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TECHNICAL SUPPORT DOCUMENT FOR

SECTION 194.14: CONTENT OF COMPLIANCE CERTIFICATION APPLICATION

U. S. ENVIRONMENTAL PROTECTION AGENCY
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I. BACKGROUND AND SUMMARY

The Waste Isolation Pilot Plant (WIPP) is a geologic repository intended for the disposal of transuranic (TRU) radioactive waste. It is constructed within salts of the Salado Formation approximately 2150 feet (655 meters) below ground surface, and is located approximately 26 miles (42 kilometers) southeast of Carlsbad, New Mexico **(Figure I-1)**.

The Department of Energy (DOE), who has constructed and will operate the WIPP in conjunction with DOE contractor(s), must demonstrate that the WIPP complies with numerous regulations before waste can be emplaced in the repository. Among these are standards set forth in 40 CFR §191, the criteria for which are codified at 40 CFR §194. DOE is required to submit a Compliance Certification Application (CCA) which demonstrates that the standards - quantitative release limits, individual exposure standards, and groundwater protection standards - set forth in 40 CFR §191 are met, following criteria and requirements presented in 40 CFR §194. Specifically, DOE must demonstrate in the CCA, that the cumulative radionuclide releases to the accessible environment over a 10,000 year period will not exceed specified release limits, individual exposure standards, and groundwater protection standards.

Key to the ability of the WIPP to contain radioactive material is the natural setting in which the WIPP was constructed. DOE stated (Appendix GCR of the CCA) that early studies performed from 1957 through the 1970's to select a site for radioactive waste disposal focused on bedded salt as the candidate disposal medium due to salt's elastic properties. Bedded salt in Kansas and New Mexico was examined for potential repository location. DOE stated that the WIPP site in New Mexico's Delaware Basin was selected in 1975 because the salts of this basin were: 1) relatively pure; 2) several hundred feet thick; 3) between depths of 1,000 and 3,000 feet below ground surface (bgs); 4) located where groundwater dissolution is relatively limited; 5) at least one mile from boreholes that completely penetrated the evaporite section; 6) generally located to avoid private land; 7) located where strata are relatively flat; and 8) located to minimize conflicts with mineral resources. (Note that many of these criteria were included in evaluations of site characterization elements, as presented in Sections IV.A, IV.B, IV.C and IV.D of this Technical Support Document).

The siting of the WIPP repository was done in the late 1970s to early 1980s, with construction initiated in 1981. Numerous site geologic studies were performed in the area from the 1970s to the late 1980s, during which structurally disrupted or "disturbed zones" were identified within salt beds of the Castile Formation underlying the WIPP's Salado Formation. Because studies indicated that such a feature could underlie the intended disposal facility and at the suggestion of the Environmental Evaluation (Oversight) Group (EEG), the WIPP repository was reoriented from it's intended construction location to a more southerly position, which was done to avoid obvious placement of the WIPP above a "disturbed zone" in the Castile Formation (CCA Appendix DEF.2, pp. DEF-1 to DEF-11). Construction of the current underground portion of WIPP occurred from 1981 - 1988. DOE intends to construct eight panels that each contain seven rooms for the disposal of waste, but only Panel 1 has been constructed to date. DOE has stated that access drifts (equivalent of two panel volumes) may also be used for waste disposal (Refer to CCA Chapter 3, pp. 3-1, 3-2, and 3-12 to 3-14 for additional information).

The engineered features associated with the design of the disposal system are also important to the ability of the WIPP to contain radioactive material. The engineered features include the shaft seals, panel closures and borehole plugs and an engineered barrier of magnesium oxide (MgO) backfill to be placed around the waste. The engineered features of the disposal system are described and evaluated in Section IV.F of this Technical Support Document.

DOE used the performance assessment methodology in its effort to demonstrate that the WIPP meets environmental performance standards of 40 CFR §191. Performance assessment is an analysis that identifies the processes and events that might affect the disposal system, examines the effects of these processes and events on the performance of the disposal system, and estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events. Key to performance assessment is a sound understanding of the natural site characteristics, as this provides the basic understanding of the undisturbed conditions of the disposal system, identifies possible natural events and processes that could impact the disposal system, provides information pertaining to how these processes could impact the disposal system over the 10,000 year regulatory period, and sets the basis whereby those natural combinations of events that could impact performance assessment are assessed to determine cumulative releases. In addition, the natural system clearly provides the basis for conceptual, mathematical, numerical, computational and computer models **(Figure I-2)**.

The CCA submitted by DOE was required to include, at a minimum, basic information about the WIPP site and disposal system design, and must also address all the provisions of the compliance criteria. 40 CFR Section 194.14 lists those topics that DOE must discuss in the CCA. This Technical Support Document addresses all elements of 40 CFR Section 194.14, with detailed emphasis on:

- Section 194.14(a)(1-3) -- location, geology, hydrology, hydrogeology, and geochemistry of the WIPP disposal system;

- Section 194.14(b)(1-2) -- information on WIPP materials of construction and standards applied to design/construction;

- Section 194.14(g) -- background radiation in air, soil, and water;

- Section 194.14(h) -- topographic maps of the disposal system; and

- Section 194.14(i) -- past and current climatological and meteorological conditions.

The remaining elements of 40 CFR Section 194.14 [Section 194.14(a)(4), Section 194.14(c), Section 194.14(d), Section 194.14(e), and Section 194.14(f)] are addressed briefly in this Technical Support Document, with references provided to other CARDs and/or documents where DOE's compliance with these elements is discussed and evaluated.

This Technical Support Document focusses on the natural and engineered system associated with WIPP. Specifically, the natural and engineered features that may affect disposal system performance, with the disposal system defined in 40 CFR Section 191.12 as "any combination of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal." [50 FR 38066, September 19, 1997]

40 CFR Section 194.14(a)(1)

40 CFR Section 194.14(a)(1) requires that a CCA include a description of the location of the disposal system and the controlled area. DOE provided WIPP site location information in Table 3-1 of the CCA and indicated that the WIPP is approximately 26 miles southeast of Carlsbad, New Mexico, in Eddy County. The U.S. Public Land Survey designation for the area within the WIPP Land Withdrawal Act boundary is Township 22S, Range 31E, Sections 15-22 and Sections 27-34. DOE considered the WIPP Land Withdrawal Act (LWA) land withdrawal area to be the controlled area for purposes of demonstrating compliance 40 CFR Part 191. Area roads, communities, and a general location map are shown on CCA Figure 1-2, with site-specific roads and range and township boundaries shown on CCA Figure 3-1. CCA Table 3-1 also provides the latitude and longitude designations and the size of the WIPP site. DOE also described the physical setting of the land surface at the WIPP site. The average east-to-west slope at the WIPP is 50 feet per mile (9.4 meters per kilometer). The Pecos River, located 12 miles (19 kilometers) southwest of the site, is the closest perennial stream. DOE provided additional disposal system information, such as site hydrologic data, in Chapters 2, 3, 6 and 7 of the CCA, as well as numerous appendices (e.g. Appendices GCR, FAC, and HYDRO). EPA examined the CCA to determine whether it contained the required information regarding the disposal system and controlled area. EPA also evaluated the accuracy and consistency of the information provided.

40 CFR Section 194.14(a)(2)

40 CFR Section 194.14(a)(2) requires that a CCA include a description of the geology, geophysics, hydrogeology, hydrology, and geochemistry of the disposal system and its vicinity and how these conditions are expected to change and interact over the regulatory time frame. EPA expected that the information provided in the CCA would support the conceptualization of the disposal system, and that major site-related characteristics will be included in performance assessment modeling. EPA examined the CCA to determine whether it contained a technically adequate description of the geology, geophysics, hydrogeology, hydrology and geochemistry of the WIPP disposal system and its vicinity and how these conditions change over time.

DOE provided information regarding the geologic history of the area around the WIPP site in Chapter 2, Section 2.1.2 (pp. 2-11 to 2-12), Appendix GCR, Section 3.6 (pp. 3-83 to 3-108), Section 4.5 (pp. 4-79 to 4-88), and HYDRO (pp. 10-22). DOE summarized the major geologic events that have occurred over time in a 200 mile radius (320 kilometer) surrounding the WIPP site. DOE indicated that the WIPP is located in the Delaware Basin of New Mexico and Texas. The Delaware Basin contains thick sedimentary deposits (15,000 - 20,000 feet) that overlay 1.1-1.5 billion year old metamorphic and igneous basement rock. Since the Permian age (~200-250 million year old) Salado was deposited, minimal structural deformation has occurred in the Delaware Basin. Reflecting the limited tectonic activity in the Delaware Basin, the sedimentary rocks of the Delaware Basin are nearly horizontal with a slight west to east dip of about 1 degree.

DOE provided information regarding the stratigraphy and lithology of the rock units surrounding the WIPP in CCA Chapter 2.1.3 (pp. 2-12 to 2-64), as well as in Appendices GCR (Section 4, pp. 4-1 to 4-94), FAC, HYDRO (pp. 10-21), and other supporting references, including Appendix SUM, Sections 1.3 (pp. 6-10) and 6.3.5 (pp. 6-28 to 6-37). **Figure IV-4** of this Technical Support Document presents the complete stratigraphic column in the WIPP area.

DOE indicated that the most significant non-tectonic features in the vicinity of the WIPP site are related to Castile structures (i.e., disturbed zones) and evaporite dissolution. These processes are described in detail in Chapter 2, Sections 2.1.3.3 (p. 2-24) and 2.1.6 (pp. 2-80 to 2-93) and Appendices DEF.2 - DEF.3 (pp. DEF-1 to DEF-33). DOE indicated that the major geomorphic process in the vicinity is dissolution. To the west, the slight dip in the beds has exposed the Salado to dissolution processes; however, DOE estimated that the dissolution front will not reach the WIPP site for hundreds of thousands of years. Near-surface dissolution of evaporitic rocks (e.g., gypsum) have created karst topography west of the WIPP site, but DOE contended that karst processes do not appear to have affected the rocks within the WIPP site itself. DOE indicated that while deep dissolution has occurred in the Delaware Basin, the process of deep dissolution would not occur at such a rate at the WIPP that it would impact the waste containment capabilities of the WIPP during the regulatory time period.

DOE provided information regarding the tectonic setting and site structural features in CCA Chapter 2.1.5 (pp. 2-68 to 2-80) and Appendix GCR, Section 4.4 (pp. 4-53 to 4-79). DOE concluded that the WIPP site is located in an area with no evidence of significant tectonic activity and a low level of regional stress. DOE indicated that evidence exists which demonstrates that the WIPP area has been tectonically stable since the Permian period. DOE provided information regarding the seismic history of the WIPP site within CCA Chapter 2.6 (pp. 2-180 to 2-205) and indicated that the current WIPP location was selected because of the absence of tectonic activity, faulting, and igneous activity. The seismic information included a description of earthquake activity and predictions of ground motions that may affect the stability of the WIPP repository.

DOE provided information regarding the geomorphology and topography of the WIPP site in CCA Chapter 2.1.4 (pp. 2-64 to 2-68) and provided information regarding the soil characteristics in the vicinity of the WIPP in Chapter 2.1.3.10. DOE concluded that the WIPP site is located in the Pecos Valley section of the southern Great Plains physiographic province. DOE indicated in Chapter 2.1.4.2 (p. 2-67) that the most prominent physiographic feature near the site is Livingston Ridge, which is a west facing escarpment located approximately 4 miles (6.4 kilometers) northwest of the center of the WIPP site. It marks the edge of Nash Draw, which is a shallow 5-mile-wide (8 kilometers), 200-300 feet (61 to 91 meters) deep feature caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. DOE indicated that Livingston Ridge is the approximate eastern boundary of terrain that has undergone erosion and/or solution collapse.

DOE provided information regarding natural resources in the vicinity of the WIPP site in CCA Chapter 2.3 (pp. 2-145 to 2-161) and indicated that the consideration of resources was an important part of the siting criteria for the WIPP. Several siting criteria emphasized the avoidance of resources that would impact the performance of the disposal system. DOE defined both economic (mineral and nonmineral) and cultural resources that may exist at or beneath the

WIPP site. Due to the depth of the disposal horizon, only the mineral resources are of significance to predicting the long-term performance of the disposal system. DOE indicated that some of the geologic formations below the repository area contain oil and gas, resources that are currently being exploited in the Delaware Basin. In addition, potash is found within the Salado that contains the WIPP waste area; however, the waste area lies below an area where there are no economically minable reserves. According to DOE's analysis, most of the water in the vicinity of WIPP is highly saline, with the closest dependable potable aquifer associated with the Capitan Reef at the edge of the Basin.

DOE provided information regarding the hydrogeologic characteristics of the geologic units in the disposal system in CCA Chapter 2.2.1 (pp. 2-97 to 2-145), Appendix FAC, Sections 7 and 8 (pp. 7-1 to 8-18), Appendix GCR, Section 6 (pp. 6-1 to 6-62), and HYDRO (pp. 22 to 75). For each of the geologic units in the vicinity of the WIPP disposal system, DOE provided information regarding hydraulic conductivity, storage coefficients, transmissivity, permeability, thickness, matrix and fracture characteristics, and hydraulic gradients in a summary table provided to EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been reproduced as **Figure IV-10** of this Technical Support Document. The CCA also provides detailed groundwater hydrology information for geologic units that could be expected to transmit radionuclides to the accessible environment.

DOE determined that the Castile, Salado, Rustler and Dewey Lake hydrological systems are the most important to disposal system performance and modeling (CCA Chapter 2.2.1, p. 2-97). The Castile provides a hydrologic barrier between the Bell Canyon and Salado and contains high-permeability zones with pressurized brine. DOE considered the Salado to be the most significant hydrologic barrier between the repository and more transmissive beds. At the WIPP site, the Rustler Formation contains two transmissive members: the Culebra and the Magenta. DOE stated that the Dewey Lake is not an extensive aquifer at the WIPP site, though DOE reports groundwater movement in a fractured zone of the Dewey Lake off-site of the WIPP.

DOE indicated that the low permeability Salado has limited water (in the form of brine) available to dissolve the halite or to transport radionuclides. If fluid is available to move through the Salado and potentially transport radionuclides, DOE contended that the major pathway for flow and transport is believed to be the more permeable anhydrite interbeds. While more permeable than the halite, the Salado anhydrite interbeds are still very impermeable ($\sim 10^{-19}$ m^2 permeability for the anhydrite versus $\sim 10^{-21}$ m^2 permeability of the halite).

To assess the capability of the WIPP site to contain radionuclides over 10,000 years, DOE considered the primary geologic units of concern to be (from below the repository to the surface):

- ♦ Castile Formation-- consisting of anhydrite and halite with pressurized brine pockets found locally throughout the vicinity of the WIPP site.

- ♦ Salado Formation-- consisting primarily of halite with some anhydrite interbeds and accessory minerals and approximately 2,000 feet (600 meters) thick.

- ♦ Rustler Formation-- containing salt, anhydrite, clastics, and carbonates (primarily dolomite), with the Culebra member of the Rustler as the unit of greatest interest.

- ♦ Dewey Lake Red Beds Formation (Dewey Lake) -- consisting of sandstone, siltstone and silty claystone.

DOE did not consider most of the geologic units above the Salado to be likely pathways for radionuclides. According to DOE, the ~8 meter thick Culebra is the major potential pathway for contaminants above the Salado.

40 CFR Section 194.14(a)(3)

40 CFR Section 194.14(a)(3) requires that a CCA include a description of the presence and characteristics of potential pathways for transport of waste from the disposal system to the accessible environment. In reviewing the CCA information applicable to Section 194.14(a)(3), EPA sought information supporting the conceptualization of the disposal system and the major site-related characteristics included in the performance assessment modeling. DOE provided a description of the presence and characteristics of potential pathways for the transport of waste from the disposal system to the accessible environment in CCA Chapter 2 and Appendix DEF. The potential pathways identified by DOE were: breccia pipes and deep dissolution along the Bell Canyon-Castile interface; lateral dissolution along the Rustler-Salado contact and within the Rustler; and shallow dissolution, including the development of karst and dissolution of fracture fill in Salado marker beds and the Rustler.

DOE identified and described numerous potential pathways and concluded that the potential for significant fluid migration to occur through most of these pathways is low. However, DOE also concluded that fluid migration could occur within the Rustler and Salado marker beds and included this possibility in performance assessment calculations.

EPA agreed with DOE’s conclusion that karst features and breccia pipes are not potential pathways. EPA also concluded that deep, lateral, and shallow dissolution pathways will not serve as significant potential radionuclide pathways and that the potential for significant fracture-fill dissolution during the regulatory time period is low.

EPA noted that the potential for fluid migration through Salado marker beds and the Culebra member of the Rustler was acknowledged by DOE and included in the performance assessment calculations. While the Dewey Lake is a potential underground source of drinking water (CCA Chapter 8.2.2), DOE’s modeling found that radionuclides will not reach the Dewey Lake, thus removing the formation as a unit needing consideration as a pathway (DOE, 1997l) (Docket A-93-02, Item II-G-26) . EPA concluded that Salado marker beds and the Culebra Dolomite were adequately identified and characterized to the level necessary for performance assessment calculations.

40 CFR Section 194.14(a)(4)

40 CFR Section 194.14(a)(4) requires that a CCA include a description of the projected geophysical, hydrogeologic and geochemical conditions of the disposal system due to the

presence of waste. DOE discussed how it considered the effects of waste presence (including heat and gas generation on geophysical, hydrological, and geochemical conditions of the repository) in CCA Chapters 4 and 6 and Appendices SCR, SOTERM, WCA, and BRAGFLO. DOE considered and screened out the impact that radioactive decay-related heat generation would have on the disposal system because the generated heat is of low consequence. In addition, heat generated via nuclear criticality was also screened out based on the low probability that a criticality event would occur.

DOE acknowledged that the presence of waste within the WIPP impacts the geochemistry of the disposal system and so included the presence of waste in the PA. The oxidation conditions within the repository are altered by the corrosion of steel waste containers, and DOE linked the changing oxidation conditions to the oxidation state of actinides considered in solubility analysis. Furthermore, degradation of cellulosic, plastic, and rubber waste could result in carbon dioxide generation, which decreases brine pH and hence increases actinide solubility. DOE indicated that MgO emplaced with transuranic waste would mitigate the solubility-enhancing effects of carbon dioxide generated from waste degradation.

In addition to considering the generation of carbon dioxide's impact on the disposal system, DOE stated that gas generation would be a critical factor to consider in the PA. DOE considered that gas will be generated through two primary processes: corrosion of steel to generate hydrogen gas and degradation of organic material to create carbon dioxide and methane. DOE modeled the cumulative impact of gas generation on repository pressure throughout the 10,000 year regulatory period and included this estimate in modeled room closure rates, porosity surface calculations, pressure-sensitive permeability calculations for Salado marker beds, and spallings particle releases estimates.

EPA reviewed the information provided in the CCA and concluded that DOE's exclusion of heat-generating mechanisms from the performance assessment was appropriate, since the impact that heat generation would have on the disposal system hydrogeology and geochemistry would be minimal. DOE identified the waste components and characteristics that impact repository performance. EPA also concluded that DOE integrated gas generation into performance assessment models.

40 CFR Section 194.14(b)(1)

40 CFR Section 194.14(b)(1) requires that a CCA include a description of the design of the disposal system including information on materials of construction. The CCA contained a general description of the entire WIPP facility and a detailed description of the disposal system (including the engineered features in the repository and shaft system as well as the geologic units). Chapter 3.1.3 briefly described the various support structures located at the ground surface (pp. 3-8 to 3-11) and offered a detailed description of the four vertical shafts connecting the ground surface with the underground waste disposal area (pp. 3-11 to 3-12). Chapter 2 provided a description of the Salado, which DOE indicated is the primary natural containment for potential radionuclide releases from the WIPP (Sections 2.1.3.4, pp. 2-29 to 2-37, and 2.2.1.3, pp. 2-108 to 2-113). Chapter 3.3 (pp. 3-14 to 3-45) provided a description of the design and materials of construction of the three types of engineered features that DOE incorporated into the disposal system design (shaft seals, panel closures, and borehole plugs) and an

engineered barrier consisting of MgO backfill around the waste that DOE incorporated for the purpose of assurance.

DOE provided information on the design and materials of construction of the disposal system. DOE identified the compacted salt column as the most critical element in the long-term performance of the shaft seal system and likewise identified the moisture content of the compacted salt as the single greatest challenge to its ability to perform as required. DOE therefore focused its shaft seal design efforts on keeping moisture out of the compacted salt column**.** DOE provided four options for panel seal closures but did not specify which panel closure option would be used at WIPP.

To assess compliance with Section 194.14 (b)(1), EPA verified that CCA contained the required information and that the construction material and general design descriptions were consistent and technically adequate throughout the CCA. EPA's certification includes a condition requiring DOE to implement the Option D panel seal closure design, with Salado mass concrete replacing fresh water concrete.

40 CFR Section 194.14(b)(2)

40 CFR Section 194.14(b)(2) requires that a CCA include a description of the design of the disposal system including the computer codes and standards that have been applied to the design and construction of the disposal system. The actual computer codes need not be submitted as part of the CCA. DOE described the design standards and identified the computer codes applied to the design and construction of the disposal system within the CCA in Chapters 3.1, 3.3.3, and Appendices DVR, PCS, and SEAL. EPA reviewed DOE's identification of the codes and standards used and its description of how they were applied to the design.

