow formation fluids to enter the wellbore) and extend at least 50 feet (15 meters) below to 50 feet (15 meters) above the perforated interval. All cement plugs, except the surface plug, have the same slurry volume requirements as those for an open hole. A bridge plug (see glossary) is also acceptable provided certain conditions are met.

- If any casing is cut and removed from the hole, a cement plug must be placed to extend at least 50 feet (15 meters) above and below the stub (the cut end of the casing). Plugging of the exposed hole resulting from casing removal must follow the procedure described above for plugging an open hole.

- An additional cement plug must be placed to extend at least 50 feet (15 meters) above and below the surface casing shoe (see glossary).

- No annular space (the space or annulus surrounding the pipe or casing in the wellbore) extending to the surface can be left open to the hole drilled below. If such a condition exists, at least the top 50 feet (15 meters) of annulus must be plugged with cement.

- Any cement plug which is the only isolating medium for a fresh water interval or a potentially valuable mineral deposit must be tested by tagging with the drill string. (Tagging refers to touching a downhole object.) If any plugs are placed where the fluid level will not remain static, they must be tested either by tagging with the casing string or establishing a pumping pressure of 1,000 pounds per-square-inch (pounds per square inch) (6,895,000 pascals). The purpose is to determine the integrity of the plug.

- If temperatures at the bottom of the hole exceed 230° F (110° C), silica sand or flour must be added to the slurry to prevent heat degradation of the cement.

- A cement surface plug at least 50 feet (15 meters) thick must be placed across all of the annuli.

- Each of the intervals between plugs must be filled with mud of sufficient density to exert hydrostatic pressure exceeding the greatest encountered during drilling. In the absence of other information, a minimum mud weight of nine pounds per gallon is required.

- A surface cap (in addition to a surface plug) is required. The surface cap is a metal plate at least .25 inch (0.6 centimeters) thick welded in place or a 4-inch (10-centimeter) diameter pipe 10 feet (3 meters) long embedded in cement and extending 4 feet (1.2 meters) above ground level. Prior to emplacing the surface cap, the casing must be cut off at the base of the cellar (a pit in the ground under the well rig floor) or 3 feet (1 meter) below final restored ground level (whichever is deeper). The cellar is then filled with suitable material and the surface restored.

The drilling of oil or gas wells in the potash area (Figure DEL-8) has not occurred in many years. However, when such wells need to be plugged, the BLM will consider the NMOCD requirements in Order R-111-P (see Section DEL.6.2.3 below). The current plugging procedure followed in the CRA is illustrated in Figures DEL-13 and DEL-14.

DEL.6.1.2.3 BLM Policy on Temporarily Abandoned and Shut-In Wells

A temporarily abandoned well is a completed well that is not capable of producing oil or gas in commercial quantities but may have value as a service well (for example, injection or water disposal well). A shut-in well is a completed well capable of producing in commercial quantities or being used as a service well. A well cannot be temporarily abandoned for more than 30 days without prior BLM approval. Similarly, BLM approval is required if a well is to have shut-in status for a year or longer. Extensions of time are available in both cases under the regulations.

On December 16, 1994, the BLM New Mexico State Office issued Instruction Memorandum (IM) No. NM-95-022 pertaining to a testing and review policy for both producing and non-producing wells (Attachment 3). The IM requires the following considerations when BLM reviews applications for temporary abandonment or continued shut-in status.

- An operator requesting temporary abandonment for a particular well (on Sundry Notice Form 3160-5; Attachment 2) must

  (1) justify why the well should be temporarily abandoned,

  (2) describe the temporary abandonment procedure to be followed, and

  (3) demonstrate the mechanical integrity of the well casing.

  Specific plugging requirements for a well being temporarily abandoned are set forth in the IM.

- (Attachment 3). The pressure test required to demonstrate the mechanical integrity of the casing is also specified in the IM.

- While a well cannot be temporarily abandoned for more than 30 days without prior BLM approval, permanent abandonment can be delayed for up to 24 months (see 43 CFR § 3262.3-4[c]).

- An operator requesting shut-in approval for a particular well (also on Form 3160-5) must demonstrate that the well is capable of producing oil or gas in paying quantities. The operator must justify why the well should receive shut-in (inactive) status rather than being activated as a producing well or service well. Shut-in approval is granted for a one-year period, renewable for up to five years if justified. This policy provides the operator with a grace period of a least a year to do something with the well (for example, reestablish production, plug and abandon, or convert to a service well). As with temporary abandonment, the operator must demonstrate the mechanical integrity of the well casing through testing procedures specified in the IM (Attachment 3).

This BLM policy and its implementation has minimized the number of inactive and unplugged wells in the New Mexico portion of the Delaware Basin.

The BLM CRA office in Carlsbad, New Mexico, has been making a concerted effort to force operators to produce or plug inactive wells by reviewing the actual status of wells classified by operators as shut-in or temporarily abandoned. Through these reviews, the BLM can determine if these wells have further economic use. If not, the operators are directed to permanently plug and abandon them.

DEL.6.1.2.4 Well Records and Reports

The BLM regulations require the operator to keep accurate and complete records on standard forms of all lease operations including, but not limited to, drilling, production, redrilling, deepening, repairing, plugging back, and abandonment (43 CFR § 3162.4-1[a]). All records and reports must be maintained for at least six years.

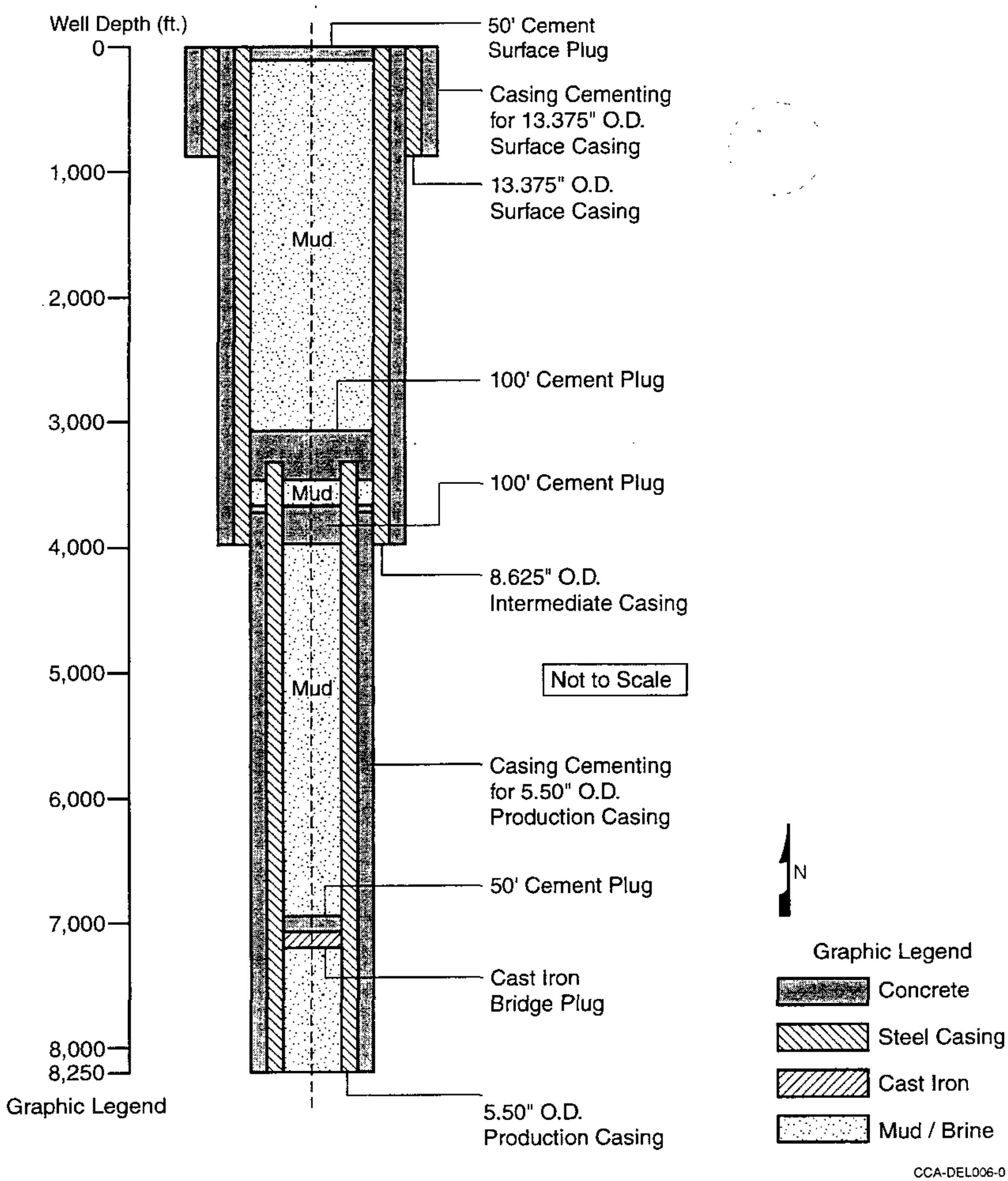
DEL.6.1.3 Agreement Between DOE and BLM on Oil and Gas Activities Affecting WIPP

The DOE and the BLM executed a Memorandum of Understanding (MOU) on July 19, 1994, directed at establishing cooperative arrangements and procedures for land and resource management within the WIPP withdrawal area (see Attachment 4). The MOU supplements the WIPP Land Management Plan (DOE/WIPP 93-004). The MOU provides as follows:

> It is the intent of the DOE to ensure that mining and gas and oil activities do not encroach upon the withdrawal area. Adherence to this MOU is crucial to protecting the repository from inadvertent human intrusion . . . . In accordance with Section 4(b)(5)(A) of the LWA (WIPP Land Withdrawal Act), no surface or subsurface mining or oil and gas production, including slant drilling from outside the boundaries of the withdrawal, shall be permitted at any time (including after decommissioning) on lands on or under the withdrawal (MOU Section VI.E; emphasis added).

Exceptions to the LWA prohibition against resource extraction are for existing rights under two existing oil and gas leases in the WIPP withdrawal area, unless the EPA determines that acquisition of these leases is needed for WIPP to comply with the 40 CFR Part 191 disposal requirements or the Resource Conservation and Recovery Act (RCRA) (LWA § 4[b][5][B]).

Under the MOU, the DOE agrees to coordinate with the BLM regarding BLM permits for oil and gas drilling (or other mining activity) on BLM lands within one mile of the WIPP site boundary. DOE also agrees to interpret, review, and verify oil and gas activity calculations performed by the BLM. The BLM agrees to allow the DOE to review and comment on any applications for a permit to drill for oil and gas resources within one mile of the WIPP site boundary. Any DOE comments must be resolved before an application for a permit to drill can be approved by the BLM.