40 CFR Section 194.14(c)

40 CFR Section 194.14(c) requires that a CCA include the results of assessments conducted pursuant to the disposal regulations. DOE was required to present the results of assessments of the WIPP's performance, given human intrusion into the disposal system (performance assessment) and undisturbed conditions (compliance assessment), that were conducted in accordance with the disposal regulations at 40 CFR Part 191, Section 13 and Subpart C. Despite the large quantity in the CCA of information pertaining to results of assessments, EPA identified numerous issues concerning the technical validity and completeness of information in the CCA. EPA's requests for clarification led to DOE to provide supplementary information related to the results of assessments. **The technical adequacy of this information, as well as EPA's requests for additional information, are discussed fully in the following CARDs: CARD 23 -- Models and Computer Codes, CARD 24 - Waste Characterization, CARD 34 -- Results of Performance Assessments, CARD 42 -- Monitoring, CARD 44 -- Engineered Barriers, and CARD 55 -- Results of Compliance Assessments.**

40 CFR Section 194.14(d)

40 CFR Section 194.14(d) requires that a CCA include a description of input parameters associated with assessments conducted pursuant to this part and the basis for selecting those

input parameters. DOE provided descriptions of input parameters to the performance assessment in Chapter 6.1 (pp. 6-13 to 6-35) and Appendix PAR. EPA reviewed DOE's justification of parameter selection in the CCA and found that the traceability and supportability of the parameters needed improvement (e.g., better database compilation, improvements in data road maps, and more extensive documentation of legacy parameters). EPA also found that the CCA lacked supporting data for some of the parameters. EPA requested supplementary information from DOE and concluded that it sufficiently addressed EPA's concerns. **EPA's review of DOE's input parameters are discussed in CARD 23 Models and Computer Codes and EPA's Technical Support Document for Section 194.23: Parameter Justification Report (EPA, 1998c) (Docket A-93-02, Item V-B-14).**

EPA conducted a detailed technical evaluation of parameters used in the performance assessment and concluded that several parameters required modification. EPA required that revised parameters be used in Performance Assessment Verification Testing in lieu of the parameter values used by DOE in the CCA Performance Assessment. **Refer to CARD 23 -- Models and Computer Codes for a complete discussion information of modified parameters and values.**

40 CFR Section 194.14(e)

40 CFR Section 194.14(e) requires that a CCA include documentation of measures taken to meet the assurance requirements of this part. Assurance requirements constitute qualitative requirements that are intended to provide confidence that the radioactive waste disposal repository will comply with the disposal regulations. They are intended to compensate for the inherent uncertainties in protecting the behavior of natural and engineered components of the repository for many thousands of years.

The six assurance requirements that DOE must satisfy involve: active institutional controls (§ 194.41), monitoring (§ 194.42), passive institutional controls (§ 194.43), engineered barriers (§ 194.44), consideration of the presence of resources (§ 194.45), and removal of waste (§ 194.46). DOE documented the measures taken to meet these assurance requirements in Chapter 7 and numerous appendices. A complete discussion of DOE's compliance with the assurance requirements, and a complete discussion of EPA's requests for additional information and an evaluation of the technical adequacy of the CCA and supplementary materials can be found in the following CARDs: **CARD 41 -- Active Institutional Controls, CARD 42 -- Monitoring, CARD 43 -- Passive Institutional Controls, CARD 44 -- Engineered Barriers, CARD 45 -- Consideration of the Presence of Resources, and CARD 46 -- Removal of Waste.**

40 CFR Section 194.14(f)

40 CFR Section 194.14(f) requires that a CCA include a description of waste acceptance criteria and actions taken to assure adherence to such criteria. DOE provided a description of waste acceptance criteria in a document entitled "Waste Acceptance Criteria for the WIPP" (DOE, 1996) [CCA Reference 208] (Docket A-93-02, Item II-G-1). Appendix WAP and the Transuranic Waste Characterization Quality Assurance Program Plan (DOE, 1995) [CCA Reference 208] (Docket A-93-02, Item II-G-1) described procedures to ensure that the waste acceptance criteria are met. DOE also identified waste limits that must be met by the WIPP,

which were presented in Appendix WCL. EPA reviewed these documents to determine whether DOE provided satisfactory waste analysis methodologies to ensure adherence to these criteria. EPA's technical review of the WIPP waste acceptance criteria is found in **CARD 24 -- Waste Characterization.**

40 CFR Section 194.14(g)

40 CFR Section 194.14(g) requires that a CCA include a description of background radiation in air, soil and water in the vicinity of the disposal system and the procedures employed to determine such radiation. DOE provided information regarding background levels of radiation in air, soil, surface water, sediments, groundwater and biota and how they were determined in CCA Chapter 2.4.4 and Appendices EMP, RBP and SER. DOE initiated the WIPP Radiological Baseline Program in July 1975 to describe background levels of radiation and radionuclides in the WIPP environment prior to the emplacement of radioactive waste. DOE established a radiation baseline under five programs: atmospheric, ambient radiation, terrestrial (soils), hydrologic (surface water, sediments and groundwater); and biotic. EPA reviewed the CCA to determine whether DOE provided sufficient information on the background radiation in air, soil and water, as well as procedures to monitor these media for radiation. EPA found that DOE provided sufficient discussion of these background levels and associated procedures to monitor these media for radiation.

40 CFR Section 194.14(h)

40 CFR Section 194.14(h) requires that a CCA include one or more topographic maps with a contour interval sufficient to show clearly the pattern of surface water flow in the vicinity of the disposal system. DOE provided four topographic maps [CCA Figure 2-18 (p. 2-69), Figure 2-25 (p. 2-99), and two USGS 15 minute quadrangle topographic maps of Livingston Ridge and Los Medanos (attached to Volume I of the CCA)] that show the pattern of surface water flow in the vicinity of the WIPP. DOE also provided CCA Figures 2-1 (p. 2-7), 2-25 (p. 2-99) and 3-1 (p. 3-3) to show the locations of the controlled area within the U.S. Public Land Survey coordinate system and provided a map showing the location of active, inactive and abandoned injection and withdrawal wells in the controlled area and in the vicinity of the disposal system in Appendix DEL, Plate DEL-6. EPA reviewed the topographic maps provided in the CCA to determine their sufficiency.

40 CFR Section 194.14(i)

40 CFR Section 194.14(i) requires that a CCA include a description of past and current climatologic and meteorologic conditions in the vicinity of the disposal system and how these conditions are expected to change over the regulatory time frame. EPA recommended that DOE list recent estimates in tabular form, using existing written records. DOE described past glaciation events, climatic changes, and precipitation and temperature averages in CCA Chapter 2.5.1 and Appendix CLI. DOE then discussed how historic climatic conditions were used to anticipate climatic conditions 10,000 years in the future. DOE concluded that it is unlikely that the WIPP site will experience future climatic extremes in excess of those occurring between the late Pleistocene (1.4 million years ago) and the present. CCA Chapter 2.5.2 described current climatic conditions in the WIPP area, including summaries of recent rainfall, temperature, and

wind data. DOE discussed how climate changes were incorporated in conceptual models in CCA Chapter 6.4.9. EPA reviewed specific studies, data and analysis provided by DOE for accuracy, technical basis, and appropriateness of associated justifications. EPA also assessed technical conclusions drawn by DOE based upon the information presented in the CCA and supplemental information based upon their reasonableness, accuracy, applicability, and relative importance to the PA.

40 CFR Section 194.14(j)

40 CFR Section 194.14(j) requires that a CCA include the information required elsewhere in this part or any additional information, analyses, tests, or records determined by the Administrator or the Administrator's authorized representative to be necessary for determining compliance with this part. After receipt of the CCA dated October 29, 1996, EPA formally requested additional information from DOE in seven letters dated December 19, 1996, and February 18, March 19, April 17, April 25, June 6, and July 2, 1997. (Docket A-93-02, Items II-I-1, II-I-9, II-I-17, II-I-25, II-I-27, II-I-33, and II-I-37, respectively) The information requested in these letters was necessary for EPA's completeness determination and technical review. EPA staff and contractors also reviewed records maintained by DOE or DOE's contractors (e.g., records kept at the Sandia National Laboratories Records Center in Albuquerque, New Mexico). No additional laboratory or field tests were conducted by DOE at EPA's specific direction; however, DOE did conduct and document laboratory tests after October 29, 1996, in order to present additional data to the Conceptual Model Peer Review Panel. (Docket A-93-02, Item II-A-39)

EPA did not formally request additional information from DOE after publication of the proposed rule. In response to comments, EPA did, however, verbally ask DOE and Sandia National Laboratory for information and other assistance in calculations related to the Hartman scenario, drilling into fractured anhydrite, and the CCDFGF code and quasi-static spreadsheet with regard to air drilling. (Docket A-93-02, Items IV-E-24, IV-E-25, IV-E-26, and IV-E-27) In addition, DOE voluntarily submitted information on the proposed rule that was considered as comments.

II. REGULATORY REQUIREMENTS, CONTENT OF THE CCA, AND CONTENT OF THIS TECHNICAL DOCUMENT

The containment requirements of 40 CFR Section191.13 state that DOE must demonstrate a reasonable expectation that the probabilities of cumulative radionuclide releases from the disposal system during the 10,000 years following closure will fall below specified limits. §194.14 specifies the criteria that any Compliance Certification Application (CCA) must fulfill to meet these standards, and specifies the information that the compliance application must contain in this regard. Specifically, this regulation states:

§194.14 Content of compliance certification application.

Any compliance application shall include:

(a) A current description of the natural and engineered features that may affect the performance of the disposal

system. The description of the disposal system shall include, at a minimum, the following information:

(1) The location of the disposal system and the controlled area.

(2) A description of the geology, geophysics, hydrogeology, hydrology and geochemistry of the disposal system and its vicinity and how these conditions are expected to change and interact over the regulatory time frame. Such description shall include, at a minimum:

(i) Existing fluids and fluid hydraulic potential, including brine pockets, in and near the disposal system; and

(ii) Existing higher permeability anhydrite interbeds located at or near the horizon of the waste.

(3) 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, solution features, breccia pipes, and other potentially permeable features, such as interbeds.

(4) The projected geophysical, hydrogeologic and geochemical conditions due to the presence of waste including, but not limited to, the effects of production of heat or gases from the waste.

(b) A description of the design of the disposal system including:

(1) Information on materials of construction including, but not limited to: Geologic media, structural materials, engineered barriers, general arrangement, and approximate dimensions; and

(2) Computer codes and standards that have been applied to the design and construction of the disposal system.

(c) Results of assessments conducted pursuant to the disposal regulations.

(d) A description of input parameters associated with assessments conducted pursuant to this part and the basis for selecting those input parameters.

(e) Documentation of measures taken to meet the assurance requirements of this part.

(f) A description of waste acceptance criteria and actions taken to assure adherence to such criteria.

(g) A description of background radiation in air, soil and water in the vicinity of the disposal system and the procedures employed to determine such radiation.

(h) One or more topographic map(s) of the vicinity of the disposal system. The contour interval shall be sufficient to show clearly the pattern of surface water flow in the vicinity of the disposal system. The map(s) shall include standard map notations and symbols, and, in addition, shall show boundaries of the controlled area and the location of any active, inactive, and abandoned injection and withdrawal wells in the controlled area and in the vicinity of the disposal system.

(i) A description of past and current climatologic and meteorologic conditions in the vicinity of the disposal system and how these conditions are expected to change over the regulatory time frame.

(j) The information required elsewhere in this part or any additional information, analyses, tests, or records determined by the Administrator or the Administrator's authorized representative to be necessary for determining compliance with this part.

The crosswalk between the criterion in 40 CFR Part 194 and the CCA presented in Volume I of the CCA identifies where this information is addressed. The portion of the crosswalk related to Section 194.14 is provided as **Figure II-1** of this Technical Support Document.

Section 194.14 presents those key elements that must be included in the CCA. Of these, §194.14(a)(4) and §194.14(c), (d), (e), (f) and (j) are all addressed under other requirements of 40 CFR §194:

Section	Where requirement is addressed
194.14(a)(4)	§194.23, §194.24 and §194.32
194.14(c)	§194.23, §194.24, §194.34, §194.42, §194.44, and §194.55
194.14(d)	§194.23, §194.34, and §194.55
194.14(e)	§194.41 through §194.46
194.14(f)	§194.24(c)(4)
194.14(j)	all sections

Because the technical elements for §194.14(a)(4) and §194.14(c)-(f) and (j) are addressed in separate technical support documents that have been prepared to address these other sections of the regulations, they are only briefly addressed herein, with references to the appropriate documents which address these sections provided. Therefore, this Technical Support Document addresses 40 CFR§194.14(a)(1)-(3), and §194.14(b),(g), (h) and (i).

III. COMPLIANCE REVIEW CRITERIA

The purpose of this Technical Support Document is to present results of EPA's assessment of DOE's assessment methodology and conclusions drawn to demonstrate compliance with 40 CFR §194.14(a), (b), (g), (h) and (i). DOE presented information within Chapters 2 and 3 and Appendices such as FAC, GCR, HYDRO, DEF, BACK, DEL, PCS and SEAL which it believes meets the requirements of §194.14(a), (b), (g), (h) and (i).

EPA prepared a Compliance Application Guidance (CAG) (March 1996) that presents EPA's expectations relative to the content of the CCA. This document is guidance, not regulation, and as such does not mandate CCA contents. However, it provides the general expectations of the EPA relative to CCA content and also includes very specific suggestions regarding CCA content as it pertains to §194.14 requirements.

A. Suggested CCA Content for §194.14(a)(1):

EPA expected that relative to §194.14(a)(1), the CCA description would specify for the WIPP the:

- physical setting;
- size;
- county;
- township and range;
- roads;
- longitude and latitude;
- appropriate graphics (maps, at a minimum); and
- boundaries of the disposal system and controlled area.

B. Suggested CCA Content for §194.14(a)(2):

EPA expected that, relative to §194.14(a)(2) requirements, the CCA would describe discuss geologic and geophysical characteristics, to include regional and site:

- geologic history;
- stratigraphy;
- lithology;
- structural geology and geotectonics (e.g., geologic structure, tectonic history, lineaments, fault or fracture zones, earthquake occurrence, subsidence);
- seismic history (e.g., earthquake activity, relation of epicenters with geologic structures and/or geologic setting);
- geomorphology and topography (e.g., geomorphic units and processes, such as secondary topographic features caused by erosion);
- soil characteristics in the controlled area that affect infiltration and runoff (e.g., hydraulic conductivity, infiltration capacity); and
- natural resources (e.g., type, occurrence, location, extent of minerals, hydrocarbons and water, such as potash, oil, gas, irrigation water). See also §194.33 and §194.45.

Hydrologic, hydrogeologic, and geochemical descriptions were expected to include, for all geologic units in the disposal system, the following general hydraulic characteristics:

- hydraulic conductivity;

- ♦ storage coefficients;
- ♦ transmissivity;
- ♦ permeability;
- ♦ thickness;
- ♦ matrix and fracture characteristics; and
- ♦ hydraulic gradients.

For geological units that could be expected to transmit radionuclides to the accessible environment during the regulatory time frame, the CCA was expected to include:

- ♦ regional and site-specific recharge and discharge areas;
- ♦ groundwater flow patterns, including horizontal flow (e.g., potentiometric surface, flow direction, effect of density on flow direction) and the estimated vertical flow into transmissive units;
- ♦ general physical characteristics (e.g., fracturing, porosity--total, effective, interstitial, and fracture--and saturated thickness);
- ♦ general transport characteristics (e.g., longitudinal and transverse dispersivity, tortuosity, matrix and fracture characteristics, retardation (physical and chemical) and a discussion of the characterization method(s) used);
- ♦ flow boundaries, magnitudes and flow rates;
- ♦ depth to water table (where applicable); and
- ♦ geochemistry and geochemical history (e.g., total dissolved solids, mineral content and distribution, fluid density, salinity).

EPA expected that any application will provide information on general hydrological, hydrogeological and geochemical characteristics of the geological units in the disposal system. In the description of the hydrogeology, hydrology and geochemistry, the application would discuss the geological units that could be expected to transmit radionuclides to the accessible environment during the regulatory time frame and for those which are not expected to transmit water, EPA recommended that the CCA discuss the hydrological properties that support this expectation.

C. Suggested CCA Content for §194.14(a)(3) and (4):

EPA recommended that relative to §194.14(a)(3)and (4), the CCA include this information as part of the waste information or the screening of events and processes. EPA also expected that the information for this requirement would be appropriately cross-referenced in all of the sections in which it is discussed. (See also §194.24, §194.32, and §194.54).

D. Suggested CCA Content for §194.14(b)(1):

EPA expected that relative to §194.14(b)(1), the CCA would provide a complete description of the disposal system design, with supporting documentation that demonstrates that the designs can be implemented and that they will function in the manner for which they were designed.

E. Suggested CCA Content for §194.14(b)(2):

EPA expected that relative to §194.14(b)(2), the CCA would contain a description of the computer codes and standards applied to the design and construction of the disposal system.

F. Suggested CCA Content for §194.14(c):

EPA recommended that DOE refer to §194.23, §194.24, §194.34, §194.42, §194.44 and §194.55 for relevant guidance.

G. Suggested CCA Content for §194.14(d):

EPA recommended input parameter descriptions be linked to the appropriate discussions of models and data as required in sections 194.23, 194.34, and 194.55.

H. Suggested CCA Content for §194.14(e):

EPA recommended that DOE refer to the guidance for assurance requirements at §194.41 through §194.46.

I. Suggested CCA Content for §194.14(f):

EPA recommended that DOE refer to the guidance for §194.24(c)(4).

J. Suggested CCA Content for §194.14(g):

EPA expected the CCA description relative to §194.14(g) to include background radiation in:

- air;
- soil; and
- water.

EPA expected the CCA to present the procedures employed to determine such radiation, to include:

- locations in which the measurements were made;

- dates on which the measurements were made;

- standard statistics, such as mean and standard deviation;

- discussion of problems (if any) encountered in the measurement process;

- identification of the instrument used and lower limit of detection for the instrumentation; and

- documentation that the measurements were quality assured.

K. Suggested CCA Content for §194.14(h):

The EPA expected that the CCA description, relative to §194.14(h) would include:

- the contour interval would be sufficient to show clearly the pattern of surface water flow in the vicinity of the disposal system;

- the map(s) would include:
    - standard map notations and symbols;
    - boundaries of the controlled area; and
    - the location of any active, inactive, and abandoned injection and withdrawal wells in the controlled area and in the vicinity of the disposal system.

EPA recommended that sufficient topographic and/or other maps be included, and that any information on the maps be discussed in the text of the application, so that any information on the maps will be clear to the reviewer.

L. Suggested CCA Content for §194.14(i):

Relative to §194.14(i), EPA recommended that any compliance application list recent estimates, using existing written records, of climatologic and meteorologic conditions in the vicinity of the disposal system in tabular form, and briefly discuss the following:

- record of annual and monthly precipitation averages;

- record of monthly temperature averages and extremes;

- wind speed and direction information that forms the basis for the exposure pathway modeling; and

- an estimate of evapotranspiration.

EPA expected any compliance application to discuss the past climatologic and meteorologic conditions for the vicinity of the disposal system including:

- climate changes, including past glaciation events; and

- ♦ past precipitation and temperature averages and variability, estimated from the geologic record, or other means.

EPA expected that any compliance application would include a discussion of how climatologic and meteorologic conditions are expected to change during the 10,000-year regulatory time period. EPA further expected any compliance application to state how climatologic and meteorologic changes were incorporated into the conceptual models used and how they were used in the performance and compliance assessments, including:

- ♦ potential changes and rates of change in precipitation, air temperatures, and resulting changes in potential evapotranspiration from the present;
- ♦ potential precipitation patterns that may evolve in the future as a result of climatic and geologic changes; and
- ♦ potential increased/decreased recharge to the disposal system.

M. Suggested CCA Content for §194.14(j):

EPA expected DOE to provide the information required by the other sections of 40 CFR part 194, as well as any additional information that EPA determined to be necessary for determining compliance.

N. Additional Review Criteria:

In addition to the criteria specified in the CAG, EPA applied the following criteria when conducting its review of the CCA for compliance with §194.14 requirements:

- ♦ EPA has commented on previous versions of the CCA, raising many technical issues of concern. These previous comments were reviewed to gain an understanding of EPA's concerns. The CCA was examined to determine if the issues were addressed, how they were addressed, where they were addressed, and if the response completely and sufficiently addressed the technical issue raised.
- ♦ The CCA was reviewed with the CAG requirements in mind, as well as how information presented in the CCA for §194.14 compliance addresses issues pertinent to other elements of 40 CFR 194 (e.g. §194.25).
- ♦ The CCA was reviewed for the following:
  - Completeness relative to §194 requirements
  - Technical:
  - Were the arguments well formed?
  - Were they based on sound science?
  - Were the issues well supported?
  - Were all sides of an issue presented and thoroughly discussed?
  - Were the arguments supported by references, appendices, etc.?
  - Were peer review concerns reflected and addressed?

- Were data traceable?

IV. SUMMARY OF CCA CONTENT/DOE'S METHODOLOGY AND EPA TECHNICAL EVALUATION RESULTS

The CCA was reviewed for compliance with applicable §194.14 requirements following the review criteria set forth in Section III of this document. DOE constructed the CCA so that Chapter 2, together with associated appendices and references, addressed many of the §194.14 requirements. Further, DOE structured the CCA so that some subsections of Chapter 2 addressed specified technical elements set forth in the §194.14 regulations and the CAG. The EPA review, while following the specified §194.14 requirements, coincidentally also generally followed the subsection designations set forth in Chapter 2 of the CCA.

The following presents how DOE addressed specific technical requirements presented in the regulations and suggested by the CAG. This Technical Support Document addresses, sequentially, CCA presentation of material that DOE believes demonstrates 40 CFR §§194.14(a) through (j) compliance. The review first summarizes DOE's approach to addressing the issue including a brief summary table indicating where, in the CCA, the supporting information is contained. This information is presented under the heading "DOE Methodology", for each technical topic examined. DOE Methodology section is then followed by a section entitled "EPA Technical Evaluation Results", which presents the results of EPA's review, based upon the criteria set forth in Section III of this Technical Support Document. The heading of each major subsection identifies the portion of the regulation addressed in brackets, and may also include the specific section in CCA Chapter 2, in parentheses, which included supporting information.

A. Location of the Disposal System [40 CFR 194.14(a)(1)]

1. DOE Methodology: Location of the Disposal System

DOE listed the WIPP site location in Table 3-1 of the CCA as approximately 26 miles (42 kilometers) east of Carlsbad, New Mexico, in Eddy County. DOE indicated that the U.S. Public Land Survey designation for the area within the WIPP Land Withdrawal Act boundary is Township 22S, Range 31E, Sections 15-22 and Sections 27-34. The latitude of the WIPP site was given as 32° 22' 11" N and the longitude is 103° 47' 30" W. Area roads, communities and a general location map were shown on Figure 1-2 of the CCA, with site specific roads and range and township boundaries shown on Figure 3-1 of the CCA. These figures have been included in this Technical Support Document as **Figures I-1 and IV-1**. Table 3-1 of the CCA also provides the latitude and longitude designations and the size of the WIPP site, with areas defined by location, use and control features in Chapter 3.0 (pp. 3-1 to 3-3).

The facility has been divided into four areas designated for protection of human health and the environment: (1) the property protection area, which is surrounded by a chain-link security fence that encloses approximately 23 acres (13.7 hectares) and provides security and protection for all major surface structures; (2) the exclusive use area, which is approximately 277 acres (112 hectares) restricted exclusively for the use of DOE, its contractors, and subcontractors in support of the project and posted against trespass and use by the general public; (3) the off limits area, which consists of approximately 1,454 acres (5.9 square kilometers) posted and managed as off limits by DOE; and (4) the WIPP land withdrawal area, the 16-section (41.4-square-kilometer) federal land area under jurisdiction of DOE and bounded by the WIPP site boundary **(see Figure IV-1)**. The WIPP land withdrawal area is the controlled area for purposes of demonstrating compliance to 40 CFR Part 191. The waste area of the repository lies within the bounds of the off limits area, and within the WIPP land withdrawal area. Refer to CCA Chapter 3, pages 3-1 to 3-14 for additional information.

The waste disposal area of the WIPP repository is located at a depth of 2,150 feet (655 meters) below ground surface (bgs). The waste disposal area consists of eight panels, each of which contains seven rooms, and the access drifts and crosscuts adjacent to the disposal panels. The access drifts and crosscuts have been labeled Panels 9 and 10 for convenience. **Figure IV-2** of this Technical Support Document shows the location of the disposal area as a projection at the ground surface and **Figure IV-3** shows the configuration of the disposal panels. Refer to CCA Chapter 3, pages 3-1, 3-2 and 3-12 to 3-14 for additional information.

DOE described the physical setting of the land surface at the WIPP site as a semiarid, wind-blown plain sloping gently to the west and southwest, hummocky with sand ridges and dunes. A hard caliche layer underlies the sand blanket. The elevation of the ground surface at the site ranges from 3,570 feet (1,088 meters) above mean sea level (amsl) in the east to 3,250 feet (990 meters) amsl in the west. The average east-to-west slope is 50 feet per mile (9.4 meters per kilometer). The surface drainage in the vicinity of the WIPP site is intermittent due to the dry climate and the Pecos River, located 12 miles (19 kilometers) southwest of the site, is the closest perennial stream (Refer to CCA Chapter 2.1.4.2, pp. 2-67 to 2-68). DOE indicated that there are no well defined drainage features at the WIPP site. Figure 2-18 of the CCA provided a topographic map of the area around the WIPP Site.

2. EPA Technical Evaluation Results: Location of the Disposal System

EPA reviewed CCA Chapter 1, Section 1.3 (pp. 1-12 to 1-14), Chapter 2 (pp. 2-1 to 2-6), Chapter 3 (pp. 3-1 to 3-14), Chapter 6, Section 6.1 (pp. 6-13 to 6-35), and Chapter 7, the primary sources of information for the location of the disposal system. Various tables and figures, including Table 3-1, Figures 1-2, 2-18 and 3-1, provide general graphical information on the location of the disposal system. Some figures, such as Figure DEL-1, Figure 1-2, and Figure 3-1 are referred to specifically in the CCA to show the geographic location of the WIPP and the associated controlled area. These figures display the roads in the vicinity of the WIPP and present the WIPP's location on a country, state, and local scale. Other figures in the CCA, while not specifically referenced, also address §194.14(a)(1) requirements, such as Figure 2-38 and Figure 7-9 of the CCA, which show the repository footprint in relation to the Township and Range grid coordinate system. Table 3-1 lists WIPP site features such as latitude and longitude of the WIPP site center, Section, Township, Range, and county.

Section 2.1.4.2 (pp. 2-67 to 2-68) is the primary section in which the physical setting of the WIPP is described. Climatological, physiographic, topographic and all other pertinent aspects of the physical setting surrounding the WIPP are discussed in various portions of the CCA and its supporting references.

EPA examined the information provided in the CCA to confirm the presence of adequate information about the location of the disposal system and control area, and also evaluated the accuracy and consistency of this information. EPA found that DOE provided the required disposal system and controlled area information, and that the information was technically adequate.

B. Site Geology(2.1) [§(194.14(a)(2)]

1. Data Sources (2.1.1)

a. DOE Methodology: Data Sources

DOE indicated in CCA Chapter 2.1.1 (pp. 2-9 to 2-11) that the principal sources of geological data used in the CCA were collected over a 20+ year period and, included data acquired by DOE and its contractors, DOE predecessor agencies, the United States Geological Survey (USGS), New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private business engaged in natural resources exploration and extraction. In addition, the historical record of geologic work in professional journals and technical documents have been included in studies, some of which extend as far back as 1858. Borehole data sets constituted a major source of information for WIPP site characterization and were useful for establishing depths, thicknesses, and other rock and fluid parameters.

DOE stated in CCA Chapter 2.1.1 (p. 2-10) that quality assurance review of geological data used in performance assessment modeling included independent review by the National Academy of Sciences (NAS), the Environmental Evaluation Group (EEG), and the State of New Mexico (Governor's Radioactive Waste Consultation Task Force).

The following lists Appendices and select cross-references that serve as examples of data sources for the CCA:

Geologic data	Appendices GCR, SUM, HYDRO, FAC.
Recent Geological data	Chapter 6.4
Conceptual models	Chapter 6.4.6
Model parameters	Appendix MASS.15
Quality Assurance Program	Chapter 5.2
Pointers to Records Packages	Appendix PAR
Records Packages	Sandia WIPP Central Files (Albuquerque)
Borehole Data Sets	Appendix BH
Delaware Basin borehole data	Chapter 2.3.1.2, Appendix DEL

b. EPA Technical Evaluation Results: Data Sources

The CCA presented, in CCA Chapter 2.2.2 (pp.2-9 through 2-11), a brief synopsis of the data collection history relative to site characterization information, and cross references many data sources throughout Chapter 2. EPA examined the information provided in the CCA to evaluate the accuracy and consistency of the data sources information provided by DOE and EPA found the data sources information provided by DOE was technically adequate.

2. Geologic History (2.1.2)

a. DOE Methodology: Geologic History

DOE summarized the major geologic events in a 200 mile radius (320 kilometer) surrounding the WIPP site in CCA Chapter 2.1.2 (pp. 2-11 to 2-12), Figure 2-3, Appendix GCR (Section 3.6), and Appendix HYDRO (pp. 10 to 22). Of particular interest relative to the WIPP is the geologic history that resulted in deposition of sediments, above the crystalline basement that is projected to be present at least 14,500 feet bgs, (4.42 kilometers - Foster, 1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1) and up to 18,200 feet bgs (5.5 kilometers - Sipes, Williamson and Aycock 1976) [CCA Reference 593] (Docket A-93-02, Item II-G-1) in the Delaware Basin. Three geologic time periods were the focus of DOE's presentation:

1) 1.5 to 1.1 billion years before the present (Precambrian-age) consisting of metamorphic and igneous rocks;

2) An erosional period from about 1.1 to 0.6 billion years before the present; no rocks from this time period are preserved in the WIPP region; and

3) Sedimentation, including shorter periods of erosion and dissolution, extending from about 0.6 billion years ago to the present.

The list of events occurring between 0.6 billion years ago to the present, included periods of erosion, deposition, tectonic, and solution activity. For example, in CCA Figure 2-3, DOE indicated that major periods of erosion that have occurred during this time period included:

- Precambrian [(570 million years before present (mybp)] time (prior to sedimentation): erosion of the Precambrian surface to a nearly level crystalline rock plain;
- Middle Devonian (384 mybp): erosion of marine sediments;
- Early Mississippian (360 mybp): regional erosion, developing deep, broad basins east and west of the Central Basin Platform;
- Early Triassic (245 mybp): erosion to a broad plain;
- Jurassic (144 mybp): formation of rolling terrain;
- Early Tertiary to mid-Tertiary (66.4 - 23.7 mybp): erosion, dominant process; no Paleocene, Eocene ,or Oligocene-age sediments are present in the WIPP area because of this; and

♦ Present landscape: erosion and solution activity.

Periods of major deposition identified by DOE included:

♦ Cambrian Bliss sandstone (to 500 mybp): quartz sandstone, dolomitic sandstone, and sandy dolomite;

♦ Early Ordovician Tobosa (to 472 mybp): deposition of shelf clastics, including detrital carbonate from the Central Basin Platform;

♦ Late Ordovician (to 438 mybp): deposition to the Marathon-Ouachita geosyncline, south of the project area;

♦ Pennsylvanian and Permian (320 - 245 mybp): deposition of clastics to shelf, shelf margin, and basin deposition settings, followed by evaporites and redbeds during the Permian Period;

♦ Early Jurassic (208 mybp): deposition of fluvial clastics;

♦ Cretaceous (114 - 66.4 mybp): deposition of marine limestones; and

♦ Late Tertiary (12 - 4 mybp): deposition of Gatuña sediments, and formation of caliche caprock.

DOE listed, in CCA Figure 3-2, the following major tectonic episodes as occurring in the general Delaware Basin area:

♦ Late Ordovician (438 mybp): regional folding related to the Marathon-Ouchita trend;

♦ Early Devonian to middle Mississippian (408-340 mybp): mild uplift, creating the Perdernal landmass and the emergent Texas Panhandle;

♦ Late Mississippian (340-320 mybp): regional tectonism, creating the Central Basin Platform, matador Arch, and Ancestral Rockies; and

♦ Tertiary (66.4 - 1.6 mybp): Laramide movements creating the Sacramento, Guadalupe-Delaware, and Rocky Mountains.

DOE noted the following solution activity preserved in the stratigraphic record:

♦ Late Pliocene and early Pleistocene time (3.45 - .795 mybp) when the caliche caprock was thinned by erosion and etched by solution, and local sinkholes formed;

♦ Solution accelerated in the middle Pleistocene (.795 mybp) followed by a drier climate, and formation of the Mescalero caliche; and

♦ Later Pleistocene to present (.795 mybp - Recent), when the rate of solution slowed compared to the middle Pleistocene, and continues to the present.

The following lists Appendices and example of cross-references for CCA Chapter 2.1.2, Geologic History:

Standard Stratigraphic Reference(s)	Palmer 1983, 503-504, for the Decade of North American Geology (DNAG) [CCA Reference 409].(Docket A-93-02, Item II-G-1)
Major Geologic Events	Figure 2-3, p. 2-15
Precambrian depth estimate	Foster, 1974, Figure 3 [CCA Reference 253] (Docket A-93-02, Item II-G-1)
Precambrian depth estimate	Sipes, Williamson and Aycock 1976, Vol. II, Exhibit. No. 2 [CCA Reference 593] (Docket A-93-02, Item II-G-1)
Key borehole for depth estimate	Section 15, T22S, R31E
Rock record for 1.1-0.6 byp	Appendix GCR, Section 3.3.1

b. EPA Technical Evaluation Results: Geologic History

EPA concluded that CCA Chapter 2.1.2 (pp. 2-11 to 2-12) and associated Appendices GCR, Section 3.6 (pp. 3-83 to 3-108), Section 4.5 (pp. 4-79 to 4-88), HYDRO (pp. 10-22), and related references (e.g., Chapter 6.0.2.2 (pp. 6-2 to 6-5)) provide a technically adequate description of the geologic history of the WIPP area for purposes of the performance assessment (PA). EPA's initial review of the CCA raised questions regarding how DOE addressed the origin, nature, and distribution of fractures within supra-Salado rock units and Salado marker beds. These questions were sent to DOE in a letter dated December 19, 1996 (Docket A-93-02, Item II-I-01). The December 19, 1996 letter (Enclosure 2, page 7, 194.32(e)(3)) indicated that Anderson commented extensively on the development of karst dissolution and the link to climatic fluctuations (Docket A-93-02, Item II-D-22, July 14, 1994, Anderson to Lovejoy), and indicated that "The Department needs to address Anderson's hypotheses specifically to discount them with more thorough analyses or data, or the results of modeling to show the proposed effects are bounded by the CCA assessments." The December 19, 1996 letter (Enclosure 1, page 4, 194.14(a)(3)) (Docket A-93-02, Item II-I-01) also requested that "The CCA should be revised to include a more detailed discussion regarding the nature, extent, geologic characteristics, etc., of pre-existing fractures within Salado Formation marker beds." Supplemental information provided by DOE in a letter dated January 24, 1997 (Docket A-93-02, Item II-I-03) and supporting EPA studies indicated that DOE's treatment of these features is acceptable (refer to detailed discussion of these topics below).

3. Stratigraphy and Lithology (2.1.3)

DOE provided information regarding the stratigraphy and lithology of the rock units surrounding the WIPP in CCA Section 2.1.3 of Chapter 2 (pp. 2-12 to 2-64), as well as in Appendices GCR (Section 4, pp. 4-1 to 4-94), FAC, HYDRO (pp. 10-21), and other supporting references, including Appendix SUM, Sections 1.3 (pp. 6-10) and 6.3.5 (pp. 6-28 to 6-37).

Figure IV-4 of this Technical Support Document presents the complete stratigraphic column in the WIPP area.

a. DOE Methodology: General Stratigraphy Below the Bell Canyon (2.1.3.1)

The CCA, Chapter 2.1.3.1 (pp. 2-19 to 2-23), and associated Appendices GCR.4.3.1 (pp. 4-12 to 4-13), FAC and HYDRO described the stratigraphy and lithology below the Bell Canyon Formation including a brief description of the Precambrian basement rocks and detailed descriptions of the overlying Paleazoic rocks.

DOE indicated that the Precambrian basement rocks beneath the site are believed to be either granitic igneous rock or metamorphosed granites and ryholites. Based on information from the two boreholes closest to the WIPP site that have reached the basement rocks (approximately 13 miles north-northwest and 12.5 miles north-northeast), the depth to the Precambrian basement rocks has been inferred to be approximately 18,200 feet (5.5 kilometers).

The basal Paleozoic rocks beneath the WIPP site are the Ordovician age Ellenberger, Simpson and Montoya groups of the northern Delaware Basin. The projections of thicknesses within the WIPP site boundaries range from 1,200 feet (366 meters - Sipes, Williamson and Aycock, 1976) [CCA Reference 593] (Docket A-93-02, Item II-G-1) to 1,300 feet (396 meters - Foster, 1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1). The rock type is predominantly carbonates, with sandstone and shale in the Simpson.

Silurian-Devonian rocks include basal dolomite and limestone approximately 1,150 feet thick (351 meters) and the Devonian Woodford shale approximately 170 feet thick (52 meters - Foster, 1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1). DOE reported that Mississippian rocks consisting of basal limestone and overlying shale are present within the boundaries of the WIPP site. The basal limestone is 480 to 540 feet thick (146 to 165 meters) and the overlying shale is 80 to 200 feet thick (24 to 61 meters).

DOE, in CCA Chapter 2.1.3.1 (pp. 2-19 to 2-23), presented the following stratigraphic nomenclature for the Pennsylvanian System (from base to top): Morrow, Atoka and Strawn, consisting of mixed clastics and carbonates, with carbonates more abundant in the upper Atoka and Strawn. The Pennsylvanian rocks were estimated to be 2,088 to 2,200 feet thick (636 - 671 meters) at the WIPP site.

DOE indicated in CCA Chapter 2.1.3 (p. 2-20) and Appendix GCR.4.3.2 (pp. 4-19 to 4-44) that the Permian age rocks are the thickest system in the northern Delaware Basin and are divided into four series from the base to the top: Wolfcampian, Leonardian, Guadalupian and Ochoan. DOE indicated that the overall thickness of the three lower series near the WIPP site has been estimated as 8,684 feet (2.6 kilometers - Sipes, Williamson and Aycock, 1976) [CCA Reference 593] (Docket A-93-02, Item II-G-1) and 8,500 feet (2.6 kilometers - Foster, 1974 isopachs) [CCA Reference 253] (Docket A-93-02, Item II-G-1). DOE indicated that the Ochoan Series is discussed in more detail later since the formations host and surround the WIPP repository horizon.

The Wolfcampian Series is also referred to as the Wolfcamp Formation in the Delaware Basin and consists of a thick sequence of interbedded limestone and shale. DOE indicated that at the WIPP site, the shale content likely equals the carbonate content. The thickness of the Wolfcampian near the WIPP site was estimated at 1,493 feet (455 meters - Sipes, Williamson and Aycock, 1976) [CCA Reference 593] (Docket A-93-02, Item II-G-1) and slightly less than 1,400 feet (426 meters - Foster, 1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1).

The Leonardian Series in the vicinity of the WIPP site is represented by the Bone Spring Limestone. DOE indicated that the lower part of the Bone Spring Limestone is commonly interbedded carbonate, sandstone and some shale, while the upper part is predominantly dolomite. Near the WIPP site the Bone Spring Limestone is believed to be approximately 3,500 feet thick (1,067 meters - Foster, 1974 and Boring Logs) [CCA Reference 253] (Docket A-93-02, Item II-G-1).

The Guadalupian Series is known as the Delaware Mountain Group in the Delaware Basin and comprises three formations: Brushy Canyon, Cherry Canyon and Bell Canyon, from base to top. The Delaware Mountain Group near the WIPP site consists of mostly submarine channel sandstones with interbedded limestone and some shale. From a borehole located approximately 2 miles northeast o f the WIPP site, the overall thickness of the Delaware Mountain Group was recorded as 3,944 feet (1,200 meters). The Shell No. 1 James Ranch well located approximately 3 miles (4.8 kilometers) southwest of the WIPP site indicated an overall thickness of 3,970 feet (1,210 meters - Foster, 1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1) which includes 1,540 feet (469 meters) of Brushy Canyon Formation, 1,070 feet (326 meters) of Cherry Canyon Formation and 1,780 feet (360 meters) of Bell Canyon Formation.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.1, General Stratigraphy and Lithology below the Bell Canyon:

Detailed discussion and structure of Precambrian	Appendix GCR, Section 3.3.1
Silurian and Devonian thicknesses	Foster, 1974, Figures 7 and 8 [CCA Reference 253] (Docket A-93-02, Item II-G-1)
Mississippian thicknesses	Foster, 1974, Figure 10 [CCA Reference 253] (Docket A-93-02, Item II-G-1) Sipes, Williamson and Aycock 1976, Vol. II, Exhibit No. 2 [CCA Reference 593] (Docket A-93-02, Item II-G-1)
Pennsylvanian thicknesses	Foster, 1974, Figure 13 [CCA Reference 253] (Docket A-93-02, Item II-G-1) Sipes, Williamson and Aycock 1976, Vol. II, Exhibit No. 2 [CCA Reference 593] (Docket A-93-02, Item II-G-1)

b. EPA Technical Evaluation: Stratigraphy Below the Bell Canyon

The CCA included information pertaining to the site geology in Chapter 2.1.3.1 and Appendix GCR, as well as additional references. Chapter 2.3.1 discussed natural extractable resources in the WIPP area, many of which occur in units below the Bell Canyon Formation. **Figure IV-4** of this Technical Support Document presents the stratigraphy of units below the Bell Canyon.

The description presented in the text of the CCA was very general and did not specifically address, for example, oil and gas-bearing units below the WIPP in detail. Chapter 2.1.3.1 did not specify which of the Paleozoic rock units contain oil and/or gas reserves, nor did it discuss the specific depositional environment, lateral continuity, etc. of these oil and gas bearing units in the WIPP vicinity. However, EPA found that although the CCA did not include a concise description of units below the Bell Canyon within the application itself, the necessary information was available in associated appendices and references (Appendix GCR, pp. 4-1 to 4-23).

Delaware Basin geologic units occurring below the Bell Canyon Formation include the Brushy Canyon Formation and the Cherry Canyon Formation. It is not expected that these units will have significant influence on the undisturbed repository based on their location and general hydrologic characteristics. Because of their depth, a relatively low number of exploratory drilling incursions have penetrated or recovered material from these units. Available evidence suggests that the Brushy Canyon and Cherry Canyon Formations have a lower permeability, due to an increased proportion of fine grained sediments (i.e. siltstone) and also increased cementation, relative to the Bell Canyon. The reasoning presented in the CCA, regarding why the Brushy Canyon and Cherry Canyon Formations will not have significant influence on the repository (e.g. based on their location and available geologic information) appears technically reasonable. The Bell Canyon Formation is the oldest geologic unit described in detail in the CCA.

c. DOE Methodology: Stratigraphy of the Bell Canyon (2.1.3.2)

The CCA, Chapter 2.1.3.2 (pp. 2-23 and 2-24) and Appendix GCR.4.3.2 (pp. 4-22 to 4-23) provided a description of the Bell Canyon Formation and indicated that it is the youngest of the Permian age Guadalupian Series (Delaware Mountain Group). The Bell Canyon was described as mostly fine-grained sandstone with varying amounts of silty and shalely interbeds. The Bell Canyon also has limestone interbeds and a limestone member at the top of the formation called the Lamar limestone. As noted above, the Shell No. 1 James Ranch well, located approximately 3 miles (4.8 kilometers) southwest of the WIPP site indicated the Bell Canyon Formation was 1,180 (360 meters) thick.