Figur DEL-13. Minimum Oil and Gas Well Plugging Requirements in the Delaware Basin

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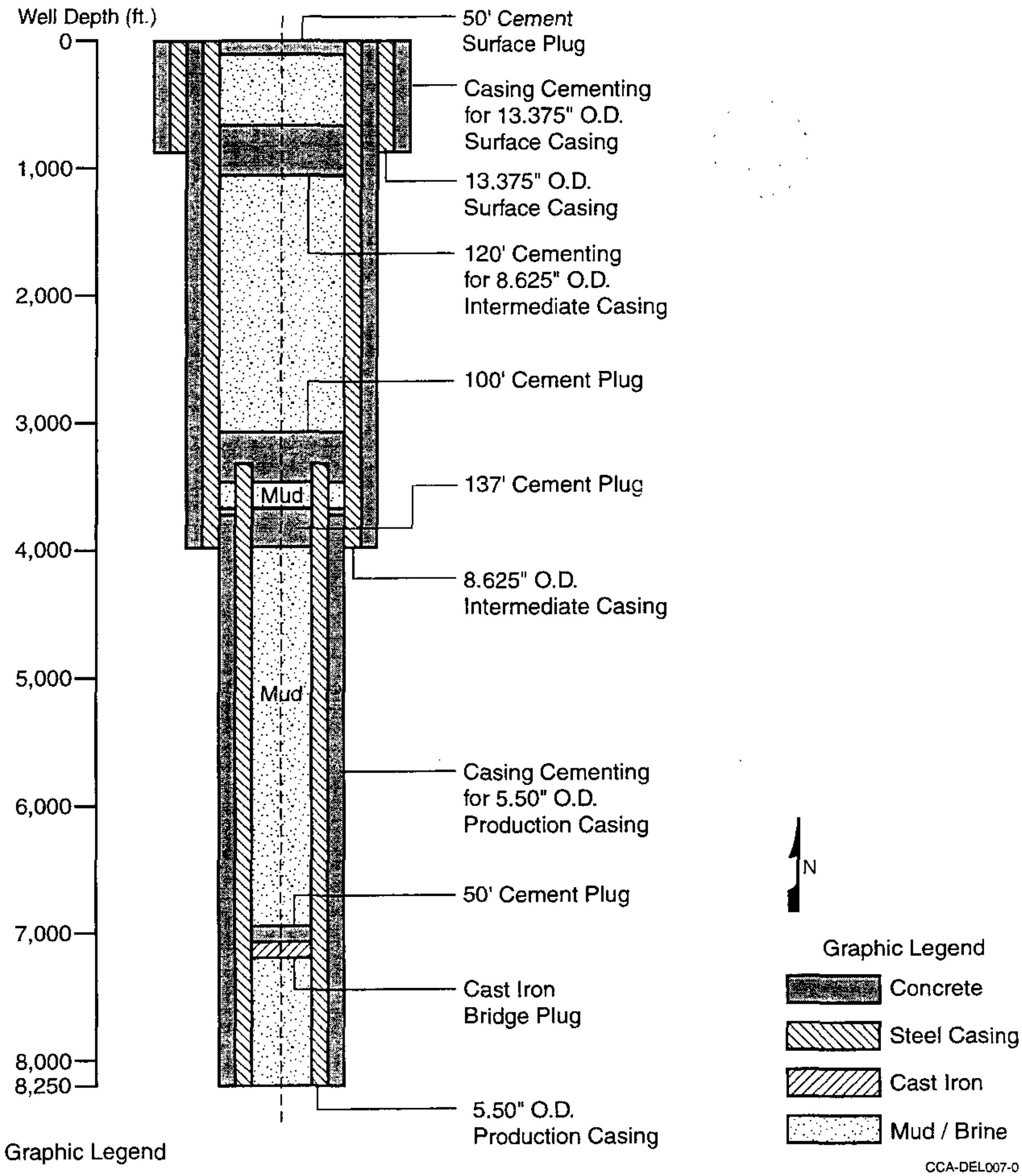

Figure DEL-14. Standard Oil and Gas Well Plugging Practices in the Potash Resource Area of the Deleware Basin

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BLM further agrees to the following as a special condition of approval for oil and gas activity within 330 feet (100 meters) of or closer to the WIPP boundary:

- Ensure that the operator provides the BLM with drill site vertical deviation surveys for each 500-foot (152-meter) drilling interval,

- Provide (BLM) technical expertise for calculating wellbore deviation and forward the results to DOE for review,

- Require the operator, in accordance with NMOCD Rule 111 (see Section DEL.6.2.1) to provide BLM with a directional survey to establish bottom hole location for wellbores with deviation angles of more than five degrees from vertical in any 500-foot (152-meter) interval,

- Require the operator to provide the BLM with a directional survey to establish the bottom hole location when it is indicated that the wellbore could deviate to within 100 feet (30 meters) of the WIPP withdrawal boundary, and

- Provide the DOE with directional survey results when it is indicated that the bottom hole location will deviate more than five degrees from vertical in any 500-foot (152-meter) interval, as well as survey results on wellbores that could deviate to within 100 feet (30 meters) of the withdrawal boundary.

The BLM also agrees to provide the DOE with well completion, alternate use, and plugging and abandonment reports related to drilling, production, injection, and mining activity on federal lands within one mile of the WIPP boundary.

DEL.6.1.4 Protection of Potash Resources

On October 28, 1986, the Secretary of the Interior issued an order entitled *Oil, Gas and Potash Leasing and Development Within the Designated Potash Area of Eddy and Lea Counties, New Mexico* (51 FR 39425). The order addressed the revision of earlier rules related to concurrent prospecting for, development, and production of oil and gas and potash resources within the Secretary's designated potash area (the legal description of which is contained in the order and shown in Figure DEL-8).

What BLM refers to as the Secretary's potash area is defined in 51 FR 39427 and encompasses approximately 497,000 acres (201,000 hectares). The NMOCD Order R-111-P potash area, which is the same as the KPLA, encompasses approximately 425 square miles (272,000 acres; 110,077 hectares) and lies within the Secretary's potash area (Figure DEL-8). The WIPP site is situated on the southeastern edge of the KPLA.

The 1986 Secretarial order reaffirmed the DOI policy of requiring that the following lease stipulations adequately protect the rights of oil and gas and potash leaseholders and operators.

- Oil and gas drilling will be permitted only if the lessee can assure the BLM that the drilling will not interfere with the mining and recovery of potash deposits.

- No oil and gas wells can be drilled at a location which would result in undue waste of potash deposits, pose a hazard to, or unduly interfere with potash mining.

- If the BLM determines that unitization (combining leased tracts on a fieldwide or reservoir-wide scale to facilitate recovery) is necessary for orderly oil and gas development and protection of potash resources, no oil and gas wells can be drilled unless they comply with the unit plan.

- The drilling or abandonment of any oil and gas well must comply with the BLM regulations in 43 CFR Part 3160 (see Sections DEL.6.1.2.1 and DEL.6.1.2.2 above) including any BLM requirements prescribed to prevent the infiltration of oil, gas, or water into potash deposits, mines, or workings.

As a reciprocal requirement, all potash permits and leases are subject to the stipulation that no mining or exploration operations be conducted that, in BLM's opinion, would constitute a hazard to oil or gas production or unreasonably interfere with orderly development and production under any oil and gas lease issued for the same (potash) lands.

The order imposes requirements on potash lessees to delineate on maps

(1) areas of current mining activity,

(2) areas where operations have been completed,

(3) areas containing minable reserves, and

(4) and areas believed to be barren of commercial ore (Figure DEL-8).

The order establishes a policy of denying oil and gas well applications for a permit to drill within these areas except for barren enclaves. In certain circumstances (for example, where the oil and gas formation cannot be reached within a barren area), the BLM may establish an oil and gas drilling island. No such island can be established within one mile of any area where potash mining will be conducted within three years.

The order requires the BLM to cooperate with the NMOCD in implementing the state regulations. Specifically, federal potash leaseholders may protest to the NMOCD the drilling of oil and gas wildcat wells on federal lands located within the State's oil-potash area as defined by Order No. R-111-P (see Section DEL.6.2.4). However, BLM has the prerogative to make the final decision. Although NMOCD oil and gas regulations, including Order No. R-111-P, do not legally apply to federal lands, the requirements for concurrent oil and gas and potash development are given due deference by the BLM.

DEL.6.1.5 Bonds, Penalties, and Enforcement

Prior to commencing any surface-disturbing activities related to drilling operations, the lessee or operator must post a surety or cash bond in an amount not less than $10,000 per lease to assure compliance with all the BLM lease terms

> . . .including complete and timely plugging of well(s), reclamation of the lease area(s), and the restoration of any lands or surface waters adversely affected . . . (43 CFR § 3104.1 and 3104.2).

Statewide bonds and nationwide bonds are established at minimums of $25,000 and $150,000, respectively, to cover all leases and operations by the same owner statewide or nationwide.

Noncompliance with the BLM regulations, terms of any lease or permit, or a BLM notice or order is subject to both civil and criminal penalties. Assessments run from $250 for a minor violation to $500 per day for such violations as failure to install blowout prevention equipment or drilling without approval (43 CFR § 3163.1). Civil penalties range from $500 to $5,000 per violation per day depending on the amount of time the violation goes uncorrected. Where public health and safety, the environment, or certain economic factors are threatened, the BLM can order an immediate shutdown of operations. Criminal penalties can be as severe as a $50,000 fine and/or imprisonment for up to two years.

According to the CRA office, the BLM rarely needs to impose civil or criminal penalties (Personal Communication 1995). Most noncompliance incidents involve surface uses rather than well drilling or plugging. There are very few violations of application for a permit to drill conditions due to BLM on-the-ground inspections and the self-interest of operators who find enforcement delays costly. Drilling permit violations involve probably not more than one in 100 wells (Personal Communication 1995).

Potentially, well plugging has more noncompliance problems than drilling because the owner/operator has no profit potential in plugging. To avoid noncompliance, well plugging has the highest inspection rate by BLM and NMOCD.

There were 788 incidents of noncompliance (INCs) involving improper drilling or production activities during fiscal years 1991 through 1996. INCs involve noncompliance with BLM regulations, orders, or instructions. Violation codes are assigned to each type of INC. The number of INCs associated with production and drilling for five selected violation codes are displayed in Table DEL-1. INCs for FYs earlier than FY 1991 have not been compiled from individual well records. As can be seen, almost all of the INCs are for surface violations associated with oil or gas production and not for well drilling or plugging.

The number of INCs has increased dramatically since FY 1993 because the BLM CRA office has greatly increased the number of inspections as a result of environmental concerns. There is increasing emphasis on such matters as surface reclamation, fencing of mud pits, removal of surface hydrocarbons to protect waterfowl, and protection of groundwater from surface seepage. The total assessments levied during FY 1991 through FY 1996 (to date) period were in the range of $20,000 to $25,000 (Personal Communication 1996a). There were no civil or criminal penalties assessed and there were no bond forfeitures.

Table DEL-1 does not reflect any INCs for improper plugging because BLM inspections require that any plugging violation be corrected immediately. Certain wells are assigned inspection priority with regard to drilling, casing, cementing, and plugging. BLM has had to compel the proper plugging of only one well in the past six years (Personal Communication 1996a).