DOE stated in Chapter 2.1.3.2 (p. 2-23) that the Bell Canyon as the "first laterally continuous transmissive unit below the WIPP repository," and is composed of a series of sandstones deposited by density currents flowing from shelf regions to the north of the WIPP Site. Between the WIPP repository and the Bell Canyon, the 1,400-to-1,600-foot (427-to-487-meter) thick Castile Formation is present, which consists primarily of anhydrite and halite. DOE recognized potential for groundwater to migrate from the Bell Canyon and cause dissolution of the Salado near the repository, but contended that this will not occur (of sufficient magnitude) within the 10,000 year regulatory period. Refer to CCA Chapter 2.2.1 (pp. 2-97 to 2-108), Appendix HYDRO (pp. 26 to 33) and Section IV.B.3.t of this Technical Support Document for additional information regarding this topic.

The presence of an evaporitic unit above a more transmissive unit led Anderson (1978) [CCA Reference 12] (Docket A-93-02, Item II-G-1) to propose the "deep dissolution hypothesis" which describes fluid circulation between the Bell Canyon and the overlying Castile-Salado. Fresher, lighter water of the Bell Canyon may migrate upward into fracture systems of the overlying evaporite units, replaced in volume by downward brine flow. Fresher fluid flows may dissolve Castile or Salado evaporites, forming collapse structures and local mounds and depression (see Appendix DEF, Figure DEF-4, p. DEF 19). Anderson suggested the process was operative on a regional scale, removing significant volumes of halite from the Salado and Castile during the Cenozoic era (66.4 mybp - Present).

Information on the Bell Canyon is available both from outcrops and from wells drilled for oil and gas exploration and production. For example, DOE indicated in CCA Chapter 2.1.3.2 (p. 2-23) that the Clayton Williams Badger Federal well (Section 15, T22S, R31E) intercepts 961 feet (293-meters) of Bell Canyon sediments, including the Lamar limestone.

The position of the Bell Canyon can be distinguished because of contrasting geophysical and geological characteristics with the overlying Castile anhydrite. DOE suggested that structure of the Bell Canyon may have occurred after deposition and independently from underlying formations.

For example, DOE indicated that surface mapping and wells WIPP 16, WIPP 31, and WIPP 32 provide evidence showing a difference between surface features, such as breccia pipes formed by deep solution, and by surficial solution such as karsting. Breccia pipes developed through the Salado were found to be related, in all cases, to the presence of an underlying Capitan Limestone, which exists more than 6 miles (10 km) north of the WIPP site (Appendix DEF.3.1, pp. DEF-22 to DEF-25).

Deep dissolution was thought to be present in an area about 2 miles north of the WIPP site, sampled by borehole DOE-2, though thickness variations in evaporite strata were attributed to deformation rather than dissolution (Borns 1987)[CCA Reference 76] (Docket A-93-02, Item II-G-1). DOE concluded that there is "no unequivocal information that supports the possibility of localized deep dissolution occurring anywhere other than at the edges of the Capitan Reef" (Appendix DEF.3.1, p. DEF-25).

The following lists Appendices and cross-references for CCA Chapter 2.1.3.2, the Bell Canyon:

Bell Canyon Hydrology	Chapter 2.2.1.2
Dissolution discussion	Appendix DEF.3.1
Bell Canyon type discussion	Sipes, Williamson and Aycock 1976, Vol. II, Exhibit No. 2 [CCA Reference 593] (Docket A-93-02,

	Item II-G-1)
Bell Canyon Structure	Figure 2-6, Appendix MASS.18 MASS Attachment 18-6, Figure 5.3-3
Relation to deeper structures	Appendix GCR, 4-59

d. EPA Technical Evaluation: Stratigraphy of the Bell Canyon

The description of Bell Canyon stratigraphy presented in the text of CCA Chapter 2.1.3.2 of the CCA is brief. However, DOE presented additional stratigraphic information for the Bell Canyon in various appendices (i.e. DEL, HYDRO, GCR) and supporting references. Appendix HYDRO provided, perhaps, the most concise description of lithology for each of the four members; Ford shale, Ramsey sandstone, Trap, and Lamar shale. EPA concluded that the description of the Bell Canyon stratigraphy appears to be technically reasonable based on lithologic information available for the Bell Canyon. The lithology, depositional environment, lateral continuity, etc. of oil and gas bearing units in the Bell Canyon in the WIPP vicinity are also generally described in the above mentioned CCA supporting appendices and references. For example, Appendix HYDRO (p. 14) stated that lithologic relationships in the Ramsey sandstone are appropriate to create some hydrocarbon traps and it is therefore the main oil and gas producing unit in the Bell Canyon.

e. DOE Methodology: Stratigraphy of the Castile (2.1.3.3)

The CCA, Chapter 2.1.3.3 (p. 2-24) and Appendix GCR.4.3.2 (pp. 4-23 to 4-44), indicated that the Castile Formation is the lowermost formation in the Permian age Ochoan Series. The Ochoan Series are the uppermost Paleozoic rocks in the vicinity of the WIPP site and includes perhaps the thickest and most extensive evaporative rock sequence in North America. The Ochoan Series rocks are entirely of marine origin and are divided into a thick lower section of evaporites and a thin upper section of redbeds (Jones et al., 1973) [CCA Reference 342] (Docket A-93-02, Item II-G-1). The lower evaporites include the Castile, Salado and Rustler Formations and the upper redbeds are the Dewey Lake Redbeds. At the WIPP site, the Ochoan rocks are about 3,900 to 4,000 feet (1,188 to 1,219 meters) thick of which 3,600 to 3,800 feet (1,097 to 1,158 meters), or about 90 percent are the evaporative sequence.

The CCA, Chapter 2.1.3.3 (pp. 2-24 to 2-29) and Appendix GCR.4.3.2 (pp. 4-23 to 4-44), described the Castile as an evaporite sequence consisting mostly of interlaminated carbonate, anhydrite and high-purity halite, having no indication of native sulfur near the WIPP site. Information on the Castile is available both from outcrops and from wells drilled for oil and gas exploration and production. DOE adopted informal member names as follows (from the base): anhydrite I (A1), halite I (H1), anhydrite II (A2), etc. In the eastern portion of the Delaware Basin, the Castile is commonly 1,400 to 1,600 feet (427 to 487 meters) thick. In Boring DOE-2, located approximately 2 miles north of the repository, the Castile was noted to be 989 feet (301 meters) thick.

DOE indicated, in Chapter 2.1.3.3 (pp. 2-24 to 2-29), that in part of the area around the WIPP, the Castile has been significantly deformed and there are pressurized brines associated with the deformed areas. The brine reservoirs are believed to be in fracture systems within the upper part of the Castile, though not all wells drilled through the Castile may encounter fractures (or brine) due to fracture spacing.

According to CCA Chapter 2.1.6 (pp. 2-8 to 2-87), deformation in the Castile is due mainly to gravity foundering, and four additional processes are also considered: dissolution; gravity sliding; gypsum dehydration, and depositional movements. Anhydrite fracturing is due to rheological contrast between halite and anhydrite, which may deform halite and fracture anhydrite, where both are in the same stress field. The tendency for denser anhydrite to sink into halite can deform strata, fracture anhydrite, and pressurize brines in fracture systems.

The CCA, Chapter 2.1.6.1.1 (p. 2-85) and Appendix DEF.2 (p. DEF-14 and DEF-17), indicated that when Borehole ERDA-6, located approximately 4.5 miles (7.2 kilometers) northeast of the site, was drilled in 1975 it encountered pressurized brine and natural gas at a depth of 2,711 feet (826 meters) in the Castile. DOE found beds within the Castile displaced upward by hundreds of feet, and Anderson and Powers (1978) reported “piercing” of upper Castile units by lower units. DOE used the ERDA-6 well data, together with knowledge of deformed Castile strata about 6 miles (10 kilometers) wide where evaporites are underlain by the Capitan Reef, to derive areas of less deformed Castile suitable for the WIPP site. In another example: results from Borehole DOE-2 suggested that depressions in the Salado, located 2 miles (3.3 kilometers) north of the site were caused by salt movement (halokinesis), rather than by dissolution. As a result, DOE asserted in Chapter 2.1.3.3 (pp. 2-24 and 2-25) that "no Castile dissolution is known to be present in the immediate vicinity of the WIPP site."

Through 1977 and 1978, DOE collected seismic geophysical data to aid in mapping “disturbed” and “non-disturbed” zones of the Castile. Results of the survey (CCA Appendix DEF, Figure DEF-2) showed an “area of complex structure” of the middle Castile strata 0.5 to 1 mile (0.8 to 1.6 km) north of the WIPP storage facility. Well ERDA-11, located 2.7 miles (4.3 km) north of the WIPP storage facility was drilled in 1978 as a result of the geophysical mapping, and the well encountered extensive deformation within the Castile, including strata extending into the overlying Salado. No over pressured brine was found in the ERDA-11 well. Refer to Chapter 2.1.6.1.1 (p. 2-85) and Appendix DEF (pp. DEF1 to DEF-16) for additional information regarding Castile deformation.

The 1977 and 1978 seismic maps also suggested faulting between the Salado and the Rustler, possibly related to deformation in the Castile. To investigate the apparent structure, DOE drilled wells WIPP 18, 19, 21, and 22 within the WIPP site boundary and found “no detectable offset” (Appendix DEF.2.1, p. DEF-5) on the contact between the Rustler and Salado. As a test of Castile fluid characteristics in relatively undisturbed Castile structure, DOE deepened the WIPP-12 well in 1981. DOE found fractured anhydrite in the upper Castile associated with pressurized brine. A subsequent electrical geophysical survey (done by Earth Technology Corporation in 1987 and calibrated to areas of known pressurized brine) (Earth Technology Corporation, 1988) [CCA Reference 229] (Docket A-93-02, Item II-G-1) suggested the presence of brine under part of the WIPP facility, south of the disturbed zone. Refer to Chapter 2.1.6.1.1 (p. 2-85) and Appendix DEF (pp. DEF1 to DEF-

16) for additional information regarding Castile deformation.

Brine chemistry and interactions with surrounding Castile strata suggested brine residence times of 25,000 to 50,000 years. DOE accepted the most recent brine movement to be 800,000 years ago (Lambert and Carter, 1984) [CCA References 379] (Docket A-93-02, Item II-G-1), and an estimated time to deform evaporites of 700,000 years. Because the time required to achieve evaporite deformation greatly exceeds site permit requirements, and because pressurized brines of the Castile are confined within evaporites, DOE concluded: the effects of brine and structure in the Castile underlying the WIPP site, such as have been encountered in the ERDA-6 and WIPP-12 wells, "represent no threat to health and safety" (Appendix DEF.2.5, p. DEF-17).

The following lists Appendices and cross-references for CCA Chapter 2.1.3.3, the Castile:

Top Castile Structure	Appendix GCR, Figure 4.4-6
Seismic time structure	Appendix DEF, Figure DEF-2
Castile deformation	Chapter 2.1.6, Appendix DEF
Castile dissolution discussion	Appendix DEF.3
Pressurized brine discussion	Chapter 2.2.1
Brine conceptual model	Chapter 6.4.8
Stratigraphic & Lithologic parameters	Appendix PAR, Table PAR-49

f. EPA Technical Evaluation Results: Stratigraphy of the Castile

The information regarding the general lithology and stratigraphy of the Castile Formation provided in CCA Chapter 2.1.3.3 (pp. 2-24 to 2-29) of the CCA and its supporting documents, including Appendix GCR appears to be technically reasonable. Information was provided regarding the definition and stratigraphic/depositional limits of the Castile Formation, associated nomenclature and lithologic variation. Graphics for the Castile were included in supporting references such as Appendix GCR, Appendix MASS, and others (Borns et al., 1983; Popielak et al., 1983)[CCA References 79 and 511] (Docket A-93-02, Item II-G-1). The deformation that has been observed in the Castile has been described, based on the limited lithologic and geophysical information available, and the most likely causes of the disturbances were discussed in Appendix DEF.

EPA concluded that information regarding the general lithology and stratigraphy of the Castile contained in Chapter 2.1.3.3 (pp. 2-24 to 2-29) and its supporting documents, including Appendix GCR, Section 4.3.2 (pp. 4-25 to 4-29) was technically adequate. EPA noted that DOE's geologic and geophysical basis for the distribution (i.e., 8 percent probability) of Castile disturbed zone structures below the WIPP appeared questionable, and therefore required [Docket A-93-02, Item II-I-25] this distribution to be revised (to a uniform distribution with a range of 0.01 to 0.6) in Performance Assessment Verification Testing. The formation of Castile brine pockets as a result of Castile deformation was described in the CCA, and although DOE's discussion of the distribution and nature of fractures in the Castile was limited, modification of parameters to include larger Castile brine pockets in the Performance Assessment Verification Testing sufficiently addressed this concern.

g. DOE Methodology: Stratigraphy of the Salado (2.1.3.4)

The CCA provided information regarding the stratigraphy and lithology of the Salado Formation (Salado) within Chapter 2.1.3.4 (pp 2-29 to 2-37) and Appendix GCR, Chapter 4.3.2 (pp. 4-29 to 4-39) and indicated that the Salado consists of approximately 2,000 feet (609 meters) of bedded halite, with interbeds or seams of anhydrite, clay, and polyhalite. The Salado Formation is the host formation for the WIPP repository and DOE stated in Chapter 2.1.3.4 (p. 2-29) that this regionally extensive evaporite provides the primary natural containment for potential radionuclide releases from the WIPP. The Salado is part of the Permian age Ochoan Series and is approximately 2,000 feet (609 meters) thick in the WIPP area and is divided into an unnamed upper member, the middle McNutt Potash Zone, and an unnamed lower member. At Borehole ERDA-9, located at the center of the WIPP site, the Salado was found to be 1,976 (602 meters) thick.

DOE indicated that there are 10 potash zones within the McNutt Member of economic significance in the vicinity of the WIPP. Potash is a potassium compound used in agriculture and industry. In addition, DOE indicated that there numerous sulfate beds (primarily anhydrite) within the Salado. The anhydrite layers are designated as marker beds and have been numbered MB100 (near the top of the formation) to MB 144 (near the base). The repository zone lies between MB 138 and MB 139 (Chapter 2.1.3.4, p. 2-30). Figure 2-8 of the CCA (**Figure IV-5** of this Technical Support Document) illustrates the location of the WIPP repository within the lower member of the Salado and a detailed view of the stratigraphy of the lower member. The underlying Salado-Castile contact is placed on the uppermost Castile anhydrite, A-3. Refer to Chapter 2.1.3.4 of the CCA for additional information.

DOE studied the mineralogy of the Salado and relative abundance of said minerals, and found halite (sodium chloride) to be most abundant followed by anhydrite (calcium sulfate), with interbeds also present that consist mainly of clay and anhydrite. Different mineral compositions respond differently to stress, and DOE noted that anhydrite, polyhalite, magnesite, and dolomite may be prone to fracturing, while halite would not fracture under similar stress conditions. DOE stated that fluid within the Salado is of two types: brine in isolated inclusions within the salt, and fluid moving within interbeds, along clay boundaries and in anhydrite fractures. Refer to Chapter 2.1.3.4 of the CCA for additional information.

Depositional environment pertaining to the Salado indicate cyclical depositional patterns are present that represent changes in an evaporitic marine environment. Lowenstein (1988) recognized two depositional cycles within the Salado. Type I cycles consist of basal mixed siliciclastic and carbonate mudstone, laminated to massive anhydrite or polyhalite, halite, and halite with mud. Type I cycles were interpreted as having formed in a shallowing upward, desiccating basin beginning with a perennial lake or lagoon of marine origin and evaporating to saline lagoon and salt pan environments. Type II cycles are considered incomplete type I cycles and consist of repetitious sequences of halite and halite with mud. The Type II cycles were interpreted as not exhibiting features of prolonged subaqueous deposition and also had more siliciclastic influx than the Type I cycles. Refer to Chapter 2.1.3.4 of the CCA for additional information.

DOE described argillaceous halites and halitic mudstone at the top of many Salado depositional cycles, based on data from the WIPP site air intake shaft (Holt and Powers 1990). DOE indicated that no evidence that post-depositional dissolution has occurred at the WIPP Site was found during detailed mapping of the air intake shaft. However, dissolution of the upper Salado halite has occurred west of the site in Nash Draw. DOE found the Salado-Rustler contact to be marked by siltstone and mudstone channeling and fossil fragments.

DOE indicated that radiometric techniques provide a means of determining the approximate time of the latest episode of regional recrystallization of evaporite minerals. DOE inferred this to be the approximate time of the latest episode of freely circulating groundwater. DOE indicated that radiometric dates for minerals of the Salado are available from mines and boreholes in the vicinity of the WIPP (Brookins, 1980; Brookins et al., 1980; Brookins, 1981; and Brookins and Lambert, 1987) [CCA References 88, 689, and 87)] (Docket A-93-02, Item II-G-1). From the available radiometric data, DOE indicated that the latest episode of regional recrystallization of evaporite minerals are 198 to 216 million years before present.

DOE indicated that one significantly younger recrystallization event has been identified in evaporites in the WIPP region and has been shown to be a contact phenomenon associated with the emplacement of an Oligocene igneous dike located approximately 8 miles (12.9 kilometers) northwest of the WIPP. Radiometric dating of the polyhalite near the dike indicated an age of 21 million years (Brookins, 1980; Calzia and His, 1978) [CCA References 88 and 18] (Docket A-93-02, Item II-G-1). DOE concluded that this exception not withstanding, the results of the radiometric determinations argue for the absence of pervasive recrystallization (and hence groundwater circulation) in the Salado in the last 200 million years (Chapter 2.1.3.4, p. 2-36).

The following lists Appendices and examples of cross-references for CCA Chapter 2.1.3.4, the Salado:

Detailed Salado descriptions	Appendix GCR
Salado conceptual model	Chapter 6.4.5
Salado thicknesses	Appendix PAR, Table PAR-57
Intra-Salado isopachs	Appendix GCR, Figures 4.3-4 to 4.3-7
Salado structure contour	Appendix GCR, Figure 4.4-10
Salado mineralogy and abundance	Table 2-2
Salado Geochemistry	Appendix GCR, Chapter 7
Interbed fluids	Appendix GCR, Sections 7.5 and 7.6
Salado cyclical deposition	Lowenstein 1988, p. 592-608 [CCA Reference 409] (Docket A-93-02, Item II-G-1)
WIPP Site Salado cycles	Holt and Powers 1990, p. 3-26.
Halite cements	Holt and Powers 1990, Appendix F [CCA Reference 311] (Docket A-93-02, Item II-G-1)
Dissolution studies	Appendix DEF.3

Radiometric dates of recrystallization	Brookins 1980, p. 29-31 [CCA Reference 88] (Docket A-93-02, Item II-G-1) Brookins et al. 1980, pp. 29-31, 635-637 [CCA Reference 88] (Docket A-93-02, Item II-G-1) Brookins 1981 [CCA Reference 689] (Docket A-93-02, Item II-G-1) Brookins and Lambert 1987, p.771 - 780 [CCA Reference 87] (Docket A-93-02, Item II-G-1)
Creep closure in the Salado	Appendix PORSURF
Salado Hydrological conceptual model	Chapter 6.4.5
Salado Hydrological parameters	Table 6-14
Interbed hydrological parameters	Table 6-15
Salado interbed fractures	Table 6-17
Fracture model assumptions	MASS 13.3

h. EPA Technical Evaluation Results: Stratigraphy of the Salado

The description of the lithology and stratigraphy of the Salado Formation, especially in the vicinity of the repository horizon, provided in Chapter 2.1.3.4 of the CCA and supporting documents appears to be technically reasonable. Information was provided on the definition of the Salado, associated nomenclature and lithologic variation. The mineralogy of the geologic units of the Salado was described in the CCA (i.e. Table 2-2) and supporting references (i.e. Appendix GCR and Stein, 1985) [CCA Reference 604] (Docket A-93-02, Item II-G-1).

EPA concluded that the description of the lithology and stratigraphy of the Salado, especially in the vicinity of the repository horizon, provided in CCA Chapter 2.1.3.4 (pp. 2-29 to 2-37), Appendix GCR, Section 4.3.2 (pp. 4-29 to 4-39), and supporting documents, was appropriate for use in performance assessment. Although Salado Marker Bed characteristics were not detailed in the CCA, DOE submitted supplemental information in a letter dated April 15, 1997 (DOE, 1997e) (Docket A-93-02, Item II-I-24) regarding fracturing within anhydrites which clarified DOE's approach to anhydrite fracture properties pressurized conditions. While Salado Marker Bed fracturing is apparently not pervasive, universal, and predictable, the large scale (i.e., the entire WIPP site) over which these fracture systems occur would tend to diminish the heterogeneity of the fracture systems.

i. DOE Methodology: Stratigraphy of The Rustler 2.1.3.5.

The CCA provided information regarding the stratigraphy and lithology of the Rustler Formation (Rustler) in Chapter 2.1.3.5 (pp. 2-37 to 2-53) and Appendix GCR, Section 4.3.2 (pp. 4-39 to 4-42), then described each of the five units of the Rustler separately under subsections 2.1.3.5.1 through 2.1.3.5.5. The Rustler overlies the Salado near the WIPP site and consists of evaporite units interbedded with siliciclastic beds and carbonates. DOE divided the Rustler into five members (from the base): Unnamed Lower member, Culebra Dolomite member, Tamarisk member, Magenta Dolomite member and Forty-niner member

[Figure 2-9 of the CCA (**Figure IV-6** of this Technical Support Document)]. DOE described the Rustler as the last evaporite sequence of the Permian age Ochoan Series, containing the largest proportion of clastics relative to rock salt of earlier evaporite sequences in the following proportions: salt 43%; anhydrite 30%; clastics 17%; dolomite and other carbonates 10%.

The Rustler has been the subject of extensive characterization activities because it contains the most transmissive hydrologic units overlying the Salado (specifically, the Culebra). The Rustler is 300 to 350 feet (91 to 107 meters) thick within most of the WIPP site. The total Rustler isopach is 294 to 398 feet (90 to 121 meters) across the WIPP site; a depocenter is mapped east and southeast of the WIPP site and thickness of the Rustler is attributed to changes in halite volume. Structure on top of the Salado (base of the Rustler) varies from elevation 2,424 feet (southeast) to elevation 2,698 feet (west) (739 to 822 meters). Structure on top of the Rustler varies from elevation 2,776 feet (northeast) to elevation 3,078 feet (southwest) (846 to 938 meters) above mean sea level.

DOE relied on the 1988 work of the Holt and Powers, provided in Appendix FAC, for descriptions of stratigraphy within members of the Rustler. The Holt and Powers study covered approximately 3,240 square miles (8,392 square kilometers), centering on the WIPP site. The study included data from 600 geophysical logs of boreholes, and data from two shafts at the WIPP site.

The Unnamed Lower member is 91-126 feet (28 to 38 meters) thick across the WIPP area, and consists of a basal bioturbated clastic interval, an overlying sandy transition zone, and an upward succession of mudstone/halite, anhydrite, and mudstone halite. Holt and Powers described halite removed from parts of the lower member, Tamarisk member, and Forty-niner member before overlying units were deposited. Basal contact with the Salado exhibits no erosion nor dissolution, and contact with the overlying Culebra dolomite is a regionally extensive gray claystone unit.

The Culebra member has an average thickness of approximately 25 feet (7.6 meters) across the WIPP site, and consists primarily of finely crystalline dolomite with vugular primary porosity and secondary fractures, both of which may have gypsum and/or anhydrite fill. A regionally extensive bed of organic, laminated carbonate, and clay occurs at the top of the Culebra at the WIPP site. The Culebra exhibits microporosity and vugular porosity. In the subsurface, vugs are partly filled or filled with anhydrite, gypsum, or clay. Culebra natural fractures can be filled with or partially lined by gypsum; gypsum infill within Culebra pore space increases to the east across the WIPP site. See CCA Chapter 2.1.3.5.2 (pp. 2-45 to 2-49) and Figure. 2-12 for more information.

The Tamarisk member consists of a basal anhydrite, an overlying claystone to halite-polyhalite, and a thick anhydrite in the upper part. The thickness of the Tamarisk member varies widely in the area around the WIPP, principally as a function of the halite in the middle part of the unit. DOE indicated that within T22S, R31E, the thickness ranges from 84 to 184 feet (26 to 56 meters). The Tamarisk isopach provided in Figure 4.9 of Appendix FAC indicates a range of 91 to 121 feet (28 to 37 meters) throughout most of the WIPP LWA boundary, with a maximum of 154 feet (47 meters) along the eastern edge of the withdrawal area. The Tamarisk is conformable with the underlying Culebra, and the upper contact with Magenta Dolomite is a transitional zone between sulfate and dolomite, exhibiting alga structures. The lower anhydrite of the Tamarisk was described as regionally continuous, though it is missing by erosion from borehole WIPP 19, located 0.5 miles (0.8 km) north of the WIPP site center.

The Magenta Dolomite member is 23 to 28 feet (7 to 8.5 meters) thick, and is gypsiferous and arenaceous. The member includes sedimentary structures such as wavy and lenticular beds, cross stratification, climbing ripple laminations, and gypsum nodules. The upper contact with the Forty-niner was described as transitional with anhydrite, and can be distinguished through the region by a gamma log profile. The Magenta Dolomite exhibits microporosity and vuggy porosity resulting from solution of carbonate and sulfate.

The Forty-niner member is 43 to 77 feet (13 to 23 meters) thick, and consists of a basal anhydrite, an overlying mudstone/halite, and an uppermost anhydrite unit. Contact with the overlying Dewey Lake redbeds was described as conformable, and "sharp and undulatory" within the WIPP shafts. Included mudstone is described as a residue from solution of halitic beds.

The Rustler was reported to be formed in environments ranging from shallow lagoons and subtidal environments to shallow saline pans and margins of saline pans. Associated rock types include mud-poor halite, mud-rich halite, mud-rich halite with evidence of subaerial exposure, muddy gypsum, and mudstone. Strata and mineralogy through the Rustler reveal seven periods when waters were fresher, and seven times when waters were more saline (CCA Appendix FAC, Figure 9.1).

The CCA indicated that dissolution of members of the Rustler included processes concurrent with deposition and post-depositional removal of evaporites. In post-depositional removal of evaporites, slumping and brecciation of overlying sediments was a consequence. Brecciation is most pronounced near Nash Draw, where the underlying Salado has been dissolved. Much of the halite originally contained in the Rustler has been dissolved; closely spaced isopach contours (Appendix GCR, Figure 4.3-8) to the east of the WIPP site indicate the location and transition to increasing amounts of halite remaining in the Rustler. The close-contours also mark the present solution margin of the Rustler.

Holt and Powers (1988) [Appendix GCR] described extensive fractures in the Rustler, and many fractures are filled with fibrous gypsum and halite. Competent beds exhibit fractures parallel to sub-parallel with bedding planes, indicating minimum principal stress at time of deformation in the vertical direction. More than one style of fracturing is present. For example, mudstones of the rustler exhibit slickenside surfaces associated with loading and unloading; some WIPP cores show fracture patterns associated with solution collapse. Fractures in the Rustler were not ascribed to dissolution processes; sediment loading and unloading are proposed as dominant processes causing fracturing in members of the Rustler.

Prior to construction of the WIPP site, DOE suspected that transmissivity in the Culebra dolomite may be related to halite solution in underlying sediments, as was observed in Nash Draw. After detailed stratigraphic studies, DOE found that Culebra transmissivity varies by about three orders of magnitude across the site, primarily due to open fractures, and Culebra fractures are related to sediment load on the Culebra, dissolution of the upper Salado, and gypsum fracture-fill.

DOE considers that thickness change within the Rustler is due to changes in halite composition, and transmissivity in the Culebra dolomite has been suspected of being related to halite dissolution. DOE found that Culebra transmissivity varies by about three orders of magnitude across the site, primarily due to open fractures, and Culebra fractures are believed to be related to sediment load on the Culebra, dissolution of the upper Salado, and gypsum fracture-fill.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.5, the Rustler:

Stratigraphic details of the Rustler	Appendix FAC
Sedimentary features of WIPP shafts and cores	Appendix FAC
Discussion of halite distribution	Appendix FAC
Regional Culebra transmissivity	2.2.1.4.1.2
Spatial variability of the Culebra	Chapter 6.4.6.2 Appendix TFIELD
Rustler thickness changes	Appendix GCR 4-39 to 4-42, Figure 4.3-8 Appendix FAC

j. EPA Technical Evaluation Results: The Stratigraphy of the Rustler (2.1.3.5)

The stratigraphy and lithology of the five members of the Rustler was described in Chapter 2.1.3.5 (pp. 2-37 to 2-53) of the CCA. The CCA relied on and was consistent with information presented in Appendices FAC and GCR (Section 4.3.2, pp. 4-29 to 4-39). The CCA described the geologic history, stratigraphy, and lithology of each member of the Rustler. The CCA referenced isopach maps for the Rustler members in Appendix FAC, Figures 4-7, 48, 4-9, and 4-13.

EPA concluded that, in general, stratigraphic information pertaining to the Rustler was technically adequate. EPA found that the CCA did not present a clear picture of the geologic history of the Rustler Formation in general, and the Culebra member of the Rustler and the history of events which caused fracturing of the Culebra in particular. Chapter 2.1.5.2 of the CCA discussed possible fracture mechanisms, but did not link these mechanisms to historical events which would have potentially caused fracturing within the Culebra. Although EPA questioned DOE's interpretation of whether the origin of some of the Rustler stratigraphic characteristics was syndepostional, the origin of the Rustler characteristics is not as important as identifying whether dissolution processes are ongoing within the Rustler. EPA agreed that dissolution processes are not presently occurring within the Rustler, and that dissolution processes are not expected to recur and affect performance of the WIPP in the future (also see the EPA evaluation of Non-Tectonic Processes and Features provided in Section IV.B.3.t of this Technical Support Document). Based on information obtained during mapping of the shafts at the WIPP and from tracer tests conducted in wells in the vicinity of the WIPP, the Culebra is not extensively fractured in the vicinity of the WIPP shafts. As a result, DOE's assumption of dual porosity may be conservative.

The requirement for a description of soil characteristics does not apply to this stratigraphic unit since it located well below the ground surface and was not discussed in the CCA. Structural geology/geotectonics, seismic history, geomophology/topography, and natural resources, as they apply to the Rustler, are discussed in later sections of this Technical Support Document.

k. DOE Methodology: Stratigraphy of the Dewey Lake Redbeds (2.1.3.6)

The CCA provided information regarding the stratigraphy and lithology of the Dewey Lake Redbeds (Dewey Lake) in Chapter 2.1.3.6 (pp. 2-53 to 2-54) and Appendix GCR, Section 4.3.2 (p. 4-42). The CCA indicated that the Dewey Lake is of Ochoan (late Permian) age and conformably overlies the Rustler. The Dewey Lake consists of reddish-brown fine-grained sandstone to siltstone or silty claystone, with greenish-gray iron-reduction spots. Sedimentary structures include thin bedding, ripple cross-bedding, channeling, soft-sediment deformation, and fractures in the lower part of the member. At the WIPP site, the Dewey Lake is approximately 498 feet (152 meters) thick, and thickens to the east (Figure 2-14 of the CCA).

DOE indicated in Chapter 2.1.3.6 (p. 2-54) that there are mineral-filled fractures within the Dewey Lake. Mapping of the air intake shaft indicates that above 164.5 feet (50 meters) bgs in the WIPP air shaft, the Dewey Lake rocks are cemented by carbonate and some of the fractures are also filled with carbonate. Below this level, the carbonate cement is harder, and the fractures are filled with gypsum and carbonate. DOE suggested meteoric water circulation as an explanation for changes in hardness of the cement.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.6, the Dewey Lake:

Fracture details in the WIPP Shaft	Holt and Powers 1986, Figures 6,7,8 [CCA Reference 309] (Docket A-93-02, Item II-G -1)
Meteoric water in the Dewey Lake	Holt and Powers 1990, p. 3-11 [CCA Reference 311] (Docket A-93-02, Item II-G -1)
	Lambert (in Siegal et al. 1991, p. 5-65) [CCA Reference 590] (Docket A-93-02, Item II-G-1)
Dewey Lake in conceptual model	Chapter 6.4.6.6
Dewey Lake parameter values	Table 6-23

l. EPA Technical Evaluation Results: Stratigraphy of the Dewey Lake Redbeds

The CCA described the geologic history, stratigraphy, and lithology of the Dewey Lake in Chapter 2.1.3.6 (pp. 2-53 to 2-54). The CCA relied on and was consistent with information presented by Schiel (1988) [CCA Reference 578] (Docket A-93-02, Item II-G-1) and Holt and Powers (1990) [CCA Reference 311] (Docket A-93-02, Item II-G-1) and with information presented in Appendix GCR. Figure 2-14 of the CCA presented an isopach map of the Dewey Lake. The environment in which the Dewey Lake was deposited is interpreted as a large, arid fluvial plain subject to ephemeral flood events. Schiel (1988) [CCA Reference 578] (Docket A-93-02, Item II-G-1) and Holt and Powers (1990) [CCA Reference 311] (Docket A-93-02, Item II-G-1) support this interpretation of depositional environments. EPA concluded that the stratigraphic and lithologic information pertaining to the Dewey Lake was technically adequate.

The Dewey Lake was described as containing fractures which are filled with minerals to varying degree. The Dewey Lake rocks were described as being cemented by carbonate above 164.5 feet bgs at the WIPP. Below this depth, the Dewey Lake cement was described as harder and the fractures filled with gypsum. Holt and Powers (1990) supported these descriptions. The CCA indicated that these cements and fracture fillings may be caused by infiltration of meteoric waters from the surface. However, the CCA did not present a clear picture of the geologic history of the Dewey Lake and did not adequately describe the history of events which caused fracturing of the Dewey Lake. Chapter 2.1.5.2 of the CCA discussed possible fracture mechanisms, but did not link these mechanisms to historical events which would have potentially caused fracturing within the Dewey Lake. In addition, the CCA did not adequately describe fracture characteristics, percentage of fractures filled and partially filled, and fracture density within the Dewey Lake. EPA concluded that although there was limited information on Dewey Lake fracture characteristics provided in the CCA and that DOE could have provided a better discussion within the CCA (see DOE, 1997g) (Docket A-93-02, Item II-I-10), the EPA Mandated Performance Assessment Verification Test (pp. 1-3) (DOE, 1997l and DOE, 1997m) (Docket A-93-02, Item II-G-28) results indicated that little or no groundwater flow would occur from the repository to the Dewey Lake, thus removing the Dewey Lake as a potential pathway.

The requirement for a description of soil characteristics does not apply to this stratigraphic unit since it located well below the ground surface and was not discussed in the CCA. Structural geology/geotectonics, seismic history, geomophology/topography, and natural resources, as they apply to the Dewey Lake, are discussed in later sections of this Technical Support Document.

m. DOE Methodology: Stratigraphy of the Santa Rosa (2.1.3.7)

The CCA described the Santa Rosa Formation (Santa Rosa) in Chapter 2.1.3.7 (pp. 2-54 to 2-59) and Appendix GCR, Section 4.3.2 (pp. 4-44 to 4-46) and indicated that the Mesozoic era is represented at the WIPP site by the late Triassic age Santa Rosa. The Santa Rosa is considered part of the Dockum Group that consists entirely of sediments of continental origin. At the WIPP site, the Santa Rosa occurs as an erosional wedge that pinches out westward just beyond the center of the site. DOE reported that the Santa Rosa has been called disconformable over the Dewey Lake, consisting of varied-colored coarse-grained rocks, including conglomerates and cross-bedded sedimentary features. The formation is thin to absent over the WIPP site, but thickens to 200 feet at the eastern boundary of the WIPP site (Figure 2-15 of the CCA). Mapping of the air intake shaft indicated that approximately 2 feet were present. The Santa Rosa was included in younger rocks for performance models.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.7, the Santa Rosa:

Sedimentary details	Lucas and Anderson 1993a, p. 231-235 [CCA Reference 408] (Docket A-93-02, Item II-G-1)
Performance models	Chapter 6.4.6.7
Performance model parameters	Table 6-24

n. EPA Technical Evaluation Results: Stratigraphy of the Santa Rosa

The CCA described the geologic history, stratigraphy, and lithology of the Santa Rosa in Chapter 2.1.3.7 (pp. 2-54 to 2-59). The CCA relied on and was consistent with information presented by Holt and Powers (1990) [CCA Reference 311] (Docket A-93-02, Item II-G-1) and Lucas and Anderson (1993) [CCA Reference 408] (Docket A-93-02, Item II-G-1) and, although not specifically referenced, with information presented in Appendix GCR. Figure 2-15 of the CCA presents an isopach map of the Santa Rosa. The environment in which the Santa Rosa was deposited was interpreted as a fluvial system descending from a predominantly crystalline terrain, which is supported by information provided in Appendix GCR. EPA concluded that the stratigraphic and lithologic information pertaining to the Dewey Lake was technically adequate.

The requirement for a description of soil characteristics does not apply to this stratigraphic unit since it located below the ground surface and was not discussed in the CCA. Structural geology/geotectonics, seismic history, geomophology/topography, and natural resources, as they apply to the Santa Rosa, are discussed in later sections of this Technical Support Document.

o. DOE Methodology: Stratigraphy of the Gatuña Formation (2.1.3.8)

The CCA provided information regarding stratigraphy and lithology of the Gatuña Formation (Gatuña) in Chapter 2.1.3.8 (p. 2-59). The CCA set the age of the Gatuña as Pleistocene to upper Miocene (0.6 million to 13 million years before present). The younger age was based on age dating a volcanic glass present within the upper Gatuña along the eastern margin of Nash Draw. The older date was from K-Ar dating of Gatuña volcanic ash sampled in Texas. The Gatuña also contains pebbles of the Ogallala caprock, which confirms age younger than Pliocene. The Gatuña consists of a light reddish-brown coarse conglomerate to claystone, with interbedded gypsiferous sections. The formation is fluvial in origin and also includes low-energy deposits and evaporites. The CCA indicated the formation is approximately 9 feet (2.7 meters) thick near the WIPP Site (Figure 2-16 of the CCA), thinning or absent to the east of the site, and it is 300 feet (91 meters) thick at Pierce Canyon and thicker in areas subparallel to the Pecos River.

The CCA described the Gatuña Formation as unconformable with underlying sediments, and usually obscured by surficial sand and caliche. The nearest outcrops were described as occurring along the west-facing slopes of Livingston Ridge at the edge of Nash Draw, located about 4 miles (6.4 kilometers) northwest of the center of the WIPP site. The Gatuña is similar in appearance to older Dewey Lake and Santa Rosa sediments, and it is slightly lighter in color.

The Gatuña includes stream, pond, solution, and collapse evidence, and represents the most humid Pleistocene stage in southeastern New Mexico. In Nash Draw, for example, the Gatuña exceeds 100 feet (30.5 meters) in thickness and fills sinkholes previously formed by dissolution of salt and other evaporites. Based on observations of Bachman (1974) [CCA Reference 21] (Docket A-93-02, Item II-G-1), modern drainages do not carry clasts of the size and quantity preserved in Gatuña stream deposits.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.8, the Gatuña Formation:

Sedimentary details	Powers and Holt 1993 [CCA Reference 408] (Docket A-93-02, Item II-G-1) Bachman 1974, [CCA Reference 21] (Docket A-93-02, Item II-G-1)
Sedimentary thickness	Holt and Powers 1990 [CCA Reference 311] (Docket A-93-02, Item II-G-1)
Gatuña age	Izett and Wilcox 1982 [CCA Reference 332] (Docket A-93-02, Item II-G-1)

p. EPA Technical Evaluation Results: Stratigraphy of the Gatuña Formation

The CCA describes a geologic history, stratigraphy, and lithology of the Gatuña in Chapter 2.1.3.8 (p. 2-59). The CCA relied on and was consistent with information presented by Holt and Powers (1990) [CCA Reference 311] (Docket A-93-02, Item II-G-1) and Powers and Holt (1993) [CCA Reference 408] (Docket A-93-02, Item II-G-1) and, although not specifically referenced, with information presented in Appendix GCR. Figure 2-16 of the CCA presented an isopach map of the Gatuña. The environment in which the Gatuña was deposited is interpreted as a fluvial system with areas of low-energy deposits and evaporitic minerals, which is supported by information in Powers and Holt (1993). EPA concluded that the stratigraphic and lithologic information pertaining to the Gatuña was technically adequate.

The requirement for a description of soil characteristics does not apply to this stratigraphic unit since it located below the ground surface and was not discussed in the CCA. Structural geology/geotectonics, seismic history, geomophology/topography, and natural resources, as they apply to the Gatuña , are discussed in later sections of this Technical Support Document.

q. DOE Methodology: Stratigraphy of the Mescalero Caliche (2.1.3.9)

The CCA provided information regarding the Mescalero Caliche (Mescalero) in Chapter 2.1.3.9 (pp. 2-59 to 2-60) and Appendix GCR (Section 4.2.2). The CCA indicated that the Mescalero is an informal stratigraphic unit that overlies the Gatuña and has been interpreted to be early-to-middle Pleistocene in age: approximately 570,000 to 420,000 years old. DOE relied on Bachman (1976) [CCA Reference 22] (Docket A-93-02, Item II-G-1) to differentiate the Mescalero Caliche from the older Ogallala Formation by the absence of breccia and pisolitic textures, and for description of the Mescalero as a soil.

The Mescalero is a thick caliche found in the region over a variety of substrates, forming an upper dense laminar caprock, and a basal, earthy-to-firm, nodular calcareous deposit. The Mescalero consists of calcareous material including sand and pebbles. DOE interpreted the laminations of the upper dense caprock as resulting from successive cycles of dissolution and reprecipitation of the matrix, occurring in the semiarid environment that followed moist conditions of Gatuña time.

DOE concluded (CCA Chapter 2.1.3.9, p. 2-60) that according to Bachman (1985) [CCA Reference 26] (Docket A-93-02, Item II-G-1) the significance of the Mescalero is that: "Where the Mescalero is flat-lying and not breached by erosion, it is an indicator of stability or integrity of the land surface over the last 500,000 years." The Mescalero covers the WIPP area as a hard, caliche crust, and DOE indicated that the unit is as thick as 10 feet (3 meters) in the WIPP area. The Mescalero dips abruptly into Nash Draw along Livingston Ridge, indicating subsidence in that area after formation of the caliche.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.9, the Mescalero:

Sedimentary details	Bachman 1973 [CCA Reference 20] (Docket A-93-02, Item II-G-1)
Age of the Mescalero Caliche	Rosholt and McKinney 1980, Table 5 [CCA Reference 555] (Docket A-93-02, Item II-G -1)
Discussion	Appendix GCR, Section 4.2.2

r. EPA Technical Evaluation Results: Stratigraphy of the Mescalero Caliche

The CCA described the geologic history, stratigraphy, and lithology of the Mescalero in Chapter 2.1.3.9 (pp. 2-59 to 2-60) and Appendix GCR (Section 4.2.2). The CCA relied on and was consistent with information presented by Bachman (1973, 1974, 1976, and 1985) [CCA References 20, 21, 22, 26] (Docket A-93-02, Item II-G-1) and with information presented in Appendix GCR. The environment in which the Mescalero caliche was formed was interpreted as a semiarid environment in which cycles of dissolution and reprecipitation of the matrix occurred, which is supported by information in Bachman (1976). The CCA addressed the occurrence and relative distribution of the Mescalero. Although a site-specific detailed map of the Mescalero Caliche distribution was not provided in the CCA, there was sufficient information to allow EPA to conclude that the stratigraphy of this unit was adequately discussed.

s. DOE Methodology: Non-Tectonic Processes and Features (2.1.6, DEF)

DOE indicated that the most significant non-tectonic features in the vicinity of the WIPP site are related to Castile structures (i.e., disturbed zones) and evaporite dissolution. These processes are described in detail in CCA Chapter 2, Sections 2.1.3.3 (p. 2-24) and 2.1.6 (pp. 2-80 to 2-93) and Appendices DEF.2 - DEF.3 (pp. DEF-1 to DEF-33). These processes are of interest because they represent mechanisms that are potentially disruptive to the repository in the long term. DOE indicated that the halite in the evaporite rock sequences behaves in a relatively plastic manner at lower stresses than other rock types, which can lead to deformation. DOE also noted that halite is also highly soluble, which can lead to the process of dissolution.

i. Castile Structures.