DEL.6.2 State of New Mexico

The NMOCD, as part of the New Mexico Energy, Minerals and Natural Resources Department, is responsible for issuing permits pertaining to drilling, development, and production of oil and natural gas resources under the authority of the Oil and Gas Act (§§ 70-2-1 through 70-2-36 NMSA 1978) and the New Mexico Water Quality Act (§ 74-6-4E NMSA 1978). The overall purpose of the NMOCD regulatory program is to protect oil, gas, potash, geothermal resources, and useable water. Special requirements pertaining to the protection of potash resources potentially impacted by oil and gas drilling activities are contained in Order R-111-P discussed in Section DEL.6.2.4.

Although the Oil and Gas Act creates the NMOCC, it delegates to the NMOCD the jurisdiction and authority over all matters relating to the conservation of oil and gas and the prevention of waste of potash as a result of oil and gas operations in this state (§ 70-2-6 NMSA 1978). The NMOCD has a day-to-day, hands-on administrative authority while the NMOCC has a quasi-judicial function in that it can hold hearings, subpoena witnesses, and implement rulemaking and enforcement functions. The NMOCD is authorized to collect data, conduct investigations, inspect properties, promulgate rules and regulations, and issue orders. It is also authorized to

- require dry or abandoned wells to be plugged in a way that confines crude petroleum oil, natural gas, or water in the strata in which it is found and prevent it from escaping to other strata;
- require a cash or surety bond in a sum not to exceed $50,000 to assure compliance with plugging and other oil and gas regulations;
- prevent drowning by water of any stratum capable of producing oil or gas;
- prevent fires, blowups, and caving; and
- spend the oil and gas reclamation fund and perform all acts necessary to plug dry and abandoned oil and gas wells.

Table DEL-1. BLM Oil and Gas Well Drilling, Production, and Abandonment Incidents of Noncompliance, FYs 1991 to 1996 According to Violation Code for the Carlsbad Resource Area

Fiscal Year	Activity Type	Violation Code 2[1]	Violation Code 3	Violation Code 6	Violation Code 50	Violation Code 53	Total
FY 91	Production	60	35	7	7	0	109
	Drilling	0	0	0	1	0	1
FY 92	Production	3	4	0	1	1	9
	Drilling	0	0		0	0	0
FY 93	Production	1	9	0	0	0	10
	Drilling	0	0			0	0
FY 94	Production	270	181	8	1	11	471
	Drilling	0	0	0	0	0	0
FY 95	Production	23	158	1	3	0	185
	Drilling	0	1	0	0	0	1
FY 96	Production	4	47	2	1	1	55
	Drilling (to 1/96)	0	1	0	0	0	1
Totals	Production	361	434	18	13	13	839
	Drilling	0	2	0	1	0	3

[1]Violation codes associated with oil or gas production, with examples, are as follows:

Code 2. Well equipment not satisfactory. Could include leaking wellhead or stuffing box (a device that prevents leakage of oil around a piston, rod, or other moving part) leaks.
Code 3. Environmental protection not satisfactory. Could include trash on location, previous oil spills not cleaned up, or pits containing fluids like oil or water.
Code 6. Surface use not in accordance with approved plan. Unauthorized pits or surface disturbance.
Code 50. Failure to comply with a BLM notice, written order, or instruction. The violation could result from the operator's failure to comply with any of the BLM regulations or orders related to INCs. Failure to correct INCs results in a money assessment or civil penalty.
Code 53. Failure to obtain approval of specific operations such as changing downhole production zones or commingling of production.

Violation codes associated with drilling or plugging, with examples, are as follows:

Code 2. Drill site not properly identified according to BLM requirements.
Code 3. Operations not conducted in a workmanlike manner or working outside of required safety guidelines.
Code 6. Downhole drilling deviation is not within the approved tolerance.
Code 50. Same as Code 50 as applied to drilling INCs.

The first comprehensive oil and gas regulations for New Mexico were issued by the NMOCC in 1935. The current rules and regulations, dated March 1, 1993 (plus some recent revisions), follow the same numbering system as those made effective on January 1, 1950. However, the

NMOCD is in the process of reformatting its rules in order to comply with the New Mexico Administrative Code (NMAC). Under this reformatting, the NMOCD regulations on petroleum, oil and gas storage and handling will be contained in NMAC Title 19 (Natural Resources and Wildlife), Chapter 15. Section letters in the 1993 rules will also be used. Thus, the former rule 101 on plugging bonds contained in Section C on drilling will become 19 NMAC 15.C.101. The rule numbers will be the same, although they will be preceded by the remainder of the NMAC citation.

All regulations promulgated by the NMOCD must be adopted by the NMOCC. The NMOCD has divided the state into four districts, each with a district supervisor, an oil and gas inspector, or a deputy oil and gas inspector. Eddy County, where the WIPP site is located, is in District 2 which also includes Otero, Dona Ana, Luna, Hildago, Grant, Sierra, Lincoln, and De Baca Counties and a portion of Chaves County. The District Office is in Artesia. District 1, immediately east of District 2, is headquartered in Hobbs and includes Lea, Roosevelt, and Curry Counties and a portion of Chaves County. Because of the geologic, hydrologic, climatic, economic, and mineralization differentiations among all or portions of the four NMOCD districts, district supervisors have considerable flexibility; the rules are often applied on a case-by-case basis. However, rule interpretations that involve fundamental property rights are the responsibility of the NMOCC.

The NMOCD regulations apply to oil and gas operations on private and state-owned lands. With a few exceptions (as agreed to by the BLM), they do not apply to BLM lands or other lands where oil and gas resources are reserved to the United States. In NMOCD Districts 1 and 2, a large percentage of the oil and gas resources are subject to federal leasing and are under BLM jurisdiction.

DEL.6.2.1 Well Drilling Requirements

The NMOCD regulations applicable to the drilling or acquisition of oil, gas, or associated service wells are contained in Rules 101 through 118 (now 19 NMAC 15.C.101 to 118). The following discussion summarizes the key provisions of selected rules that may potentially bear on the effects of future oil and gas drilling at the WIPP site. Numerous other drilling requirements are not directly relevant to human intrusion scenarios.

- **Rule 101 - Plugging Bond.** Anyone who has drilled or acquired, or is proposing to drill or acquire, an oil, gas, or service well on private or state-owned lands must supply a surety or cash bond to assure that the well is plugged and abandoned in compliance with the NMOCD rules. Plugging bonds are of two types: (1) a blanket bond in the amount of $50,000 covering all wells drilled in the state by the same owner/operator; and (2) a one-well plugging bond in an amount determined by well depth and location. For example, one-well plugging bonds in Eddy and Lea Counties are established by well depth as follows: less than 5,000 feet, $5,000; 5,000 to 10,000 feet, $7,500; and more than 10,000 feet, $10,000. When approved by the NMOCD District Office, a well can be drilled 500 feet deeper than the maximum depth covered by the bond. For a deviated well, the bond is determined by the measured depth, not the vertical depth. The bond is not released until the plugging and abandonment of the well has been approved by the NMOCD. If the operator fails to properly plug and abandon the well(s) covered by the bond, the NMOCD may require that the bond be forfeited. Also, the NMOCD may take legal action to recover any additional costs.

- **Rule 102 - Notice of Intent to Drill.** Before commencing operations, the operator must notify the NMOCD of its intent to drill an oil, gas, or injection well on Form C-101, the application for a permit to drill, reenter, deepen, plugback, or add a zone (Attachment 5). Information supplied on Form C-101 includes well surface location, bottom hole location, and the proposed casing and cementing program.

- **Rule 104 -Well Spacing Acreage Requirements.** A well location and acreage dedication plat must be filed by the operator on Form C-102 (Attachment 5). Wildcat gas wells drilled in Eddy and Lea Counties must be located on 160-acre (65-hectare) tracts at least 660 feet (183 meters) from the tract's outer boundary and at least 330 feet (101 meters) from any quarter-quarter section (40-acre; 16-hectare) inner boundary. However, if a wildcat well is proposed to be drilled in the Wolfcamp or older formations, the drilling tract must consist of two contiguous quarter sections (360 acres; 146 hectares). (The rule defines a side boundary and an end boundary.) Wildcat oil wells must be located on tracts of approximately 40 acres (quarter-quarter sections), at least 330 feet (101 meters) from the tract boundary. All well tracts should be essentially square in shape and capable of being identified as legal subdivisions established by U.S. Public Land Surveys. Development oil wells in all New Mexico counties must be located on 40-acre (16-hectare) tracts at least 330 feet (101 meters) from the tract boundary and at least the same distance from the closest well capable of producing from the same pool. (Note: More than one well can be drilled on 40-acre [16-hectare] spacing if the wells are producing from different pools.) Development gas wells in Eddy and Lea Counties must be located on 160-acre (65-hectare) drilling tracts (with the same boundary distances as for wildcat wells) and at least 1,320 feet (402 meters) from the nearest gas well capable of producing from the same pool. Under the rather complex requirements of Section F of Rule 104, the NMOCD may approve oil or gas wells in unorthodox locations based on topographical or geological conditions. The NMOCD well spacing requirements are also applied by the BLM.

- **Rule 105 - Pit for Drilling Fluid and Drill Cuttings.** Before drilling is commenced, operators must provide a pit adequate for the disposal of drilling fluids and drill cuttings in a manner protective of surface or subsurface waters. Removal of the pit contents for offsite disposal is not permitted unless approved by the NMOCD. (Note: There is no current requirement for sampling or testing mud pit contents for hazardous or radioactive characteristics.)

- **Rule 106 - Sealing Off Strata.** During the drilling of an exploration, production, injection, or service well, all oil, gas, and water strata above the producing and/or injection horizon must be sealed or separated to prevent their contents from migrating into other strata. Groundwater valuable for domestic, commercial, or livestock purposes must be confined to their respective strata and protected by methods approved by the NMOCD. Shut-off of water from oil- and gas-bearing strata is generally accomplished by cementing the well casing into the wellbore.

- **Rule 107 - Casing and Tubing.** All wells drilled for oil or gas must be equipped with surface and intermediate casing strings and associated cement as are necessary to seal off and isolate all water-, oil-, and gas-bearing strata encountered in the well. Production wells must be equipped with a string of properly cemented production casing at sufficient depth to protect all oil- and gas-bearing strata encountered in the well, including those from which the well is producing. Sufficient cement must be used around the surface casing to fill the annular space (or annulus, the space between the outside of the casing and the side of the wellbore). With certain exceptions, all cementing must be accomplished with hard setting cements which have been mixed with the appropriate additives. All casing strings must be pressure-tested after cementing and proved satisfactory before any other operations can proceed. The casing must remain stationary and under pressure for a least 8 hours following cementing. In Eddy and Lea Counties, casing strings my be allowed to stand until the compressive strength has reached 500 pounds per square inch before testing commences. All producing oil and gas wells with casing larger than 2.9-inch (7.3-centimeter) diameter casing must be tubed (running a small-diameter pipe through the casing to serve as a conduit for the passage of oil or gas).

- **Rule 109 - Blowout Prevention.** A blowout or gusher can occur when the underground formation pressure exceeds the pressure applied to it by the column of drilling fluid. This results in an uncontrolled flow of gas, oil, or other well fluids into the atmosphere or another underground formation. Under this rule, operators are required to install blowout preventers on all drilling rigs operating in areas of known high pressures (at or above the projected depth of the well) and in all areas where underground pressures are unknown. For any drilling operation requiring blowout prevention equipment, the operator must submit a blowout prevention program on Form C-101 (Attachment 5).

- **Rule 111 - Deviation Tests and Directional Drilling.** This rule is particularly relevant to inadvertent intrusion into the WIPP site. It was extensively revised on June 13, 1995. It requires that any well drilled or deepened must be tested at reasonably frequent intervals to determine the deviation of the drilling from vertical. Such tests must be made at least once every 500 feet (152 meters) or at the first bit change succeeding 500 feet (152 meters). All deviation tests must be tabulated, notarized, and submitted to the NMOCD on Form C-104 (Attachment 5). If the deviation averages more than five degrees in any 500-foot (152-meter) interval, the operator must calculate the maximum possible horizontal deviation of the wellbore. The

NMOCD can then require a directional survey to establish the location of the producing interval.

The appropriate NMOCD District Office may approve the drilling of a deviated wellbore, the deviation of an existing wellbore to straighten a crooked hole, side track junk in the hole, or side track an existing wellbore when the operator follows specified procedures. The bottomhole location will be considered acceptable if the actual subsurface location is no more than 50 feet (15 meters) from the approved subsurface location. The director of the NMOCD has authority to approve a directional wellbore project when a number of conditions are met. The major requirement is that the wellbore be totally confined to a producing area.

- **Rule 116 - Notification of Fire, Breaks, Leaks, Spills, and Blowouts.** The NMOCD must be notified by the owner/operator of any fire, break, leak, spill, or blowout occurring at any injection or disposal facility or at any oil or gas drilling, producing, transporting, or processing facility. Notification must be immediate, as soon as possible after discovery either in person or by telephone to the NMOCD District Office. (See the notification of fire, breaks, spills, leaks, and blowouts form in Attachment 5.) A written report of the incident must be submitted to the NMOCD within 10 days following discovery.

DEL.6.2.2 <u>Well Plugging and Abandonment Requirements</u>

Abandonment and plugging of wells are covered in Section D of the NMOCD regulations, Rules 201 through 204 (now 10 NMAC 15.D.201 to 204). These rules are included in their entirety in Attachment 6. Under Rule 201, the operator is responsible for plugging not only oil, gas, and injection wells but also seismic, core, or other exploration or service well. (Note: A service well is a nonproductive well used for injecting liquids or gas to enhance recovery, disposing of salt water, or producing a fresh water supply.) The well must be plugged and abandoned, or temporarily abandoned, within (a) 150 days following the suspension of drilling operations, (b) a determination that the well can no longer be put to beneficial use, or (c) a period of one year of continuous inactivity.

DEL.6.2.2.1 <u>Plugging and Permanent Abandonment - Rule 202</u>

Under Rule 202, a notice of intention to plug must be filed with the NMOCD on Form C-103, Sundry Notices and Reports on Wells (Attachment 5), by the operator before plugging operations commence. The notice must identify the well and the proposed plugging procedures, and provide a wellbore plugging diagram (see examples in Attachment 5). Under Rule 1103 on sundry notices, the plugging notice must also contain a detailed statement of the proposed work and plans for pulling casing, mudding, cementing (including the number of sacks of cement and depths of plugs), and the time and date of the proposed plugging operations. If not filed previously, a complete log of the well on Form C-105 (Attachment 5) must accompany the notice to plug. In the case of a newly-drilled dry hole, the operator is allowed to plug after obtaining verbal approval from the NMOCD District Supervisor. However, written notice must be filed within 10 days of the verbal approval.

Before any well is abandoned, it must be plugged in a manner which will permanently confine all oil, gas and water in the separate strata in which they are originally found (Rule 202.B[1]). This can be accomplished by using mud-laden fluid, cement, and a single plug or a combination of plugs. The exact method employed must be approved by the NMOCD as based on the notice of intention to plug. Minimum plugging requirements and standard plugging practice in the potash resource area are shown in Figures DEL-13 and DEL-14.

Within a year following completion of plugging, the operator must accomplish the following:

(1) fill all pits,

(2) level the location,

(3) remove deadmen (buried anchors to steady the derrick) and all other junk, and

(4) take whatever measures are necessary to restore the site to a safe and clean condition.

When plugging and cleanup have been completed, the operator must contact the NMOCD and arrange for an inspection. The NMOCD will not approve the record of plugging until all necessary reports (Forms C-103 and C-105; Attachment 5) have been filed and the location has been inspected and approved.

Well marking requirements are specified in Rule 202.B(2). All plugged and abandoned wells must be marked with a 10-foot (3-meter) long steel marker at least 4 inches (10 centimeters) in diameter, set in cement, and extending at least 4 feet (1 meter) above mean ground level. The name of the operator, lease name, well number, and legal location (section, range, and township) must be welded, stamped or otherwise permanently engraved on the marker.

An exception is made for wells that can safely be used as a fresh water source. In such a case, the well need not be plugged above the sealing plug that is set below the fresh water formation. When this plugging has been completed, the operator seeking a bond release must file with the NMOCD a written agreement under which the landowner agrees to assume responsibility for the well.

DEL.6.2.2.2 *Temporary Abandonment - Rule 203*

A well can be temporarily abandoned for up to five years, during which period it must either be permanently plugged and abandoned or returned to beneficial use. After five years, an operator can apply for a new temporary abandonment approval. (Compare with BLM policy on temporarily abandoned and shut-in wells as discussed in Section DEL.6.1.2.3.) In order to receive NMOCD approval, the operator must submit a notice of intent to temporarily abandon on Form C-103 (Attachment 5). A well cannot be temporarily abandoned unless the casing is mechanically sound and in good enough condition to prevent

(1) damage to the producing zone,

(2) migration of hydrocarbons or water,

(3) contamination of fresh water or other resources, and

(4) leakage of any substance to the surface.

If the well cannot meet the required mechanical integrity test, it must be plugged and abandoned or the casing problem must be corrected and confirmed by retesting. Methods of testing are detailed in Rule 203.C (Attachment 6).

DEL.6.2.3 Incidence of Unplugged Oil and Gas Wells

Criteria in 40 CFR Part 194 include the following:

> Performance assessments shall document that in analyzing the consequences of drilling events, the Department assumed that:
>
> (1) Future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time a compliance application is prepared. Such future drilling practices shall include . . . the fraction of such boreholes that are sealed by humans . . . (40 CFR § 194.33[c]).

Following these criteria, it was concluded that the fraction of boreholes that have been sealed by humans should be determined by evaluating all wells in the New Mexico portion of the Delaware Basin that were drilled and plugged since 1988 (the date the current plugging regulations became effective). Texas wells were not considered because a well drilled at the WIPP site would not subject to Texas regulations. The total number of hydrocarbon boreholes in the New Mexico portion of the Delaware Basin with completion dates from 1988 to 1995, as taken from the Petroleum Information Corporation database, is 875. The NMOCD records for each of these 875 wells were examined to determine the current status of each well.

Wells plugged or scheduled to be plugged on federal land were examined in detail. There were 47 wells found in this category. NMOCD records contain final plugging records for 43 of these wells and intent-to-plug notices for the remaining four wells.

A field verification for these four wells was conducted on March 14, 1996. Two of these wells were plugged, one was being plugged on that date, and one well was unplugged. The intent-to-plug notice for the unplugged well was approved on December 4, 1995, and, according to the Carlsbad, New Mexico, BLM office, the company responsible for this well was currently processing the appropriate paperwork to plug the well.

Based on this information, it is proposed that the performance assessment incorporate the assumption that no oil and gas wells would be left unplugged.

DEL.6.2.4 Oil and Gas Development in Potash Areas - NMOCC Order R-111-P

The New Mexico Oil and Gas Act declares as waste

> [D]rilling or producing operations for oil or gas within any area containing commercial deposits of potash where such operations would have the effect unduly to reduce the total quantity of such commercial deposits of potash which may reasonably be recovered -- or where such operations would interfere unduly with the orderly development of such potash deposits [§ 70-2-3(F) NMSA 1978].

Both the BLM (see Section DEL.6.1.4) and the NMOCD have been dealing with conflicts between the potash industry and oil and gas drilling and production operations for many years. The first NMOCC order addressing oil and gas drilling and potash mining activities in areas where leaseholds are overlapping was Order No. R-111-A of July 14, 1955.

On April 21, 1988, the NMOCC issued a major revision to Order No. R-111-A: Order No. R-111-P (now 19 NMAC 15.R.111). The objective of this order, which is still in effect, is to prevent waste, protect correlative rights (rights of an owner of an oil and gas property to produce his or her equitable share without waste), and ensure maximum conservation of New Mexico oil, gas, and potash resources. The key provisions of Order No. R-111-P are as follows:

- No oil and gas wells can be drilled so as to result in an undue waste of potash deposits, pose a hazard to, or unduly interfere with potash mining.

- No potash mining can be conducted which will pose a hazard to oil or gas production or unreasonably interfere with orderly oil or gas development.

- The intermediate string and production string of well casing must meet certain cementing requirements.

- A salt protection string of casing must be installed at least 100 feet (30 meters) below and not more than 600 feet (183 meters) below the base of the salt section. Cementing requirements for both shallow wells (above 5,000 feet [1,524 meters]) and deep wells (below 5,000 feet [1,524 meters]) above or below the Delaware Mountain Group are specified.

- All oil and gas wells drilled within the potash area (same as the KPLA) must provide a solid cement plug through the salt section and any water-bearing horizon and prevent liquids or gases from entering the hole above or below the salt section.

- The fluid used to mix the (plugging) cement must be saturated with salts common to the salt section penetrated but not more than three percent of calcium chloride by weight of cement wherever possible.

- Regardless of whether the potash lease is on federal or state lands, each potash lessee must file with the BLM and the State Land Office a designation of potash deposits considered by the lessee to be its life-of-the-mine reserves (LMR). LMRs are deposits believed to be economically minable using present mining methods and technology. Information on LMRs filed with the BLM and the State Land Office is considered proprietary and cannot be released to the general public.

- Before commencing oil or gas drilling operations within the potash area, the well operator must forward a map showing the location of the proposed well to every potash operator holding potash leases within a radius of one mile of the proposed well.

Permit applications for oil or gas well drilling on federal lands in the KPLA are processed by BLM while those on state or private lands are processed by the NMOCD. If State lands are involved, the State Land Office enters the picture because the NMOCD must determine from either the BLM or the State Land Office if the proposed well location is within a potash LMR area. Any application to drill in a potash LMR area must be approved by the lessor and lessees of both the potash and the oil and gas interests.

DEL.6.2.5 <u>Bonds, Penalties, and Enforcement</u>

Criminal and civil penalties for violations of the New Mexico Oil and Gas Act and related NMOCD rules and regulations are governed by §§ 70-2-28 through 70-2-32 NMSA 1978. Suits brought by the NMOCD through the State Attorney General may result in obtaining injunctions or temporary restraining orders. Knowing and willful violations can result in a $1,000 per day fine for each violation. Criminal violations (for example, fraudulent representations) are subject to a fine of up to $5,000, imprisonment up to three years, or both.