The CCA provided information regarding Castile Structures in Chapter 2.1.6.1 (pp. 2-80 to 2-87) and Appendices DEF.2 and DEF.3 (pp. DEF-1 to DEF-33). DOE indicated, in Chapter 2.1.6.1.1 (p. 2-80) and Appendix DEF.2 (pp. DEF-14 to DEF-17), that the Castile has been known for many years to be deformed in parts of the Delaware Basin, especially along the northern margin where the Castile was found to be thicker from the northwestern to the northern part of the basin, just inside the Capitan reef. As part of the program to characterize an initial site for the WIPP, boring ERDA-6 was drilled in 1975 and was located approximately 5 miles (8.4 kilometers) northeast of the current center of the WIPP site. The borehole encountered increasingly deformed beds through the Salado into the Castile, and at 2,711 feet (826 meters) depth, the borehole began to produce pressurized brine and gas. Interpretations of information from the borehole indicated that some beds had been displace structurally by as much as 950 feet (289.5 meters) and that some of the lower beds may have pierced the overlying beds (Anderson and Powers - 1978) [CCA Reference 18] (Docket A-93-02, Item II-G-1). DOE concluded that the beds were too structurally deformed to mine reasonably along single horizons and relocated the WIPP to the current site in 1976. DOE indicated that the deformed beds encountered in ERDA-6 were considered part of the deformed zone within about 6 miles (10 kilometers) of the inner margin of the Capitan reef. Refer to Appendix DEF.2.1 (pp. DEF-1 to DEF-11) for additional information.

As noted in Appendix DEF.2 (pp. DEF-1 to DEF-17), beginning in 1977, DOE characterized the present site for the WIPP via geophysical surveys including seismic reflection and drilling. The seismic reflection data indicated a disturbed zone in the Castile north of the site. DOE indicated that Figures 4.4-4, 4.4-5, and 4.4-6 of Appendix GCR generally show the disturbed zone in the Castile beginning about 1 mile north of the WIPP site center, where the seismic reflector character was poor to uninterpretable. Another interpretation indicated that the limits of the disturbed zone where about 0.5 miles north of the WIPP site center where the dip of the Castile begins to steepen. The borehole WIPP-11, was drilled in 1978 approximately 3 miles (5 kilometers) north of the center of the WIPP site and encountered highly deformed structures within the Castile, but no over-pressurized brine and gas were found (Chapter 2.1.6.1.1, p. 2-85).

DOE indicated in Chapter 2.1.6.1.1 (p. 2-85) and Appendix DEF (pp. DEF-4 to DEF-

11) that 1977 and 1978 seismic maps also suggested faulting in the Salado and the Rustler, possibly related to deformation in the Castile. To investigate the apparent structure, DOE drilled boreholes WIPP 18, 19, 21, and 22 within the WIPP site boundary and found no detectable offset on the contact between the Rustler and Salado. As a test of Castile fluid characteristics in relatively undisturbed Castile structure, DOE deepened WIPP-12 in 1981. Information obtained from borehole WIPP-12, located approximately 1 mile (0.6 kilometers) north of the WIPP site center indicated that the top of the Castile was 160 feet (49 meters) higher than the same contact in ERDA-9, located at the WIPP site center. In addition, pressurized brine and gas were encountered in the fractured anhydrite in the upper Castile. As a result of this information, the EEG recommended reorienting the proposed waste disposal areas from the north to the south of the WIPP site center, as currently proposed. A time-domain electromagnetic survey (TDEM) conducted at the WIPP suggested the presence of brine under part of the WIPP facility, south of the disturbed zone (Chapter 2.2.1.2.2).

DOE indicated in CCA Chapter 2.1.6.1.3 (p. 2-87) and Appendix DEF.2.3 (pp. DEF-14 to DEF-16) that the principal hypotheses for the occurrence of deformational features in the Castile are gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes. DOE summarized each of the hypotheses in Appendix DEF (Section DEF.2.3), but indicated that gravity foundering is the most comprehensive and best-accepted hypothesis. DOE indicated that gravity foundering is based on the fact that anhydrite (2.9 gm/cc) is much more dense than halite (2.15 gm/cc) so that when anhydrite beds overlie halite, there is a considerable potential for the anhydrite to sink and the halite to rise. DOE indicated that mathematical and centrifuge models of similar systems confirm the potential for such deformation and suggest a rate of deformation of about 0.02 inch per year (0.05 cm per year) (Appendix DEF.2.3, p. DEF-14) (Borns et al. 1983). DOE indicated that at this rate, the Castile disturbed zone could be inferred to develop over about 700,000 years. DOE indicated that there is still some question as to why the disturbed zones in the Castile, and particularly the pressurized brine and gas occurrences, only occur over a relatively small part of the Delaware Basin. Refer to Appendices DEF.2.3 and DEF.2.4 (pp. DEF-14 to DEF-18) for additional information.

DOE indicated that the dissolution of halite from the lower Salado to the Castile could be the cause of the Castile deformational features, but that the overlying beds would be expected to deform in response to the removal of salt. DOE further indicated that data from boreholes indicate that the Rustler shows no discernible overall structural lowering over the disturbed zone (Appendix GCR).

DOE indicated that gravity sliding of the Castile could be driven by the general eastward dip of the basin, and the dip off the Capitan Reef and the forereef into the basin. This mechanism would result in sliding blocks moving mainly laterally as well as downslope. While DOE did not completely rule out the dip of the reef-forereef slope hypothesis since some deformation is located adjacent to the reef, DOE did indicate that if the general eastward dip of the basin was the cause, then the Castile deformational features would be expected to be more consistent throughout the basin.

DOE indicated that as temperature and pressure increase, gypsum dehydrates to form anhydrite and that this process could fracture the anhydrite, but that the major difficulty with this hypothesis is that there should remain relicts of the original gypsum with the sedimentary column and that these were not observed (Borns et al. 1983) [CCA Reference 79] (Docket A-93-02, Item II-G-1). In addition, DOE indicated that Borns et al. 1983 suggested that mostly anhydrite was deposited in the Castile, thus providing little support to the dehydration hypothesis.

DOE indicated that the potential depositional or syndepositional processes that have been suggested include penecontemporaneous folding, resedimentation, slump blocks off reef margins and sedimentation on inclined surfaces. Overall, DOE indicated that there is no evidence to support these mechanisms as the cause of the Castile deformational features.

DOE indicated that there are a number of interpretations regarding the timing of the Castile deformation. Appendix DEF.2.4 (p. DEF-17) indicated that Castile rocks may have been deformed during any time period from Permian to the present. DOE indicated that for some hypotheses, the general conditions thought necessary to deform the Castile and Salado are still present, and mechanisms, such as gravity foundering, are potentially active.

DOE indicated in Appendix DEF.2.4 (p. DEF-17) that brines from ERDA-6 and WIPP-12 were analyzed and were calculated to have moved last about 800,000 years ago (Lambert and Carter, 1984) [CCA Reference 379] (Docket A-93-02, Item II-G-1). DOE further stated that one set of reasonable assumptions about brine chemistry and interaction with rock leads to calculated residence times of about 25,000 to 50,000 years for these brines and that this may relate to the last time deformation was active on this structure. DOE indicated that a second point of interest is that some modeling calculations indicate, that the kinds of structures observed in the disturbed zone may require periods on the order of 700,000 years to form. This calculation gives no indication of when the structures were formed, but it is relevant to timing and assessing how these structures might affect the WIPP.

Overall, DOE concluded that the deformation of the Castile and the presence of pressurized brine and gas in the anhydrite layers of the upper Castile will not have a significant impact on the containment of waste in the WIPP (Appendix DEF.2.5, pp. DEF-17 and DEF-18).

<u>ii. Evaporite Dissolution.</u>

The CCA provided information regarding evaporite dissolution in Chapter 2.1.6.2 (pp. 2-87 to 2-93) and Appendix DEF.3 (pp. DEF-18 to DEF-33). DOE indicated in Chapter 2.1.6.2 (p. 2-87) that because evaporites are known to be much more soluble than most other rocks, DOE has considered it important to understand the dissolution processes and rates that occur at the WIPP and the surrounding area. DOE indicated that a number of studies have been conducted to identify the surface and subsurface features in southeastern New Mexico interpreted to have been caused by dissolution and that the distribution of halite for various units has been mapped.

DOE discussed three dissolution mechanisms potentially pertinent to WIPP in Chapter 2.1.6.2 (pp. 2-87 to 2-93) and Appendix DEF.3 (pp. DEF-18 to DEF-23). The mechanisms include: deep dissolution, including Bell-Canyon-Castile interface dissolution and breccia pipe development; lateral dissolution along the Rustler-Salado contact and within the Rustler; and shallow dissolution, including karst development. DOE concluded that while these dissolution mechanisms may have occurred to varying degrees in the Delaware Basin, there is a high level of confidence that dissolution sufficient to affect the performance of the disposal system is physically unreasonable and will not occur over the regulatory time frame. See Appendix DEF.3.4 (p. DEF-33) for more information.

DOE stated that breccia pipes are deep dissolution features that are vertical or near vertical cylindrical features filled with collapse debris and typically extending from near the ground surface down to the Castile; see Appendix DEF.3.1(pp. DEF-18 to DEF-25). DOE indicated that breccia pipes were known to be present in the northern part of Nash Draw, approximately 12 miles (19 kilometers) northwest of the WIPP repository. During a resistivity field program that covered about 37 square miles (93.25 square kilometers), DOE identified several potential anomalies but no breccia was encountered in the boreholes drilled to investigate the anomalies.

DOE also conducted studies of known breccia pipes to develop an understanding of the mechanisms leading to their formation. DOE indicated that deep dissolution is a possible mechanism for the formation of breccia pipes and introduced the concept of brine density flow, which allows upward flow of water through an overlying fractured/permeable unit, dissolution of evaporates, and subsequent downward flow of the ensuing, more dense brine. The overlying rocks may then collapse into the resulting solution cavity. DOE indicated that there are no known breccia pipes that are not underlain by the Capitan Limestone or Bell Canyon (where the Bell Canyon is not overlain by the Castile). Breccia pipes can form above these two formations because the hydraulic conductivity of the formations is sufficiently high to allow significant groundwater flow and transport of dissolved material, thereby allowing the formation of solution cavities. The Capitan Limestone does not occur below WIPP, and the Bell Canyon below is of low transmissivity and is overlain by the Castile.

More generalized dissolution of deeper units such as the Castile, due to the flow of unsaturated groundwater within the Bell Canyon Formation and subsequent dissolution salt along the fresher-water interface, represents another potential deep dissolution feature. DOE drilled a borehole within a feature where structural depressions in the Salado suggested slow removal of salt at depth. DOE's interpretation of the resulting data indicated that the feature was the result of deformation rather than dissolution. DOE concluded that there is no unequivocal information that supports the possibility of deep dissolution occurring anywhere other than the edges of the Capitan Reef (Appendix DEF.3.1, p. DEF-25).

DOE stated that lateral dissolution results from groundwater movement within units that lead to lateral variations in porosity and permeability. DOE indicated that lateral dissolution of the upper Salado and within the Rustler in the region of the WIPP has been recognized and studied since at least 1970 (Appendix DEF.3.2, p. DEF-25). DOE indicated that lateral dissolution of the upper Salado (and the subsequent collapse of the overlying Rustler) formed Nash Draw, located approximately 1 to 5 miles (1.6 to 8 kilometers) west of the WIPP site. DOE indicated that the maximum eastward lateral extent of dissolution at the top of the Salado is east of Livingston Ridge. DOE concluded that the edge of halite dissolution at the top of the Salado will not reach the repository until well after the period of regulatory concern (Appendix DEF.3.2, p. DEF-29).

DOE indicated that dissolution within the Rustler also led to further development of Nash Draw and that in the vicinity of Nash Draw, halite is absent from all the units of the Rustler (Chapter 2.1.3.5, pp. 2-37 to 2-38). Further east, toward the WIPP site, halite progressively appears in younger units, which has led many investigators to conclude that halite has been dissolved from the Rustler by groundwater in a process similar to the lateral dissolution at the top of the Salado. DOE presented an alternative interpretation, based on shaft mapping and core logging, stating that the Rustler was formed in variable depositional environments and that the current distribution of halite in the Rustler is similar to that when the unit was deposited. DOE concluded, however, that neither interpretation of the Rustler would appear to threaten the integrity of the disposal system during the regulatory time period (Appendix DEF.3.2, p. DEF-29).

DOE also discussed shallow dissolution, including karst development and dissolution of Culebra fracture fills. Karst topography is developed through dissolution of soluble rock units. DOE indicated that karst features such as dolines, collapse sinks, karst valleys, blind valleys, and other solution/subsidence-related features are present in Nash Draw, which is a dissolution feature approximately one mile west of the LWA boundary. DOE indicated that east of Nash Draw, "only a few small clusters of shallow dolines on the Mescalero caliche have been identified" (Appendix DEF.3.3, p. DEF-30). DOE indicated that dissolution of fracture fill within the Culebra would significantly impact the transmissivity of this unit. DOE stated that "there is no evidence for progressive change in this pattern [of fracture fill] across the area although some dissolution and precipitation of gypsum as fracture infills will inevitably occur in the next 10,000 years." DOE submitted supplemental information in letters dated June 13, 1997, May 14, 1997, March 12, 1997, February 26, 1997, February 7, 1997 and January 24, 1997 (DOE, 1997 c, d, f, g, j, and k) (Docket A-93-02, Item II-H-44, Item II-I-31, Item II-H-22, Item II-I-10, Item II-I-07, and Item II-I-03) concerning fracture fill dissolution in response to questions raised in EPA's December 19, 1997 letter requesting additional information (Docket A-93-02, Item II-I-01) and public comments received on EPA's ANPR for the certification decision. In this information, DOE concluded that the possibility of fracture fill dissolution is very low because infiltrating waters that would cause the dissolution would be saturated with respect to calcium sulfate. Because infiltrating water is saturated with fracture fill mineral, the likelihood that these waters could dissolve and remove existing fracture fill is remote.

DOE concluded that while these dissolution mechanisms may have occurred to varying degrees in the Delaware Basin, "there is a high level of confidence that dissolution sufficient to affect the performance of the disposal system is physically unreasonable and will not occur over the regulatory time frame" (Appendix DEF, p.

DEF-33). Appendix SCR (Section 1.1.5.1) provides a summary of the screening of these dissolution mechanisms with respect to the PA.

The following lists Appendices and cross-references for CCA Chapter 2.1.6, Non-Tectonic Processes and Features.

Evaporite Deformation details	Appendix DEF

t. EPA Technical Evaluation Results: Non Tectonic Processes and Features

i. Castile Structures.

The CCA presented information pertaining to the occurrence of deformational features in the Castile in Chapter 2.1.6.1 (pp. 2-80 to 2-87) and Appendices DEF.2 and DEF.3 (pp. DEF-1 to DEF-33). DOE noted that these features have been postulated to have been formed by processes including gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes. Of these, DOE believed that gravity foundering is the most comprehensive and best accepted hypothesis for the formation of these deformational features. After evaluation of information presented in Chapter 2.1.6, Appendix DEF, and associated references and Appendices, EPA agrees with DOE's conclusion that the mechanism most likely responsible for the Castile deformation is gravity foundering, although other mechanisms could occur to some degree. The anhydrite-halite sequences within the Castile would be amenable to the formation of gravity/density related structures. The formation of "salt domes" due to gravity foundering is common throughout the geologic sequences.

While deep seated dissolution is a possible cause of the deformational features, the distribution of Castile features is not necessarily proximal to basin margins where dissolution appears to be more prevalent. In addition, there appears to be no evidence of upsection rock unit disruption in the area over the deformational structures as would be expected if deeper dissolution of the lower Salado or Castile were the cause of the structures. Gravity sliding, while also a possible cause of the deformational features, would likely have caused relatively profound effects within both the Castile and overlying units (depending upon when the sliding took place). However, data indicate that the disturbed zone appears to decrease upsection. Also, gravity sliding would appear to have more prominent and consistent effects of unit thickening and thinning from the basin margins eastward, but observed features do not consistently coincide with the anticipated structure effects of gravity sliding.

From a depositional perspective, anhydrite rather than gypsum would be the primary depositional mineral, which would be re-hydrated to form gypsum. Subsequent dehydration may occur, and the effects of this would result in fracturing/volumetric changes in the calcium sulfate beds. However, it is unclear whether this mechanism alone could results in the observed Castile structures, nor is it clear that the necessary rehydration-dehydration sequence is supported entirely by the rock record. Note that DOE stated the Culebra at ERDA 6, northeast of the WIPP site, exhibits structural elevation correlatable to underlying Castile structures.

The performance assessment assumes an 8% probability of encountering a Castile feature (brine pocket) based in part on the conclusion that the distribution of "high-angle fractures spaced widely enough that a borehole can penetrate through a volume of rock containing a brine reservoir without intersecting any fractures" (page 6-162, lines 20-22). Data presented within Appendix MASS and the TEDM study imply that this probability could be higher, but a question that is not answered is whether the Castile features could form below the WIPP during the regulatory time period. DOE's assumption that the mechanism(s) which formed Castile features is still active today appears to be technically reasonable. DOE also indicated that the brines present in known Castile structures at wells ERDA-6 and WIPP-12 were calculated to have moved last about 800,000 years ago. DOE also stated, on page DEF-17, that "one set of reasonable assumptions about brine chemistry and interactions with the rock leads to calculated residence times of about 25,000 to 50,000 years for these brines," but provided no reference for these statements. DOE went on to state that "some modeling" indicate that the kinds of structure observed in the disturbed zone may require periods on the order of 700,000 years to form, but this modeling was not referenced or further detailed.

As a result of the review of the information provided in the CCA, EPA concluded that the distribution of these deformational features below the WIPP is uncertain, especially in terms of what DOE has chosen in performance assessment modeling as the probability of encountering a brine pocket (CCA Chapter 2.1.6.1.3, p. 2-87, and Appendix DEF.2, pp. DEF-1 to DEF-18). While DOE concluded that the brine reservoirs in the Castile occurred primarily within high-angle fractures, the potential for horizontal brine bearing fractures cannot be ruled out. The presence of over-pressurized brine within horizontal fractures in the Castile would increase the probability of a borehole encountering a brine pocket. EPA addressed this uncertainty by requiring DOE to vary the brine pocket probability in the Performance Assessment Verification Testing between 0.01 and 0.6 (Docket A-93-02, Items II-G-26 and II-G-28). EPA concluded that DOE's assertions regarding timing of deformation feature formation or brine movement within these features were not unreasonable but could be better referenced in the CCA and more fully discussed in associated appendices and references. Information in the CCA was sufficient to conclude that creation of these features is beyond the regulatory time period (see Chapter 2.1.6.1.3, p. 2-87, and Appendix DEF.2, pp. DEF-1 to DEF-18).

ii. Evaporite Dissolution.

CCA Chapter 2.1.6.2 (pp. 2-87 to 2-93) and Appendix DEF.3 (pp. DEF-18 to DEF-33) identified three dissolution mechanisms potentially pertinent to WIPP. The mechanisms include: deep dissolution, including Bell-Canyon-Castile interface dissolution and breccia pipe development; lateral dissolution along the Rustler-Salado contact and within the Rustler; and shallow dissolution, including karst development. DOE concluded in Appendix DEF.3.4 (p. DEF-33) that while these dissolution mechanisms may have occurred to varying degrees in the Delaware Basin, there is a high level of confidence that dissolution sufficient to affect the performance of the disposal system is physically unreasonable and will not occur over the regulatory time frame.

DOE indicated that deep dissolution is a process that could explain removal of evaporite section and formation of breccia pipes. DOE's conclusion that the breccia pipes are features resulting from dissolution associated with upward movement of fluids from permeable units underlying the Salado and where the Castile is absent - i.e. the Capitan Formation - appears to be somewhat supported by the geologic data. These data indicated that the breccia pipes discussed within the CCA do occur above the Capitan Formation. Also, DOE's contention that the features form due to enhanced hydraulic conductivity/transmissivity of the Capitan Formation and subsequent dissolution of overlying sediments appears to be technically plausible. However, other authors (Anderson) have pointed out that additional information which indicates breccia pipes occur within the Salado that are not associated with the Capitan aquifer, but this information was not included in the CCA. Therefore, EPA's preliminary review found that DOE could not reasonably conclude that the mechanism for breccia pipe formation presented in the CCA is the only breccia pipe formation mechanism that could be present within the WIPP area without additional discussion of potential non-Capitan related breccia pipes. EPA transmitted questions regarding breccia pipe development to DOE in a letter dated December 19, 1996 (Docket A-93-02, Item II-I-01). DOE submitted supplemental information in a letter dated January 24, 1997 (Enclosure 2, p. 7) (DOE, 1997k) (Docket A-93-02, Item II-I-03) regarding non-Capitan related breccia pipes (i.e., those associated with the Bell Canyon where it is relatively shallow). EPA reviewed this information and concurred that the geologic evidence indicates that the breccia pipes are not likely to occur under the repository.