It is the bonding requirement that provides the teeth for the plugging requirements (see the discussion of NMOCD Rule 101 on plugging bonds in Section DEL.6.2.1). The NMOCD can order any well to be plugged and abandoned. Because failure to plug or improper plugging can result in pollution of both surface and underground water, well plugging and its enforcement would normally also be under the jurisdiction of the New Mexico Water Quality Control Commission. However, the Commission has delegated water quality matters related to oil and gas development to the NMOCD to prevent duplication of effort. The delegation of authority is authorized by the New Mexico Water Quality Act (§ 74-6-4E NMSA 1978).

A summary of oil and gas well data is provided in Table DEL-2 for the period 1971 through 1995. The table shows wells completed, wells plugged and abandoned, number of active wells, the number of regulatory cases docketed, and the number of cases pertaining to compulsory plugging.

DEL.6.3 Regulation of Injection Wells

This section discusses the regulation of injection wells (which are often included in the definition of service wells) by the BLM and the NMOCD. Injection wells located near the WIPP are shown in Figure DEL-6.

DEL.6.3.1 Definitions

BLM onshore oil and gas operations regulations and related orders do not define either injection or service wells. The NMOCD rules define an injection or input well as any well used for the injection of air, gas, water, or other fluids into any underground stratum (Rule 0.1). The NMOCD rules do not define the term service well. *The Dictionary for the Petroleum Industry* (University of Texas 1991) defines injection well as

> a well through which fluids are injected into an underground stratum to increase reservoir pressure and to displace oil.

The same source defines service well as

> a well used for injecting liquid or gas into a reservoir for enhanced recovery as well as saltwater disposal wells and water wells.

For the purpose of this analysis, injection well is defined broadly to mean wells used for injecting liquids or gases into a reservoir for enhanced (or secondary) recovery, wells used to dispose of saltwater, and wells used for underground storage of hydrocarbons. It does not include wells that are initially drilled for oil or gas exploration or production but are later used as water supply wells.

Most injection wells used in the oil and gas industry are not drilled only for injection purposes. In most cases, exploratory wells or producing wells that have reached an advanced state of depletion are converted to injection wells, either for water disposal or enhanced production purposes. Thus, the same drilling and plugging requirements that apply to oil and gas wells also apply to injection wells (see Sections DEL.6.1 and DEL.6.2).

DEL.6.3.2 Bureau of Land Management

The BLM does not have specific requirements that apply only to injection wells. Injection wells are not addressed in either the 43 CFR Part 3160 regulations on onshore oil and gas operations or the various onshore oil and gas orders. The requirements for drilling and plugging of oil and gas wells described in Section DEL.6.1.2 apply equally to injection wells.

Instead of having its own regulations governing injection wells, the BLM defers to the NMOCD (or Texas Oil and Gas Division) requirements. In other words, the BLM requires oil and gas operators to abide by the applicable state requirements and procedures. Of course, BLM would still issue the drilling permit on federal lands.

Table DEL-2. New Mexico and SE New Mexico Oil and Gas Well Data, 1971 to 1996 [1]

Year	Wells Completed [3]	Wells Abandoned [4]	Active Wells [5]	Docketed Cases [6]	Compulsory Plugging [7]
1996[2]	1200	400	29,690	300	25
1995	1139	342	29,172	283	19
1994	897	335	28,663	322	2
1993	916	357	28,163	371	0
1992	797	348	27,671	314	1
1991	929	284	27,461	383	2
1990	832	264	27,117	592	0
1989	668	272	26,965	457	3
1988	803	274	26,928	432	0
1987	770	313	26,664	302	2
1986	868	307	26,486	346	7
1985	1272	349	26,103	430	11
1984	1197	212	25,190	525	6
1983	1212	344	24,641	326	6
1982	1573	180	24,124	342	18
1981	1419	118	23,137	399	7
1980	1221	159	22,365	410	16
1979	997	155	21,671	383	12
1978	999	126	21,062	346	29
1977	849	204	20,515	335	15
1976	784	309	20,171	264	15
1975	794	264	20,170	258	10
1974	901	241	20,127	262	18
1973	600[8]	207	19,952	276	18
1972	666[9]	295	19,845	302	3
1971	NA	NA	NA	169	4

Notes on following page.

[1] The first three columns of data are for southeastern New Mexico. The remaining columns show statewide data. Southeastern New Mexico includes NMOCD District 1 (Lea, Roosevelt, Curry, and a portion of eastern Chaves Counties) and District 2 (Eddy, most of Chaves, DeBaca, Lincoln, Otero, and Dona Ana Counties).
[2] Numbers for 1996 were estimated by E. Martin, NMOCD, Santa Fe, New Mexico, on March 12, 1996.
[3] Includes oil, gas, dry hole, and service wells for NMOCD Districts 1 and 2.
[4] Includes oil, gas, and service wells abandoned in NMOCD Districts 1 and 2.
[5] Includes oil, gas, and injection wells for NMOCD Districts 1 and 2.
[6] Docketed cases are those enforcement actions set for a hearing. They result in various types of hearing orders. The numbers are for cases statewide, not only for NMOCD Districts 1 and 2. Docketed cases are categorized into 16 different subjects. Compulsory plugging was selected as the subject most relevant to inadvertent drilling into the WIPP.
[7] These numbers are statewide and not only for NMOCD Districts 1 and 2. Compulsory plugging refers to wells not totally in compliance with plugging requirements. The term does not refer to wells left unplugged.
[8] No service wells are included in this number for 1972 and 1973.
[9] This number for 1972 is for wells drilled, not wells completed.

DEL.6.3.3 State of New Mexico

The NMOCD regulations applicable to injection wells are contained in Rules 705 through 708 (19 NMAC 15.I.705-708). The rules apply to injection used for secondary or other enhanced recovery, pressure maintenance, salt water disposal, and underground storage. The rules apply to the injection of both fluids and gases. A permit is required from the NMOCD for the injection of gas, air, water, or any other medium into any oil or gas reservoir in order to maintain pressure for secondary or other enhanced recovery (Rule 701-A). A permit is also required for injection of water for disposal or for underground storage. The permit will be granted only after notice and hearing unless otherwise provided by the NMOCD rules. Because applications for underground storage are rare in New Mexico, storage injection well requirements are not discussed in this section.

DEL.6.3.3.1 Injection Application

Application for an injection permit (authorization to inject) must be made on NMOCD Form C 108 (Attachment 5) and contain the following information:

- complete well data for each proposed injection well,

- map identifying all wells and leases within two miles of each proposed injection well with a one-half mile radius circle showing the well's area of review,

- tabulation of data (well type, location, depth, and plugging detail if plugged) for all wells within the one-half mile area of review that penetrate the proposed injection zone,

- detailed data on the proposed injection well operation (volume of injection fluids, injection pressure, and chemical analyses of injection fluid),

- geological data including lithologic detail, thickness and depth of injection zone, and location of all underground sources of drinking water (USDW),

- well logging and test data (if not previously submitted),

- chemical analysis of fresh water from two or more existing and producing water wells within one mile of any injection or disposal well, and

- statement to the effect that available geologic and engineering data do not indicate the existence of open faults or other hydrologic connections between the disposal zone and any USDW.

One of four purposes for which the injection project requires a permit from the NMOCD is specified on Form C-108: secondary recovery, pressure maintenance, disposal, or storage.

Injection well permit applicants must provide, by certified or registered mail, a copy of the application to the surface landowner where the well is to be located and to each oil or gas lease operator within one-half mile of the proposed well location. (In actual practice, the NMOCD determines if all wells within a one-half mile radius of the proposed injection well are cased and cemented across the injection zone). If the application is for administrative approval without a hearing, the applicant must publish notice in a newspaper of general circulation in the county in which the proposed injection well will be located. If a written objection is filed with the NMOCD within 15 days of the filing of the application, a hearing must be held (Rule 701-D).

DEL.6.3.3.2 *Salt Water Disposal Wells*

The injection of water into any formation for the purpose of water disposal is permitted by the NMOCD only after notice and hearing (Rule 701-A). However, under Rule 701-E, an exception may be made for water disposal wells only when the waters to be disposed of are mineralized to such a degree as to be unfit for domestic, stock, irrigation, or other general use and when the waters are disposed of into a formation older than the Triassic (in Lea County only), provided there are no objections. Water disposal is not permitted into zones containing waters with TDS concentrations of 10,000 milligrams per liter or less, except after notice and hearing. Nevertheless, the NMOCD can authorize water disposal in such zones (TDS of 10,000 milligrams per liter or less) if the water to be disposed of is of higher quality than the water in the disposal zone. These restrictions do not apply to exempted aquifers which the NMOCD may establish.

DEL.6.3.3.3 *Pressure Maintenance Projects*

In pressure maintenance projects, fluids are injected into the oil- or gas-producing horizon in order to increase or maintain reservoir pressure in an area which has not reached the stripper well degree of depletion. All injection well permit applications for pressure maintenance projects require both notice and a hearing unless the NMOCD grants an exception under certain circumstances (Rule 701-F). Although not prescribed by rule, the NMOCD practice is to limit all injection well pressures to 0.2 pounds per square inch (1,379 pascals) for each foot of well depth to the top of the injection zone.

DEL.6.3.3.4 *Water Flood Projects*

In water flooding, water is injected into a producing horizon in sufficient quantities and pressure to stimulate production from other wells in the area. It is limited under Rule 701-G to areas in which the wells have reached an advanced or stripper well state of depletion. All applications for water flood projects require a hearing. However, if there are no objections, a hearing is not required to permit additional injection wells that may be necessary to develop or maintain a thorough and efficient water flood injection for any authorized project (Rule 701-G [7]).

DEL.6.3.3.5 *Casing and Cementing of Injection Wells*

NMOCD Rule 702 requirements for casing and cementing of injection wells are, for all practical purposes, the same as for exploration and production wells. Wells must be cased with safe and adequate casing or tubing to prevent leakage and movement of either formation or injected fluid from the injection zone into any other zone or to the surface.

DEL.6.3.3.6 *Injection Well Operation and Maintenance*

NMOCD Rule 703-A provides as follows:

> Injection wells shall be equipped, operated, monitored, and maintained to facilitate periodic testing and to assure continued mechanical integrity which will result in no significant leak in the tubular goods and packing materials and no significant fluid movement through vertical channels adjacent to the wellbore.

Any injection project must be operated so as to prevent surface damage or pollution resulting from leaks, breaks, or spills. The failure of any injection well which may endanger a USDW must be reported immediately (that is, as soon as possible after discovery) to the appropriate NMOCD District Office under the procedures specified in Rule 116. Detailed injection well testing and monitoring requirements are outlined in NMOCD Rule 704.

DEL.6.3.3.7 *Commencement, Discontinuance, and Abandonment*

The operator of any injection well must immediately notify the NMOCD of the date when injection operations commenced (Rule 705-B). The operator must also notify the NMOCD within 30 days of the operations being discontinued and for what reasons. An injection well cannot be temporarily abandoned longer than six months unless the injection interval has been isolated by installing a cement plug or a bridge plug. Plugging requirements may be delayed if there is a continuing need for the well, it is mechanically sound, and its temporary abandonment will not endanger a USDW. When injection operations have ceased for a *continuous period of six months, the well will be considered abandoned; the permit will* terminate automatically.

DEL.6.3.3.8 Records and Reports

The operator of an injection well must keep accurate records and make monthly reports to the NMOCD regarding the volumes of gas or fluids injected, stored, or produced. Various forms (C-115, C-120-A, and C-131-B) are available for this purpose.

DEL.7 Inadvertent and Intermittent Intrusion by Drilling

Information pertinent to the assessment of the likelihood of inadvertent intrusion into the repository is presented in this section.

DEL.7.1 Regulatory Context

The EPA criteria for certification of WIPP's compliance with the 40 CFR Part 191 disposal regulations state that performance assessments examine deep and shallow drilling that may potentially affect the disposal system during the 10,000-year regulatory time frame (40 CFR § 194.33[a]). Deep drilling is defined by the criteria as drilling events that reach or exceed 2,150 feet (655 meters) below the surface while shallow drilling means drilling events that do not reach a depth of 2,150 feet (655 meters) (40 CFR § 194.2). The total rate of deep drilling must be calculated as the sum of the rates of deep drilling for each resource in the Delaware Basin over the past 100 years. The total rate of shallow drilling must be calculated as the sum of the rates of shallow drilling over the same time period for each resource in the Delaware Basin that is of similar type and quality as the resources in the WIPP controlled area.

DEL.7.2 Shallow Drilling Events

The majority of shallow holes are composed of water wells, potash coreholes, and sulfur coreholes. The identification, location, and depth of the shallow boreholes in the Delaware Basin have been taken from existing commercial databases and maps. The data gathered on shallow boreholes was taken directly from commercial databases and BLM records as described below.

DEL.7.2.1 Water Wells

Information on water wells in the Delaware Basin was obtained from a commercial database developed by Whitestar Corporation of Englewood, Colorado.

DEL.7.2.2 Potash Coreholes

Information on potash coreholes in the Delaware Basin was compiled from BLM records.

DEL.7.2.3 Sulfur Coreholes

Sulfur corehole information was obtained from a commercial database developed by Whitestar Corporation of Englewood, Colorado, and the Petroleum Information Corporation of Denver, Colorado.

DEL.7.3 Deep Drilling Events

Only the drilling of a deep well could result in inadvertent human intrusion into the WIPP repository. Information on the identification, location, and depth of the deep boreholes in the Delaware Basin has been derived from existing commercial databases and maps. The data gathered on the deep oil and gas boreholes are available from several commercial sources. To assure the accuracy of these commercial databases and maps, and obtain the best possible count of deep wells in the basin, these commercial sources were verified against one another.

The data sources selected for determining the number of oil and gas wells in the Delaware Basin were maps obtained from the Midland Map Company and a database obtained from the Petroleum Information Corporation. Both the Midland Map Company and Petroleum Information Corporation obtained well records from the NMOCD and the Railroad Commission of Texas Oil and Gas Division. These companies have a reputation for data reliability; the information they provide is regarded as a standard within the industry. However, these companies do not provide any warranty on the accuracy or the completeness of the data.

It is not considered economically feasible to validate these data. The process of validating the data would require field verification of wells in an area covering approximately 8,910 square miles (23,077 square kilometers) as well as a comparison of NMOCD and BLM records with the private records of the various oil and gas companies.

While it was not considered feasible to validate the original data, it was considered reasonable to determine a verifiable deep well count. By comparing the two selected commercial sources of data, a count of deep wells in the Delaware Basin has been prepared. In comparing the Petroleum Information Corporation database to the Midland Map Company maps, some wells were found to be identified either in the database or on the maps, but not in both sources. The well count presented here was derived using all wells in the Petroleum Information Corporation database plus the wells identified on the Midland Map Company maps that were not in the Petroleum Information Corporation database.

DEL.7.4 Rate of Drilling in the Basin

The number of boreholes listed in the Petroleum Information Corporation database and the number of boreholes shown on the Midland Map Company map but not listed in the Petroleum Information Corporation database are provided in Table DEL-3. In addition, the number of shallow and deep boreholes created in the Delaware Basin over the past 100 years is shown by type of borehole in Table DEL-4.

In the case of water wells, the available data do not include the depths of all of the water wells shown in the database. To arrive at an estimate of the total number of deep and shallow water wells, the ratio of known deep wells (that is, those 2,150 feet [656 meters] or greater) versus known shallow water wells was calculated and applied to the total number of water wells shown in the database.

The intrusion rate for boreholes drilled per square kilometer (0.39 square mile) over 10,000 years has been calculated using the borehole counts listed in Tables DEL-4, DEL-5, and DEL-6. The calculated rates suggested for use in the performance assessment are shown in Table DEL-7. As provided by 40 CFR § 194.33(b)(4)(iii), the calculated rate for shallow boreholes excludes sulphur holes because no economically extractable sulphur is located within the WIPP land withdrawal area (NMBMMR 1995). In addition, consistent with EPA guidance in the EPA 1996 *Response to Comments Document For 40 CFR Part 194,* page 12-8, last paragraph, both shallow and deep holes created as part of WIPP site characterization efforts have been excluded from the count. Based on the data provided in these tables, the calculated rates are 21.821 shallow holes per square kilometer (0.39 square mile) and 46.765 deep holes per square kilometer (0.39 square mile) over 10,000 years.

DEL.7.5 Pressurized Brine Encounters Within the Delaware Basin

Some of the human intrusion scenarios evaluated in the WIPP performance assessment include the assumption that a borehole results in the establishment of a flow path between the repository and a pressurized brine pocket that could be located beneath the repository in the Castile. To identify reasonable assumptions for use in the performance assessment, commercial drillers and operators with experience in the Delaware Basin were surveyed to determine the frequency of occurrence and typical depths of abnormally pressurized brine zones within the Delaware Basin (Personal Communication 1996d; Personal Communication 1996e; Personal Communication 1996f; Personal Communication 1996g).

For the purpose of this investigation, abnormally pressurized brine zones are defined as those that exhibit pressures exceeding the hydrostatic pressure of the column of drilling fluid in the hole. Consistent with this definition, any brine encounter having pressure exceeding hydrostatic pressure is considered abnormally pressurized. Flow to the surface driven by differential pressures just above hydrostatic pressure, however, would typically not be noticed by a driller, and is expected to be of little impact to performance assessment.

Table DEL-3. Boreholes Within the Delaware Basin

Borehole Type	Boreholes Listed in the PI Database	Boreholes Shown on the Midland Map But Not Listed in the PI Database	Total Number of Boreholes by Type
Hydrocarbon Boreholes			
Oil Well	5,728	37	5,765
Gas Well	1,569	2	1,571
Oil/Gas Well	14	0	14
Abandoned Wells	167	1	168
Dry Hole	3,453	56	3,509
Injection Well	72	2	74
Service Well	147	0	147
Total Hydrocarbon Boreholes	11,150	98	11,248
Other Resource, Exploratory, or Test Boreholes			
Sulphur Corehole	584	0	584
Potash Corehole	925	0	925
Stratigraphic and Core Test Hole [1]	1,271 [1]	0	1,271 [1]
Water Well	2,311	0	2,311
Brine Well (Solution Mining)	1	0	1
Total Other Boreholes	5,092	0	5,092

[1] Excluding boreholes drilled as part of WIPP site characterization programs.

When asked how often abnormally pressurized brine zones are encountered, each of the drillers surveyed stated that it was an uncommon occurrence in the Delaware Basin, and that they believe the actual frequency to be less than five percent. This estimate captures those occurrences where the differential pressure could be great enough to drive a noticeable quantity of drilling fluid to the surface. The drillers reported that these zones are most frequently encountered in the Castile Formation in the Delaware Basin.

The Castile Formation within the land withdrawal area is approximately 1,250 feet (381 meters) thick. It is primarily an anhydrite formation and has been found to have isolated areas that hold quantities of brine. Based on observed Castile porosity (amount of space in the

Table DEL-4. Number of Shallow and Deep Boreholes Within the Delaware Basin, by Resource or Type

Borehole Type	Shallow Borehole [1]	Deep Borehole [2]
Hydrocarbon Borehole	608	10,640
Sulphur Corehole	495	89
Potash Corehole	906	19
Stratigraphic and Core Test Hole [3]	1,215 [3]	56 [3]
Water Well	2,311	0
Brine Well (Solution Mining)	1	0
Total Boreholes, by Depth	5,536	10,804

[1] Equal to or less than 2,150 feet (655 meters).
[2] Greater than 2,150 feet (655 meters).
[3] Excluding boreholes drilled as part of WIPP site characterization programs.

Table DEL-5. Number of Shallow Boreholes Per Square Kilometer in the Delaware Basin, by Resource or Type [1]

Borehole Type	Shallow Boreholes [2]	Boreholes Per Square Kilometer
Hydrocarbon Borehole	608	2.632
Sulphur Corehole	495	2.143
Potash Corehole	906	3.922
Stratigraphic and Core Test Holes [3]	1,215 [3]	5.259 [3]
Water Wells	2,311	10.003
Brine Well (Solution Mining)	1	0.004
Total Shallow Boreholes	5,536	23.963

[1] The area of the Delaware Basin is 23,102.1 square kilometers (14,356 square miles). The number of holes per square kilometer is calculated as follows: (number of holes) × 10,000 years / area / 100 years.
[2] Equal to or less than 2,150 feet (655 meters).
[3] Excluding boreholes drilled as part of WIPP site characterization programs.

Table DEL-6. Number of Deep Boreholes Per Square Kilometer in the Delaware Basin, by Resource or Type [1]

Borehole Type	Deep Boreholes [2]	Boreholes Per Square Kilometer
Hydrocarbon Borehole	10,640	46.056
Sulphur Corehole	89	0.385
Potash Corehole	19	0.082
Stratigraphic and Core Test Holes [3]	56 [3]	0.242 [3]
Water Well	0	0
Brine Well (Solution Mining)	0	0
Total Deep Boreholes	10,804	46.765

[1] The area of the Delaware Basin is 23,102.1 square kilometers (14,356 square miles). The number of holes per square kilometer is calculated as follows: (number of holes) × 10,000 years / area / 100 years.
[2] Greater than 2,150 feet (655 meters).
[3] Excluding boreholes drilled as part of WIPP site characterization programs.

Table DEL-7. Number of Boreholes Per Square Kilometer to be Used in Performance Assessment Calculations

Type of Borehole	Number of Boreholes	Boreholes Per Square Kilometer
Shallow Borehole	5,041 [1]	21.821
Deep Borehole	10,804 [2]	46.765

[1] Excluding sulphur coreholes and boreholes drilled as part of WIPP site characterization programs.
[2] Excluding boreholes drilled as part of WIPP site characterization programs.

formation to store brine) and permeability (ability of the formation to conduct fluids), brine present in the unit may be released into an intersecting uncased wellbore. This brine may be normally or abnormally pressured.