DOE further indicated that flow of unsaturated groundwater within the Bell Canyon could provide a source of water that could lead to dissolution of the overlying Castile Formation. However, DOE also concluded that "there is not equivocal information that supports the possibility of localized deep dissolution occurring anywhere other than at the edge of the Capitan Reef " (Appendix DEF.3.1, p. DEF-25). This conclusion was not shared by Anderson (1978), who stated that deep-seated dissolution could be the cause of large volumes of halite removal in the Delaware Basin. (In contrast, Anderson indicated that the presence of breccias within the Salado and Castile at the Delaware Basin boundary support the occurrence of deep dissolution.) The occurrence of deep seated dissolution processes below the WIPP cannot be wholly ruled out, due to the presence of more permeable, non-halite saturated rock units immediately below evaporite units. However, while the deep dissolution mechanisms may be operative/occurring, available data presented in the CCA and other references do not indicate that this mechanism would be sufficiently rapid to fracture overlying salts (i.e. ductile response of salt beds is instead anticipated). Therefore, available data indicate that this dissolution mechanism, while possible, would not be of sufficient magnitude to compromise the containment capabilities of the disposal system during the 10,000 year regulatory time frame.

EPA concluded that deep-seated dissolution has occurred in the Delaware Basin; however, there is little evidence to show this mechanism is active below the WIPP. Even if it is occurring, it would not be of sufficient magnitude to compromise the containment capabilities of the disposal system during the 10,000 year regulatory time frame.

DOE contended that lateral dissolution of halite within the Rustler or along the Rustler-Salado contact is not a process of concern during the regulatory time frame

(Appendix DEF.3.4, p. DEF-33). EPA concluded that while limited dissolution at the Rustler-Salado contact and within the Rustler halites could be ongoing, the process is very slow and would take hundreds of thousands of years to reach the repository.

Karst features such as Nash Draw have formed via shallow (surface down) dissolution in the WIPP area. DOE indicated that the development of karst features near and above the WIPP has been the subject of considerable study, and concludes that development of karst does not pose a threat to the containment capabilities of the disposal system. EPA examined the information presented within the CCA, and EPA acknowledges that karst terrain is present in the vicinity of the WIPP site boundary (CCA Chapter 2, Sections 2.1.3.4 and Chapter 2.1.6.2, pp. 2-87 to 2-93, and Appendix DEF 3.3). Nash Draw, which is approximately one mile west of the WIPP site, is attributed to shallow dissolution and contains karst features. EPA recognized the potential importance of karst development on fluid migration. Karst terrain typically exhibits cavernous flow, blind streams, and potential for channel development that would enhance fluid and contaminant migration.

EPA reviewed information and comments submitted by DOE (Chapter 2.1.6.2, pp. 2-87 to 2-93, and Appendix DEF3.3, pp. DEF-29 to DEF-30) and stakeholders (Docket A-93-02, Item II-D-102) regarding the occurrence and development of karst at the WIPP. EPA agrees that karst features occur in the WIPP area but concluded that karst features are not pervasive over the disposal system itself. Available data suggest that dissolution-related features occur in the immediate WIPP area (e.g., WIPP-33), but these features are not pervasive and are not associated with any identified preferential groundwater flow paths or anomalies. Data from Sandia National Laboratories tracer tests do not indicate the presence of anomalous cavernous-type flow; for example, the interpretation of the H2 hydropad, located just west of the waste panel area, is one of single (matrix) porosity, not channeling (Jones et al., 1992) [CCA Reference 343] (Docket A-93-02, Item II-G-1). The Environmental Evaluation Group (EEG) (II-D-102) stated "...that while the WIPP site is located in a karst region, the groundwater is not abundant and is of poor quality and while pathways of higher permeability may be present, solution channels as potential pathways for fast movement of water do not appear to be [present]." EEG further states (ibid) that "the karst phenomena do not appear to warrant a rejection of the WIPP site."

EPA reviewed information pertinent to the potential development of karst in the WIPP area. The relative pervasiveness of the Mescalero Caliche and its occurrence in relatively dry climates (which supports climatic variation conclusions drawn by DOE), combined with DOE's near-future precipitation assumptions, led EPA to conclude that karst feature development will neither be pervasive nor impact the containment capabilities of the WIPP during the 10,000 year regulatory period.

4. Structural Geology and Geotectonics (Seismic History)

a. DOE Methodology: Tectonic Setting and Site Structural Features (2.1.5)

The tectonic setting and site structural features were described in Chapter 2.1.5 (pp. 2-68 to 2-80) and Appendix GCR (Section 4.4, pp.4-53 to 4-79) of the CCA. DOE described the

WIPP site as located in an area with no evidence of significant tectonic activity, with a low level of stress in the region. Broad scale structural features developed during the Late Palezoic in the area around the WIPP site, although activity related to the Basin and Range tectonics formed major structures to the southwest of the site during the Tertiary period (**Figure IV-7** of this Technical Support Document).

A broad subsidence of the region around the WIPP site created a sag called the Tobosa Basin during the Ordvician period, into which clastic sediments were deposited. A general tectonic stability prevailed until regional tectonic activity began in the late Mississippian and continued through the Pennsylvanian and into the Permian. The Central Basin Platform uplifted and separated the Tobosa Basin into two parts, the Delaware Basin where the WIPP site is located to the west and the Midland Basin to the east. Other structural features adjacent to the Delaware Basin were also created by the folding which occurred during this time. The Diablo Platform was uplifted to the west of the Delaware Basin. The Matador Arch and the Northwestern Shelf of the western extent of the Permian Basin were formed to the north of the Delaware basin, and the Val Verde Basin formed to the south. All of these features combined to effectively bound the Delaware Basin, and create conditions which were conducive to the deposition of the evaporite strata selected to host the WIPP.

DOE indicated that evidence exists which demonstrates the tectonic stability of the WIPP area in the time since salt deposition. For example, the large structure features creating and surrounding the Delaware Basin are reflected only indirectly in the Mesozoic and Cenozoic rocks overlying the Palezoic era features. Also, the Late Permian Ochoan rocks and Triassic rocks do not reflect movements related to the basinal development. Their major structural feature is a regional eastern slope, which appears to be a transitional expression of the Tertiary-era Guadalupe Mountain uplift.

DOE indicated that evaluation of the regional stress field as it presently exists provides additional demonstration that the WIPP site is located in an area of tectonic quiescence. The WIPP site lies within the Southern Great Plains stress province, which is a transition zone between the extensional stress regime of the Basin and Range province to the west and the compressive stress regime of the Mid-Plate province to the east. The level of stress in the Southern Great Plains is low, balanced as it is between two opposite conditions. While the extensional stresses associated with the Basin and Range province are the more extreme of the two stress conditions proximal to the WIPP site, the boundary for that province and the extensional stresses is the Rio Grand Rift, located to the west and with a significantly different crustal condition than the Southern Great Plains province where the WIPP site is located. The crustal variation between the Rio Grand Rift and the Southern Great Plains province is suggestive of a sharp transition in the regional stress field. DOE indicated that a resurgence of tectonic activity at the WIPP site is highly unlikely in the near geologic future defined as less than 10,000 years.

In Chapter 2.1.5.3 (p. 2-79) of the CCA, DOE indicated that there are known fault zones along the Central Basin Platform located east of the WIPP. DOE indicated that interpretation of geophysical logs showed that the faults displaced Rustler rocks of at least Permian age. While the overlying Dewey Lake showed marked thinning along the same trend, the structure contours of the top of the Dewey Lake were not clearly off set. No surface displacement or fault has been reported along this trend.

DOE indicated that the nearest known Quaternary faults of tectonic origin to the WIPP have been mapped along the Salt Basin graben west of both the Guadalupe and Delaware Mountains, which is over 50 miles west of the site. DOE concluded (p. 2-79) that there are no known Quarternary or Holocene faults of tectonic origin that offset rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains.

In Chapter 2.1.5.4 (pp. 2-79 to 2-80) of the CCA, DOE indicated that within Delaware Basin there is only one feature of igneous origin known to have formed since the Precambrian. It is an igneous lamprophyre dike (or series of dikes) approximately 75 miles (120 kilometers) long that trends northeast-southwest. At its closest point, the dike trend passes about 8 miles (13 kilometers) northwest of the WIPP site center. DOE indicated that radioactive dating of the dike yielded an age of 30 ± 1.5 million years to 34.8 ± 0.8 million years.

DOE determined in Appendix SCR.1.1 (pp. SCR-1 to SCR-17), that regional tectonic, magamatic, and structural processes are not relevant to site performance during the 10,000-year regulatory period due either to low probability of occurrence or low consequence to repository performance. The one exception was earthquakes, which DOE indicated may create new faults or reactivate old faults.

The following lists Appendices and cross-references for CCA Chapter 2.1.5, the Tectonic Setting and Site Structural Features:

Screening discussion	Appendix SCR
Area seismicity	Chapter 2.6
Location of Faults	Muehlberger et al. 1978 [CCA Reference 446] (Docket A-93-02, Item II-G-1)
Radiometric dating of igneous dike	Calzia and Hiss 1978 [CCA Reference 18] (Docket A-93-02, Item II-G-1)

b. EPA Technical Evaluation Results: Tectonic Setting and Site Structural Features

DOE provided information regarding the occurrence, timing, and nature of structural features and tectonic events in Chapter 2.1.5 and Appendix GCR of the CCA. In Appendix SCR.1.1, DOE screened out any technical or structural features as potentially affecting the containment capabilities of the disposal system through the 10,000 year time frame. Based upon geologic data presented within the CCA and from general geologic text concerning structural history of the Delaware Basin, DOE's conclusion that the tectonic setting should remain stable within the 10,000 year period appears to be technically reasonable, although recognition of the expansion of the basin and range province adjacent to the WIPP area is not included (note that this is not expected to expand to the west at a sufficient rate to impact the WIPP during the 10,000 year regulatory time period).

Appendix GCR and Chapter 2.1.5 of the CCA appear to have presented a technically reasonable discussion of deformation (joints, faults and flexures) in the Delaware Basin area that result from tectonic activity. Based upon geologic data presented within the CCA and from a general geologic text (Slemmons et al. 91) [CCA Reference 595] (Docket A-93-02, Item II-G-1) concerning the structural history of the Delaware Basin, EPA concluded that DOE's argument that the tectonic setting should remain stable within the 10,000 year period (CCA Chapter 2.1.5, pp. 2-68 to 2-80) is acceptable. The timing, location, orientation and nature of structural features in the WIPP area were discussed in detail and were adequately supported by references.

c. DOE Methodology: Loading and Unloading

In Chapter 2.1.5.2 (pp. 2-74 to 2-79) of the CCA, DOE evaluated stratigraphic loading and unloading during the geological history since Permian deposition (**Figure IV-8** of this Technical Support Document), because the stress changes could have caused fracturing which would influence site hydrology. Two scenarios were developed for the WIPP site by DOE. The first scenario addressed an extreme deposition and erosion model, representing the maximum likely loading and unloading sequence based on deposition or erosion evidence which is regional but not necessarily local in occurance. The second scenario applied to a more moderate likely sequence, consistent with the currently observable conditions and strata found near the WIPP site.

For the maximum likely sequence, DOE theorized that up to 1,863 feet (586 meters) of rock may have been deposited above the Culebra at the air intake shaft in two stages encompassing less than 50 million years. The Dewey Lake formation may have reached a maximum thickness of about 787 feet (294 meters) at the end of the Permian, concluding the Palezoic deposition in the Delaware Basin. Over a period of perhaps 35 million years, erosion of the Dewey Lake may have removed about 115 feet (35 meters) of overburden. Additional sediments were deposited during the Triassic as the Dockum group, which may have reached a maximum thickness of about 1,233 feet (376 meters), based on comparisons with the maximum local thickness of the group and in contrast to the 26 feet (8 meters) of Dockum found northeast of the WIPP site.

DOE indicated that Jurassic deposition at the WIPP site is believed to be unlikely, and erosion during this time is considered to be generally insignificant. Based on outcrops about 70 miles (112 kilometers) south-southwest of the site, Cretaceous age rocks of a maximum thickness of 1000 feet are possible, although nearer outcrops suggest less thickness. Late Createaceous and Cenezoic erosion would have removed these rocks from the site. Finally, a Miocene deposition and Pliocene-Pleistocene erosion of up to 330 feet (100 meters) possibly occurred at the site, based on the maximum known thickness in the area around the site. This deposition-erosion cycle represents a brief pulse of loading occuring over a few million years at most.

The second scenario described by DOE, which represented more moderate deposition and erosion rates, was considered by DOE to be more likely (CCA Chapter 2.1.5.2, pp. 2-74 to 2-79). This conclusion was based on evidence of relatively quiescent tectonics and fairly uniform rock structure around the WIPP site, suggesting a more modest loading and unloading history than required for the first scenario. The moderate loading scenario also assumed that up to 1,863 feet (586 meters) of the Dewey Lake and the Dockum Group rocks were deposited by the end of the Triassic period. In the moderate scenario, erosion of the Dockum probably began in the Jurassic, slowed or stopped during the Early Createaceous as the area was nearer or at base level, and then accelerated during the Cenozoic, especially in response to uplift as Basin and Range tectonics encroached on the area and the basin was tilted more. Short period erosion rates may have been relatively high, creating the greatest stress relief on the Culebra and underlying sediments. The moderate loading scenario assumed that virtually no Cretaceous period rocks were deposited in the vicinity of the WIPP site. Some additional loading occurred during the late Cenezoic, but DOE infered that the amount was probably not much greater than exists today.

The following lists appendices and cross-references for CCA Chapter 2.1.5.2, Loading and Unloading: Powers and Holt, 1995 [CCA Reference 514] (Docket A-93-02, Item II-G-1); Borns 1987 [CCA Reference 76] (Docket A-93-02, Item II-G-1).

d. EPA Technical Evaluation Results: Loading and Unloading

Chapter 2.1.5.2 (pp. 2-74 to 2-79) of the CCA discussed possible depositional and erosional histories at the WIPP site from the Late Permian through the Cenozoic. Figure 2-20 of the CCA, presented a graphical representation of several interpretations of the depositional and erosional histories at the WIPP site.

The CCA discussed different interpretations of depositional and erosional histories for specific time intervals for the WIPP site. The interpretations discussed ranged from maximal deposition and erosion to more moderate interpretations. On page 2-76 of the CCA, DOE indicated that a more realistic interpretation suggests a more modest loading and unloading history for the WIPP site, which is supported by Powers and Holt (1995) [CCA Reference 514] (Docket A-93-02, Item II-G-1).

EPA concluded that DOE's choice of a more moderate loading and unloading history at the WIPP site appears to be technically adequate, based on a review of the various depositional and erosional interpretations (scenarios) presented in CCA Chapter 2.1.5.2 (pp. 2-74 to 2-79). The CCA, however, did not specify which loading and unloading event(s) most likely influenced the hydrology of the Permian units, as well as other units, at the WIPP site and does not link this information with observed fracturing in the Rustler. Nonetheless, EPA concluded that it is unlikely that loading/unloading will be of sufficient magnitude to significantly impact the Rustler unit's characteristics over the regulatory time period. **For more detailed discussion, refer to CARD 25 -- Future State Assumptions (Docket A-93-02, Item V-B-2).**

e. DOE Methodology: Seismology

The CCA provided information regarding the seismology of the WIPP site in Chapter 2.6 (pp. 2-180 to 2-205). In Chapter 2.6 of the CCA (p. 2-180), DOE indicated that the current WIPP location was selected because of the absence of tectonic activity, faulting, and igneous activity in the Delaware Basin. DOE described igneous activity as limited to a single known feature, a series of dikes which occur along a linear trace passing no closer than about 8 miles 12.9 kilometers) northwest of the WIPP site. The dike was radiometrically dated as approximately 35 million years old.

The WIPP site was characterized by DOE as located within the Great Plains seismotectonic province, a region that has no evidence of Quaternary faulting, even above major buried structures such as the Central Basin Platform. The nearest Quaternary faulting in the area around the WIPP site is located west of the Guadalupe Mountains, over 50 miles (80 kilometers) away, and were interpreted to be at least 500,000 years old. The nearest Holocene faulting is even farther away, and found at two faults in the Basin and Range Province, with evidence in the Basin and Range for twenty two other faults of Quaternary age. Refer to **Figure IV-9** of this Technical Support Document for the location of regional earthquake epicenters occurring between 1961 and 1964.

DOE studied seismic activity to build a basis for prediction of ground motions that may affect the WIPP repository during operations and in the distant future, when the repository has been sealed. Two aspects of regional seismicity were evaluated, tectonic stability and potential ground motion. Historic earthquakes formed the basis for the evaluation, using the record of felt earthquakes in southern New Mexico which dates back to 1923, and measured earthquakes from the seismic instruments which have been in place in the state since 1961. The distribution of epicenters suggested three source zones representing the Central Basin Platform area, the combined Southern Basin and Range and the Rio Grande Rift areas, and a WIPP site source zone representing background conditions.

Recurrence intervals and maximum magnitudes were calculated for each source zone, and a potential ground motion evaluated as a function of earthquake response spectra and acceleration attenuation. Potential ground motion is expressed as curves of peak ground acceleration versus level of probability of occurance. A Design Basis Earthquake (DBE) was established, with a recurrence interval of 1000 years, and a peak acceleration estimated. For the WIPP site, the DBE was considered equivalent to a Richter magnitude 5.5 earthquake at the site, a magnitude 6.0 earthquake on the Central Basin Platform, or a magnitude 7.8 earthquake in the Basin and Range-Rio Grande Rift area. The peak acceleration associated with the DBE is 0.075 g, where g is the acceleration due to gravity. For additional conservatism, DOE selected 0.1 g as the peak design acceleration to be used at the WIPP site for surface confinement structures and components. Underground structures and components are not subject to DBE design requirements because of past experience showing that underground tunnels are not damaged at sites having peak accelerations below 0.2 g.

The following lists Appendices and cross-references for CCA Chapter 2.6, the Seismology:

Long-term tectonic activity	Chapter 2.1.5
Seismic magnitudes	Appendix GCR

f.   EPA Technical Evaluation Results: Seismology

Chapter 2.6 (pp. 2-180 to 2-205) of the CCA presented generalized information regarding earthquake occurrence in the WIPP area, and Appendix GCR includes additional information pertaining to specific earthquake lactations prior to 1978. Based on the information provided in the CCA, EPA concluded that the information provided regarding the seismology of the WIPP site and surrounding area is acceptable.

5. Physiography and Geomorphology/Topography (2.1.4)

a. DOE Methodology: Physiography and Geomorphology/Topography (2.1.4)

DOE provided information regarding the geomorphology and topography of the WIPP site in CCA Chapter 2.1.4 (pp. 2-64 to 2-68). DOE indicated that geomorphology and physiography are potentially important to disposal system performance because of the nature of regional water tables.

However, in the Introduction to Chapter 2.1.4 (p. 2-64), DOE indicated that certain geomorphic processes, were eliminated from consideration based on either low consequence or low probability of occurrence as discussed in Appendix SCR.1.4 (pp. SCR-21 to SCR-28). These included: weathering; erosion; sedimentation; soil development. In screening out processes, DOE considered slope of terrain, proximity to watercourses, dissection of the land, historical and present erosion.

DOE indicated that the WIPP site is located in the Pecos Valley section of the southern Great Plains physiographic province. The Pecos Valley section was described as dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 miles (8.3 to 50 kilometers) wide and as much as 1,000 feet (305 meters) deep in the north. The Pecos River system receives almost all of the surface and subsurface drainage in the region, and most of its tributaries are intermittent due to the semi-arid climate.

The WIPP site is near the eastern edge of the Pecos Valley section. The Pecos Valley section is bordered on the east by the virtually uneroded plain of the Llano Estacado, of the High Plains section of the southern Great Pains physiographic province. The Llano Estacado is a poorly drained eastward sloping surface covered by gravels, windblown sand and caliche that has developed since early-to-middle Pleistocene time.

DOE indicated that the physiography of the land surface in the vicinity of the WIPP site is a semi-arid, windblown plain sloping gently to the west and southwest. The ground surface is hummocky with sandridges and dunes. DOE indicated that the Mescalero caliche is typically present beneath the sand. The elevations of the site range from 2,570 feet (1,088 meters) in the east to 3,250 feet (990 meters) in the west with an average slope of 50 feet (9.4 meters per kilometer) from east to west.

DOE indicated the WIPP site is located near a natural drainage divide which helps protect it from flooding and serious erosion due to heavy run-off. The surface drainage is described as intermittent, with the Pecos River the nearest perennial stream.

DOE indicated in Chapter 2.1.4.2 (p. 2-67) that the most prominent physiograhic feature near the site is Livingston Ridge, which is a west facing escarpment with approximately 75 feet (23 meters) of topographic relief. The Livingston Ridge is approximately 4 miles (6.4

kilometers) northwest of the center of the WIPP site and marks the edge of Nash Draw. Nash Draw is a shallow 5-mile-wide (8 kilometer) wide, 200 - 300 feet (61 to 91 meters) deep that was caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. DOE indicated that Livingston Ridge is the approximate eastern boundary of terrain that has undergone erosion and/or solution collapse.