Hydrostatic pressure at any depth in the wellbore is calculated using the following formula:

$$Pm = MW \times D \times 0.052 \qquad (1)$$

where
Pm = ressure (pounds per square inch),
MW = mud weight (pounds per gallon),
D = depth (feet), and
0.052 = a conversion factor representing mud density.

For example, at 3,000 feet (915 meters), the hydrostatic pressure is calculated at 1,560 pounds per square inch (1.08 × 10^7 pascals) based upon the use of a 10-pounds-per-gallon saturated brine as the drilling fluid. In this example, brine flow to the surface would be possible only if the brine source is pressurized greater than 1,560 pounds per square inch.

Typically, the driller would become aware of abnormally pressurized brine only if the pressure of the brine encounter is sufficient to cause a noticeable gain of fluid in the mud pit. When this occurs and the flow is not great enough to cause immediate concern, drilling will typically continue, but the driller will calculate the rate of brine flow. This is accomplished by shutting off the pumps and using a bucket of known capacity to catch the free-flowing brine and noting the time that it takes to fill the bucket. From this measurement, the driller can determine the rate of flow in barrels-per-minute. If the flow rate is not so great as to cause concern of over-filling the reserve pit, drilling would continue until the hole reaches the Bell Canyon Formation. The intermediate casing would then be run and cemented. Once in place, the casing string would isolate the overpressurized zone and prevent further flow to the surface.

A very heavy brine flow, however, such as one that could potentially fill the pit within one-to-two hours, would not be allowed to continue. Corrective action would be taken in the form of killing the flow of brine. This is accomplished in the field by shutting in the blowout preventor and calculating the downhole pressure. Using this pressure, the driller then determines the quantity of barite (the mud additive most often used) that must be added to the drilling fluid to sufficiently increase the hydrostatic pressure exerted by the column, so that the differential pressure results in downward flow from the drilling fluid column into the formation. When brine flow to the surface has stopped, drilling continues to the depth originally determined in the well plan. Once this depth is reached, intermediate casing is run and cemented in place.

The drillers reported that measures to kill pressure-driven flow to the surface are required only rarely. They are generally able to drill through the Castile Formation while brine is flowing and successfully set the intermediate string in the Bell Canyon Formation (the usual drilling horizon).

Using a typical drilling scenario based on a pressurized zone at a depth of 3,000 feet (915 meters) with a hydrostatic pressure of 1,560 pounds per square inch (1.08 × 10^7 pascals), flow rates necessary to fill the pit at one-and-two-feet-per-hour increments have been calculated. This calculation is provided below.

Assume:

A. Well Depth, ΔZ :	3,000 feet
B. Mud Pit Volume:	125 feet * 125 feet * 6 feet = 93,750 cubic feet = 701,298.701 gallons
C. Casing Weight:	32 pounds per foot
D. Casing Inner Diameter	8.625 inches
E. Open Hole Inner Diameter	11.5 inches = 0.958 feet
F. Unit Volume:	15,625 cubic feet per foot of vertical height
G. Unit Volumetric Flow Rate:	4.34 cubic feet per second
H. Drilling Fluid:	Case 1: 10.25 pounds per gallon brine Case 2: barite

I.	Density (ρ):	Case 1: 76.68 pounds per cubic foot [3]	Case 2: 263.3 pounds per cubic foot
J.	Friction Factor (f):	0.06 for coated casing/open hole	
K.	Internal Casing Pipe Area (A):	$\pi d^2/4 = \pi(0.958)^2/4 = 0.721$ square feet	
L.	Gravity (g):	32.17 feet per square second	
M.	Velocity (1 ft/ hr Brine Pit Disp.):	V = Q/A = 4.34*1/0.721 = 6.017 feet per second	
N.	Velocity (2 ft/ hr Brine Pit Disp.):	V = Q/A = 4.34*2/0.721 = 12.034 feet per second	

Equation:

$$\frac{\Delta P}{\rho} = \frac{\Delta V^2}{2g} + \Delta Z + E_{12} \qquad (2)$$

$$\Delta P = \rho \left[\frac{\Delta V^2}{2g} + \Delta Z + \frac{fLV^2}{2gd} \right] \qquad (3)$$

Derived from Gieck (1987)

For the case of 1 ft/hr brine pit displacement: ΔP = 1,654.099 pounds per square inch (1.14046×10^7 pascals) gauge

For the case of 2 ft/hr brine pit displacement: ΔP = 1,823.784 pounds per square inch (1.25745×10^7 pascals) gauge

The calculation shows that a one-foot-per-hour pit level increase would be possible only if encountering bottom-hole pressures of at least 1,654 pounds per square inch gauge. A two-foot-per-hour increase in the pit level would require a pressure of 1,824 pounds per square inch (1.25745×10^7 Pa) gauge. Those surveyed indicated that pressures of this magnitude are seldom experienced in the Delaware Basin, and that both one- and two-foot-per-hour pit level rises would be noticed by the driller.

The low rate of occurrence of abnormally pressured brine has been further supported by information documented in the drilling records. Using databases assembled by Petroleum Information Corporation and Midland Map Company, which provide well name, operator, location, total depths, casing sizes, and dates of drilling and completion, the DOE has developed a list of all oil and gas wells that have been drilled within the New Mexico portion of the Delaware Basin. Wells on this list are located in the southern portions of Eddy and Lea Counties, which are the only New Mexico counties within the Delaware Basin.

The well files at the Oil Conservation Division offices in Artesia and Hobbs, New Mexico, (the NMOCD maintains the records of wells drilled on both state and federal leases in Eddy and Lea Counties) were also reviewed. The files record activities entered by the drillers from initiation of drilling to completion of a particular well. Drillers note in these reports any unusual occurrences such as abnormally pressured brine. Incidents of this type are reported in the form of daily reports. Although there is no requirement that they do so, drillers may include pressurized brine encounters in their daily reports, even if there has been no effect on drilling activities. The Texas portion of the Delaware Basin was not evaluated. The rationale for not including the Texas portion is that wells nearer the WIPP land withdrawal area are of greatest interest in determining the presence of brine within the Castile.

Of a total of 3,406 well files reviewed, 28 were found to have notations by the driller indicating the encounter of pressurized brine. (See Figure DEL-15.)

Another factor influencing performance assessment analyses is the time that flow from a pressurized zone to the surface would continue prior to the installation of the intermediate casing string. As stated previously, the intermediate casing is typically run when the Bell Canyon Formation is reached, which is approximately 4,000 feet (1,220 meters) in depth near the WIPP site. At this time, the drill string is removed from the hole and intermediate casing is run and cemented from 4,000 feet (1,220 meters) to the surface. After cementing is completed, the driller is required by regulation to wait 24 hours for the cement to set before drilling resumes.

Drilling time from the repository depth at 2,150 feet (656 meters) through the remaining portion of the Salado and all of the Castile (an additional 1,250 feet; 381 meters) is calculated to be 54 hours. This number is based on drilling rates of 50-to-60 feet (15-to-18 meters) per hour from the base of the surface casing at 800 feet (244 meters), to the top of the Castile at 2,750 feet (838 meters) (New Mexico Junior College 1995). The drilling rate is expected to slow to 30-to-40 feet (9-to-12 meters) per hour through the Castile (New Mexico Junior College 1995). Once the Bell Canyon has been entered, an additional 14 hours are typically required to remove the drill string from the hole and run and cement the 3,200 feet (976 meters) of casing.

In the majority of drilling operations, the driller will be able to safely drill ahead, reach the Bell Canyon, and complete the intermediate casing, without having to resort to killing the pressure. However, if pressures encountered are great enough that the driller is forced to engage the blowout preventer and add weight to the drilling fluid, the maximum time that flow to the surface would occur is one to two hours. Therefore, two hours represents a reasonable lower bound duration and is derived from high pressure situations where the blowout preventer would be used to stop the flow to the surface and control the pressure by adding weight to the drilling fluids.

DEL.7.6 Borehole Permeability Assessment

Human intrusion scenarios evaluated in the WIPP performance assessment assume that one or more boreholes intercept the repository and that the boreholes are subsequently plugged. To support the evaluation of the potential consequences of scenarios of this type, the DOE has assessed the permeabilities that may be expected in plugged boreholes in the Delaware Basin. The permeability of the borehole plugs is important because this is a measure of the quantity of contaminated fluids that could hypothetically flow through the borehole plug.

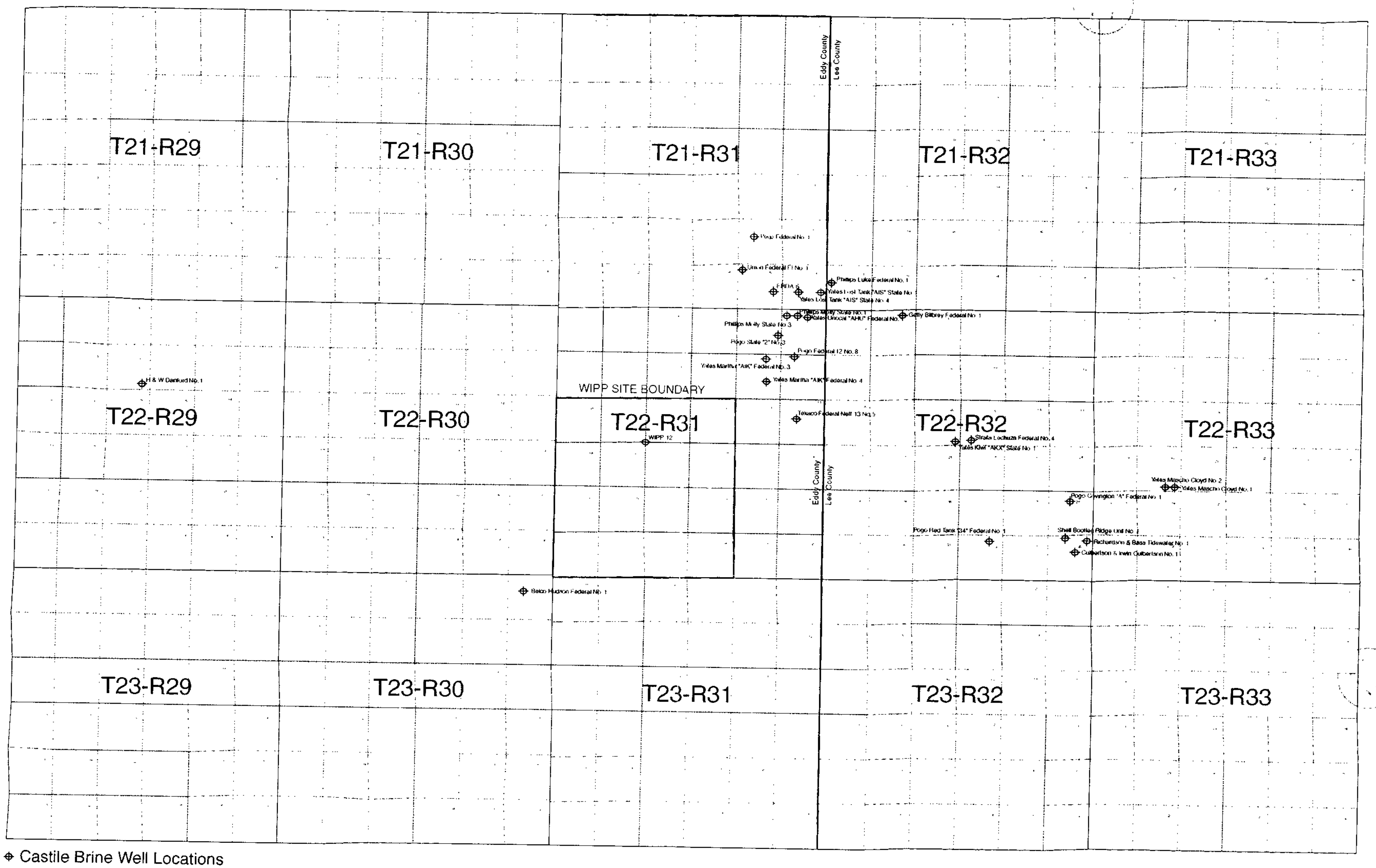
Results of this work are reported in *Inadvertent Intrusion Borehole Permeability*, included as Attachment 7. The DOE report summarizes plugging practices in the Delaware Basin and identifies three plugging configurations typically used in the basin:

- a single continuous plug through the evaporite sequence,
- a two-plug configuration that contains one plug in the Bell Canyon Formation (below the depth of potential brine reservoirs) plus one plug in the Rustler Formation (between the Culebra aquifer and the repository), and
- a three-plug configuration that contains the two plugs described for the two-plug configuration, plus an additional plug in the Salado Formation.

Conclusions presented in the DOE report for each of these configurations include the following:

- In the case of the single continuous plug, the permeability of the plug is expected to remain at 5×10^{-17} square meters for the entire 10,000-year period of interest.
- For the two-plug configuration, the permeability between the repository and the surface is expected to be 5×10^{-17} square meters for a period of 200 years and 10^{-11} square meters to 10^{-14} square meters after that. The plug between the Castile and the repository is expected to have a very high permeability for 200 years and values of 10^{-11} to 10^{-14} square meters up to 1,200 years, and 10^{-12} to 10^{-15} square meters after that.
- With the three-plug configuration, the permeability between the intermediate plug and the surface is expected to be 5×10^{-17} square meters for 200 years and 10^{-11} to 10^{-14} square meters after that. The intermediate plug is expected to have a permeability of 5×10^{-17} square meters for a median time of 5,000 years, and the borehole between the Castile and the repository is expected to have values ranging from 10^{-11} to 10^{-14} square meters for 1,000 years more, and 10^{-12} to 10^{-15} square meters after that.

Under all scenarios considered in the report, the permeability of the borehole plug systems never exceed that of silty sand (10^{-11} to 10^{-14} square meters).



Note: A full-sized map of this figure is in a pocket at the end of Volume I, labeled Figure 2-28

Figure DEL-15. Recent Occurrences of Pressurized Brine in the Castile

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GLOSSARY OF TERMS

accessible environment	The atmosphere, land surface, surface waters, oceans, and all of the lithosphere that is beyond the controlled area. (40 CFR § 191.12)
acidize	Treat oil-bearing formations with acid in order to increase production. This is accomplished by injecting hydrochloric or other acid into the formation under pressure. The acid etches the rock, enlarging the pore spaces for increased flow of reservoir fluids.
active institutional control	(1) Controlling access to a disposal site by any means other than passive institutional controls; (2) performing maintenance operations or remedial actions at a site; (3) controlling or cleaning up releases from a site; or (4) monitoring parameters related to disposal system performance. (40 CFR § 191.12)
annulus	The annular space surrounding the pipe in the wellbore.
blowout preventer	Also blowout preventer, this is one of several valves installed at the wellhead to prevent the escape of pressure in the annular space between the casing and the drill pipe or in an open hole with no drill pipe.
bottomhole	The lowest or deepest part of a well. Pertains to the bottom of the wellbore.
cast iron bridge plug	A metal plug with large rubber o-rings that is mechanically set against the interior casing wall in an oil or gas well. The plug is placed above the perforations in an oil or gas well that is to be plugged and abandoned.
casing shoe	A metal device attached at the base of the first casing joint that is placed into the borehole of a well. The shoe acts as a guide to divert cement into the casing annulus during the process of cementing the casing string.
cellar	A pit usually lined with concrete or steel pipe that provides space between the drilling rig floor and the wellhead to accommodate other functions or equipment. It also collects drainage water and other fluids for disposal.

certification The EPA is required by §8(d)(1)(B) of the WIPP Land Withdrawal Act to certify whether the facility will comply with the disposal regulations in 40 CFR Part 191, Subpart B. Under §7(b)(1) of the act, the DOE may commence emplacement of TRU waste in the repository only after EPA certification has been granted. Certification criteria are contained in 40 CFR Part 194.

compliance assessment The analysis conducted to determine compliance with 40 CFR § 191.15 and Part 191, Subpart C (40 CFR § 194.2).

controlled area (1) A surface location, to be identified by passive institutional controls, that encompasses no more than 100 square kilometers and extends horizontally no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system; and (2) the subsurface underlying such a surface location (40 CFR § 191.12). The WIPP controlled area is the 16-square mile area withdrawn by the WIPP Land Withdrawal Act for use by the DOE for the WIPP project.

cuttings Fragments of rock dislodged by the drilling bit and brought to the surface in the drilling fluids. These are often washed, dried, and analyzed to obtain information about the formations through which the drill bit is passing.

deep drilling For purposes of this report, deep drilling is oil or gas well drilling to a depth of 2,150 feet (655 meters) or greater.

disposal system Any combination of engineered and natural barriers that isolate radioactive waste after disposal (40 CFR § 191.12). The WIPP disposal system includes the controlled area.

downhole Downward, as pertaining to a wellbore or borehole.

drilling fluids Circulating fluids which lift drill cuttings out of the wellbore, cool the drilling bit, and counteract downhole formation pressure. Such fluids commonly consist of a mixture of brine, barite, clay, water, and chemical additives. However, air, gas, water, or oil-based drilling muds are also used.

drill stem All of the machinery and equipment assembled together for rotary drilling.

drill string The column or string of drill pipe with attached tools for transmitting fluids and rotational power.

future state assumptions The EPA WIPP compliance certification rule assumption that all present day conditions will continue to exist in their present state for the entire 10,000-year regulatory time frame. The only exception is that geologic, hydrogeologic, and climatic processes and events are assumed to evolve (change) over the same time period. (40 CFR § 194.25)

kelly A length of pipe or hollow forging with shoulders on the outside that make it square or hexagonal. The kelly fits into a matching shouldered hole in the rotary table of the drill rig and is screwed into the top of the drill string.

land withdrawal area The 16 sections of land (10,240 acres; 4,144 hectares) approximately 33 miles east-southeast of Carlsbad, New Mexico withdrawn under the WIPP Land Withdrawal Act of 1992 (Pub. L. 102 – 579) from jurisdiction of the U.S. Department of Interior, Bureau of Land Management and transferred to the DOE for operation of the WIPP disposal site.

mousehole A 20-to-30 feet (6-to-9 meter) deep hole, usually 12 inches (30 centimeters) or more in diameter, located in the cellar adjacent to the borehole. The mousehole, as with the rathole, serves as a place to put the drillstem when the drillstem in not in the main borehole.

passive institutional controls (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 the disposal system.

perforation A hole or holes made in the casing, the cement, or the rock formation through which formation fluids can enter the wellbore. Holes are usually made with a perforating gun.

performance assessment — An analysis that (1) identifies the features, events and processes that might affect the disposal system, (2) examines their effects on the performance of the disposal system, and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties. These estimates must be incorporated into an overall probability distribution of cumulative releases to the extent practicable. (40 CFR § 191.12)

permeability — The resistance offered by a material to the movement of fluids, measured in darcies. In geoscience, permeability is a property which indicates the relative ease with which a specified fluid will flow through rock, soil, or an engineered material such as a borehole plug.

pipe — A long, hollow cylinder (usually steel) through which fluids are conducted. Pipe can refer to casing, drill pipe, tubing, or line pipe.

porosity — The relative volume of pore spaces between mineral grains as compared to the total rock volume. Porosity measures the capacity of rock to hold oil, gas, water, and other fluids. The usual porosity range is 15 to 20 percent.

rathole — A 20-to-30 foot (6-to-9-meter) deep hole, usually 12 inches (30 centimeters) or more in diameter. It is located adjacent to the cellar and serves to hold the kelly when the kelly is not in the main borehole.

regulatory time frame — The time period beginning when shafts are sealed and ending 10,000 years after disposal.

reserve pit — Can be either a mud pit for storage of drilling fluid or a waste pit. It is usually lined with plastic or other material to prevent soil contamination.

rig up — To install the tools and machinery necessary for preparing the drilling rig. Rig down means to dismantle the drilling rig following completion of drilling operations.

shallow drilling For purposes of this report, shallow drilling is drilling to a depth of 2,150 feet (655 meters) or less.

transuranic (TRU) wastes Wastes containing more than 100 nanocuries per gram of alpha-emitting transuranic isotopes with half-lives greater than 20 years except for (1) high-level radioactive wastes, (2) wastes that do not need the degree of isolation required by 40 CFR Part 191, or (3) wastes that the Nuclear Regulatory Commission has approved for disposal under 10 CFR Part 61. (40 CFR § 191.02[i])

trip in/trip out To go into or enter the drill hole or wellbore, as with a drill pipe. Come out of the hole.

wellbore A borehole or hole drilled by a bit. It may be cased, uncased, or partly cased.

well completion The activities and techniques employed to prepare a well for production of oil or gas or for some other function, such as underground injection of fluids.

well logging The recording of information about subsurface geologic conditions as well as data concerning drilling fluids, cuttings, drill stem conditions, drill cores, radioactivity, and other factors.

wellhead The equipment installed at the surface of the wellbore.

zone A rock stratum that is different from another rock stratum. Often the drilling zone or production zone.

ATTACHMENTS

Attachment 1	Typical Oil or Gas Drilling Sequence in the Delaware Basin
Attachment 2	U.S. Bureau of Land Management Forms
Attachment 3	U.S. Bureau of Land Management Instruction Memorandum No. NM-95-022 on Temporarily Abandoned Wells (September 30, 1996)
Attachment 4	Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Department of the Interior Bureau of Land Management and Waste Isolation Pilot Plant Statement of Work for the U.S. Department of the Interior Bureau of Land Management
Attachment 5	State of New Mexico Energy, Minerals, and Natural Resources Department Oil Conservation Division Forms
Attachment 6	State of New Mexico Energy, Minerals, and Natural Resources Department Oil Conservation Division Rules on Abandonment and Plugging of Wells
Attachment 7	Inadvertent Intrusion Borehole Permeability

Appendix A	Regulatory Basis for Consequence Analysis of Boreholes
Appendix B	Corrosion of Steel
Appendix C	Degradation of Concrete
Appendix D	Creep Closure of Boreholes

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