The following lists Appendices and cross-references for CCA Chapter 2.1.4, Physiography and Geomorphology:

Water table characteristics	Chapter 2.2.1
Geomorphic processes	Appendix SCR
Tectonics and physiography	Chapter 2.1.5
Nontectonic processes	Chapter 2.1.6

b. EPA Technical Evaluation Results: Physiography and Geomorphology/Topography

Chapter 2.1.4 (pp. 2-64 to 2-68) of the CCA described the Physiography and Geomophology of the WIPP site and surrounding area. Also included was a discussion of the topography of the WIPP site and surrounding area. DOE indicated that in Appendix SCR.1.4 (pp. SCR-21 to SCR-28) several features, events, and processes (FEPs) associated with physiography, geomophology, and topography were screened out based on low consequence. These FEPS are discussed in the following paragraphs. EPA concluded that the description of the physiography, geomorphology, and topography presented in this Chapter was technically reasonable.

The CCA screened out several FEPs associated with physiography, geomophology, and topography. The FEPs which were screened out include: (1) weathering; (2) erosion; (3) sedimentation; and (4) soil development. A description of these FEPs and the reasons that they were screened out was presented in Section SCR.1.4 of Appendix SCR.

Weathering was screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. EPA concluded that this is technically reasonable and adequate since mechanical and chemical weathering should be limited to the surface and near surface environment.

Erosion and sedimentation were screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. Aeolian erosion/deposition will continue to occur over the WIPP site and surrounding area; however, DOE concluded that no significant changes in the overall thickness of aeolian material is likely to occur within the performance period. The limited extent of water courses within the WIPP area will limit the amount of fluvial and lacustrine erosion/ deposition. Mass wasting could be significant if it results in dams or modifies streams. However, the Pecos River is located approximately 12 miles from the WIPP site in a broad valley, which precludes either significant mass wasting or large impoundments from forming that could be of sufficient size or volume to impact the WIPP. EPA concluded that DOE’s explanations were technically reasonable for screening out sedimentation from the performance assessment.

Soil development was screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. The Mescalero caliche lies directly beneath the surficial soils at the WIPP site. The Mescalero caliche has been dated at 410,000 to 510,000 years old. Berino soil, which makes up a thin horizon over the Mescalero caliche, is interpreted to be 333,000 years old. These relationships indicate a period of relative stability of the WIPP area for the past 500,000 years. EPA concluded that this interpretation is technically reasonable for screening out soil development from the performance assessment calculations.

6. Soil Characteristics (Surficial Sediments - 2.1.3.10)

a. DOE Methodology: Soil Characteristics (Surficial Sediments - 2.1.3.10)

DOE provided information regarding the soil characteristics in the vicinity of the WIPP in CCA Chapter 2.1.3.10 (pp. 2-60 to 2-63). DOE indicated that there are three soil associations within 5 miles (8.3 kilometers) of the WIPP Site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. All of the soils were developed in a sunny, semiarid, continental climate with low relative humidity, erratic and low rainfall, and in a wide range in daily and seasonal temperatures. The soils in the region were developed from Quaternary Mescalero caliche and Permian age parent material.

DOE indicated that only the Kermit-Berino soil association has been mapped at the WIPP site . The Berino Series soils cover about 50% of the site, include active dune areas, and consist of noncalcareous, yellow-red to red sandy soils. A sandy “A” horizon has developed, as has a “B” horizon that includes more argillaceous material and weak-to-moderate soil structures. The Berino Series soil includes a C horizon which is commonly caliche. The Berino Series soil is estimated to be 330,000 +/- 75,000 years old, and is susceptible to wind erosion, primarily in the months of March, April and May, when rainfall is minimal and winds are highest.

The Kermit Series soils consist of deep, non calcareous, excessively drained loose sands that are typically yellowish-red fine sands. The Kermit Series soils consist mostly of stabilized dunes with a relatively thin 0.6 foot (0.17 meter) A horizon and an approximately 4.5 foot (1.4 meter) thick C horizon. There is no defined B horizon. The wind erosion potential for the Kermit Series is high if the vegetative covers is removed.

The following lists Appendices and cross-references for CCA Chapter 2.1.3.10, Soil Characteristics (Surficial Sediments):

Kermit-Berino Soil mapping near WIPP	Chugg et al. 1952, Sheet No. 113 [CCA Reference 132] (Docket A-93-02, Item II-G-1)
Monument Design and Soils	Appendix PIC, Section III
Groundwater in soils	Appendix HYDRO
Berino soil dating	Rosholt and McKinney 1980, Table 5 [CCA Reference 555] (Docket A-93-02, Item II-G-1)

b. EPA Technical Evaluation Results: Soil characteristics (Surficial Sediments)

The soils/surficial sediments were described in Chapter 2.1.3.10 (pp. 2-60 to 2-63) of the CCA. The CCA relied on and was consistent with information presented in Appendix GCR and Appendix HYDRO and the soil survey for Eddy County (Chugg et al. 1952)[CCA Reference 132] (Docket A-93-02, Item II-G-1). The CCA described soil characteristics within the WIPP area and identifies three soil associations within 5 miles of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three soil associations, only the Kermit-Berino has been mapped at the WIPP site and is discussed in the CCA. EPA concluded that the description of the soil series at the WIPP provided in the CCA was technically reasonable.

7. Natural Resources (2.3)

a. DOE Methodology: Resources (2.3)

DOE provided information regarding natural resources in the vicinity of the WIPP site in CCA Chapter 2.3 (pp. 2-145 to 2-161). DOE indicated that the consideration of resources was an important part of the siting criteria for the WIPP. Several siting criteria emphasized the avoidance of resources that would impact the performance of the disposal system including selecting a site that: maximized the use of the federal lands; avoided known oil and gas trends; minimized the impacts on potash deposits; and avoided existing drill holes. DOE acknowledged that the WIPP site did not meet all of these criteria totally, but stated that the information in the CCA shows that the favorable characteristics of the location compensate for any increased risks due to the presence of resources.

DOE defined resources as both economic (mineral and nonmineral) and cultural resources that may exist at or beneath the WIPP site. DOE indicated the discussion of resources is important to obtain an understanding of past uses in the area; show future use of the area; and identify possible uses that could disrupt the closed facility. DOE indicated that due to the depth of the disposal horizon, it is believed that only the mineral resources are of significance to predicting the long-term performance of the disposal system. DOE referenced CCA Appendix SCR and Chapter 6 for discussion of the screening of Features, Events and Processes (FEPs) related to resources. To support the screening decisions, DOE provided information on:

- natural resource distributions;
- potable groundwater;
- drill holes & drillhole distribution;
- drill holes & drillhole distribution used for injection;
- mines
- excavations;

- other man-made features for resource exploitation;
- activities that alter the surface of the land;
- agricultural activities that may affect the disposal system;
- archeological resources requiring deep excavation; and
- technological changes that may alter local demographics.

Mineral resources of potential economic interest include potassium salts and hydrocarbons, and DOE identified both proven and probable reserves for these natural resources. For both petroleum resources and potassium salt mining, DOE gathered information on the following:

- resource type;
- number, location, depth of resource;
- present state of development including penetrations through the disposal horizon;
- accessibility, quality and demand for the resource; and
- mineral ownership.

DOE indicated that there are five mineral natural resources of practical concern that are expected to occur beneath the site. They are: two potassium salts (sylvite and langbenite) in the McNutt Potash Zone of the Salado; and three hydrocarbons (crude oil natural gas and distillate liquids associated with natural gas) which occur in the strata below the Castile. DOE indicated that while the mineral resources caliche, salt gypsum and lithium are present beneath the site, there are enormous deposits of these minerals near the site and else where in the country that are more than adequate (and more economically attractive) to meet future requirement for these materials.

DOE indicated that in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site (NMBMMR 1995) [CCA Reference 460] (Docket A-93-02, Item II-G-1). The information provided by DOE in the CCA is based in part on this study.

DOE indicated that commercial quantities of potassium salts are restricted to the middle portion of the Salado Formation, called the McNutt. Eleven potash zones have been recognized and are numbered from top to bottom. DOE indicated that the conclusion reached by Griswold in the NMBMMR was that only the 4th and 10th are zones containing economic potash reserves and that none of these lie directly above the waste panels. DOE provided Figure 2-38 of the CCA to show the extent of possible future mining within the controlled area around the WIPP.

DOE indicated that an initial hydrocarbon resource study in southeastern New Mexico was conducted by Foster (1974) [CCA Reference 253] (Docket A-93-02, Item II-G-1) of the NMBMMR in 1974. A reassessment of hydrocarbon resources within the WIPP site boundary and the first mile and adjacent to the boundary was included as part of the 1995 NMBMMR study. Calculations were made for amounts of probable oil and gas resources beneath the site by extrapolating currently productive oil and gas resources that are though to extend beneath the study area. DOE provided the results in Tables 2-8 and 2-9 of the CCA.

CCA Chapter 2.3.1.2 (p. 2-148) referred to Appendix DEL.5 (pp. DEL-26 to DEL-46) and Appendix MASS.16 (pp. MASS-87 to MASS-99) for detailed information regarding modeling parameters related to hydrocarbon resources and their exploration.

DOE indicated that there are groundwater wells in the vicinity of the WIPP that are used primarily for watering livestock. The wells are considered shallow, generally no deeper than the Culebra. DOE referenced Appendix DEL and Appendix USDW for an evaluation of underground sources of drinking water in the vicinity of the disposal system.

DOE provided information regarding the demographics, landuse, history and archaeology in the vicinity of the WIPP site. DOE concluded that in no case does it appear that past or present land use has had an impact on the subsurface beyond the development of shallow groundwater wells to water livestock.

The following lists Appendices and cross-references for CCA Chapter 2.3, Natural Resources:

Cultural resources screening criteria	Appendix FEPs, Chapter 6 Appendix SCR
Petroleum resource definitions	NMBMMR 1995, V-2 and V-3 [CCA Reference 460] (Docket A-93-02, Item II-G-1)
Specific impacts of resource development	Chapter 6.4.6.2.3
Potash ore zone database	Appendix DEL
Potash leases	Appendix MASS, Attachment 15-5
Hydrocarbon resources	Appendix DEL

b. EPA Technical Evaluation Results: Resources

DOE concluded that the most important extractable resources in the WIPP are hydrocarbons, potassium salts, and water. EPA agreed that this conclusion is reasonable. CCA Chapter 2.3 (pp. 2-145 to 2-161) and Appendices DEL.4 (pp. DEL 9 to DEL 25), DEL.5 (pp. DEL-26 to DEL-46), and NMBMMR, 1995 [CCA Reference 460] (Docket A-93-02, Item II-G-1) discuss estimates of these resources in detail, including current and future mining and oil and gas extraction technologies. With respect to potash, the CCA indicated that only the 4th and 10th horizons are economic reserves, although remaining ore zones are considered resources that would be mined with advances in thin-seam extraction technologies. This map was similar to that identified in an EPA Technical Memorandum to Docket A-93-56, Item IV-B-07. EPA concluded that DOE's presentation was sufficient, given DOE's requirements to assess resources relative to those currently being mined. **See CARD 32, Scope of Performance Assessments, for additional discussion.**

EPA concluded that neither DOE's nor Department of Interior's estimate shows the area above the WIPP waste panels as containing mineable reserves. EPA also found that CCA Chapter 2.5 focused on extractable resources of most apparent immediate import but did not address other resource removal activities, such as the extraction of salt-bearing waters for use in oil-extraction or potash solution mining. DOE provided supplemental information in a letter dated May 14, 1997 (DOE, 1997d) (Docket A-93-02, Item II-I-31) indicating that potash solution mining and brine extraction do not need to be considered for the PA, based on low consequence to the containment capability of the repository. EPA reviewed the supplemental data and concurs with DOE's conclusion. **Refer to CARD 32, Scope of Performance Assessments, for additional discussion.**

DOE addressed groundwater resources and calculated the rate of shallow drilling (including that for water resources) in the WIPP area, as required under Section 194.33. **Refer to CARD 33, Consideration of Drilling Events in Performance Assessments, for additional discussion.** DOE concluded that shallow drilling will have little consequence on the repository containment capabilities and screened shallow drilling from the performance assessment within Appendix SCR.3.2.1 (pp. SCR-101 to SCR-104) and Appendix SCR.3.3.1 (pp. SCR-108 to SCR-135). EPA concurred with this assessment **(refer to CARD 32, Scope of Performance Assessments)** and also noted that most of the water in the vicinity of WIPP is highly saline, with the exception of the Capitan aquifer (which is the aquifer most commonly tapped for domestic use) that occurs near the edge of the Delaware Basin, tens of miles from the WIPP.

C. Site Hydrology (2.2) [194.14(a)(2)]

1. Groundwater Hydrology (2.2.1)

a. DOE Methodology: Overall Summary of Groundwater Hydrology (2.2.1)

DOE provided information regarding the hydrogeologic characteristics of the geologic units in the disposal system in CCA Chapter 2.2.1 (pp. 2-97 to 2-145), Appendix FAC, Sections 7 and 8 (pp. 7-1 to 8-18), Appendix GCR, Section 6 (pp. 6-1 to 6-62), and HYDRO (pp. 22 to 75). For each of the geologic units in the vicinity of the WIPP disposal system, DOE provided information regarding hydraulic conductivity, storage coefficients, transmissivity, permeability, thickness, matrix and fracture characteristics, and hydraulic gradients in a summary table provided to EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table is included here as **Figure IV-10** and will be referred to in the description of the hydrology of individual units provided below. The CCA also provided detailed groundwater hydrology information for geologic units that could be expected to transmit radionuclides to the accessible environment in the subsections of

Chapter 2.2.1.

DOE gathered hydrological data for the Castile, Salado, Rustler, and Dewey Lake Formations in 27 boreholes within the WIPP site boundary and from approximately 30 boreholes outside the WIPP site boundary (Fig. 2-2 of the CCA).

Hydrological data was obtained via borehole geophysical logs, standard drill stem tests (for pressure measurements, fluid samples and permeability), and slug injection or fluid withdrawal tests (for transmissivity and fluid storage data), water salinity, and depths to the hydraulic heads of hydrological systems and to the water table.

DOE determined the Castile, Salado, Rustler and Dewey Lake hydrological systems to be most important to disposal system performance and modeling (Chapter 2.2.1, p. 2-97). DOE indicated there are other hydrological units that are significant to the screening of hydrological processes or they play lessor roles in the conceptual model including: the Bell Canyon, the Capitan, the Rustler-Salado contact zone, and the Supra-Dewey Lake units. Table 2-4 of the CCA showed hydrologic characteristics of the Rustler at the WIPP and in Nash Draw.

DOE indicated that the Bell Canyon hydrology is of interest because it is the first regionally continuous water bearing unit beneath the WIPP. The Castile provides a hydrologic barrier between the Bell Canyon and Salado, and the Castile is also of interest because it contains high-permeability zones of pressurized brine. The Salado is considered the most significant hydrologic barrier between the repository and more transmissive beds. At the WIPP Site, the Rustler contains two transmissive members: the Culebra and the Magenta. The Dewey Lake exhibits no flow at the WIPP site, though DOE reported flow from a fractured zone off-site of the WIPP. The Santa Rosa is unsaturated at the WIPP site.

The following lists Appendices and cross-references for CCA Chapter 2.2.1, Groundwater Hydrology:

Conceptual models for groundwater flow	Chapter 6.4
Pressurized brine discussion	Chapter 2.1.6.1
Dewey Lake fracture zone flow	WQSP-6A
Culebra studies	La Venue et al. 1988, 1990 [CCA References 392 and 393] (Docket A-93-02, Item II-G-1) Haug et al. 1987 [CCA Reference 288] (Docket A-93-02, Item II-G-1) Siegal et al.1991 [CCA Reference 590] (Docket A-93-02, Item II-G-1)
Rustler units hydrology overview	Table 2-4
Hydrology models	Appendix MASS.14.1 Chapters 6.4.5, 6.4.6
Culebra hydrology models	Appendix MASS.15.1

b. EPA Technical Evaluation Results: Overall Summary of Groundwater Hydrology

The CCA includes information regarding groundwater hydrology of the geologic units in the vicinity of the WIPP site in Chapter 2.2.1 (pp. 2-97 to 2-145), Appendices GCR, Section 6 (pp. 6-1 to 6-62) and HYDRO (pp. 22-75), and numerous references cited throughout Chapter 2.2.1, e.g., Appendix MASS.2 (pp. MASS-1 to MASS-11). For each of the geologic units in the vicinity of the WIPP, DOE provided information regarding hydraulic conductivity, storage coefficients, transmissivity, permeability, thickness, matrix and fracture characteristics and hydraulic gradients in a Summary Table provided to EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). The CCA also provides detailed groundwater hydrology information for those geologic units that could be expected to transmit radionuclides to the accessible environment.

In general, EPA concluded that information regarding the groundwater hydrology for the various geologic and hydrostratigraphic units at the WIPP site identified the important characteristics of the disposal system for performance assessment and was therefore technically sufficient. EPA noted that the primary hydrogeologic units of concern relative to containment capability of the WIPP are the Castile, Salado, Rustler, and the Dewey Lake.

Several potential issues identified during the EPA evaluations are described briefly below. Detailed evaluations of the groundwater hydrology information provided by DOE in the individual subsections of Chapter 2.2.1 of the CCA are provided below in the EPA Technical Evaluation Results for each of the subsections of Chapter 2.2.1.

DOE's discussion of the size, orientation, and repressurization potential of the Castile brine reservoirs did not appear to be well supported through discussions in the text or through references.

DOE descriptions of the groundwater hydrology of the Salado did not include an estimate of the volume of water expected to enter the repository excavations due to both near-field flow from the disturbed rock zone surrounding the excavations and from far-field flow via the marker beds.

In general, DOE's overall description of the hydrology of the Rustler Formation appeared to be technically reasonable although EPA did raise questions during the initial review. There appeared to be inconsistencies between the hydrological characteristics description of the various Rustler members that is based on the results of site characterization, compared to the conceptual model used in the performance assessment. For example, the physical description of the hydrology implied that the Culebra acts as a drain for the hydrostratigraphic units above it, but the conceptual model indicated that the Culebra is conceptualized as a horizontal, confined aquifer. This inconsistency also carried through for the Tamarisk Member and the Forty-niner Member of the Rustler Formation, which the conceptual model considered confining layers, but if the Culebra actually acts as a drain for the hydrostratigraphic units above it, then the Tamarisk and Forty-niner Members must allow at least some downward leakage from the overlying Magenta Member and Dewey Lake Redbeds.

The description of the groundwater hydrology for the Dewey Lake Redbeds indicated that the unit contains an inconsistently productive zone of saturation that appears to derive much of its transmissivity from open fractures and that the fractures beneath this intermittent productive zone tend to be completely filled with gypsum. The Dewey Lake productive zones occur only in certain areas and are not continuous, which suggests a possible perched water table. However, it was not clear that the secondary porosity caused by the fractures in the unit was not considered in the conceptual model for performance assessment.

Technical issues relative to Castile brine, Salado marker bed permeability, and Culebra hydraulic properties (e.g. transmissivity variation) were initially raised by EPA in a letter dated December 19, 1996 (Docket A-93-02, Item II-I-01) (see various hydrology discussions below). DOE provided supplemental information in letters dated January 24, 1997, February 7, 1997, April 15, 1997, June 13, 1997, June 27, 1997, and July 3, 1997 (DOE, 1997a, b, c, e, j, and k) (Docket A-93-02, Item II-H-46, Item II-H-45, Item II-H-44, Item II-I-24, Item II-I-07, and Item II-I-03) addressing EPA's concerns. The supplemental information provided by DOE alleviated EPA's concerns.

c. DOE Methodology: Conceptual Models of Groundwater Flow (2.2.1.1)

The CCA provided a description of the conceptual models of groundwater flow within Chapter 2.2.1.1 (pp. 2-98 to 2-106). DOE classified three hydrologic units as hydrostratigraphic units in modeling: units below the Salado; the Salado; units above the Salado. The Castile and Salado form a single groundwater system of relatively low permeability. The Castile and Salado evaporite beds form the base for the groundwater-flow basin in the overlying rocks of the Rustler, Dewey Lake, and Santa Rosa. A hydrostratigraphic unit is a continuous region of rock across which hydraulic properties are similar or vary within described or stated limits. Rock stratigraphic units may be different from hydrostratigraphic units in relation to fracturing, dissolution, and flow characteristics of confining layers.

In DOE models, confining layers are units in which only vertical flow is significant. In conductive units, flow is both vertical and lateral. The size of lateral flow, or volume flux, relates to hydrostratigraphic unit thickness, conductivity, and pressure gradient within the unit. The direction of groundwater flow is generally related to depth below the land surface. For example, flow direction in shallower units are influenced by local slopes of the land surface and in deeper conductive units flow directions generally align with the highest and lowest points in a groundwater basin. The pattern of groundwater flow depends on the lateral extent of the basin, shape of the water table, and permeability to flow at different scales within rocks of the basin.

DOE included concepts of an idealized groundwater basin model. Conceptual ideas included a three-dimensional closed hydrological unit bounded by an underlying impermeable rock unit, a ground surface at the top, and by groundwater divides on the sides. All rocks in the model basin are in hydraulic continuity, and potential for flow between units exists. All recharge to the model basin is by precipitation to the water table, and all discharge from the basin is by flow across the water table to the land surface.

DOE implemented the groundwater basin conceptual model for flow within the rocks above the Salado, and DOE stated that the most transmissive unit above the WIPP site is the Culebra member of the Rustler Formation. DOE studied the potential for lateral contaminant transport in the Culebra, and except for a breach directly to the surface, considers the formation to be the most direct pathway between the WIPP underground site and the accessible environment. DOE believed that the Magenta is less transmissive, though DOE performed studies on both the Culebra and Magenta.

The following lists Appendices and cross-references for CCA Chapter 2.2.1.1, Conceptual Models of Groundwater Flow:

Background for regional groundwater flow	Appendix MASS.14.1 Appendix MASS.14.2
Conceptual models for groundwater flow	Chapter 6.4
Key modeling assumptions	Appendix MASS.14.2

d. EPA Technical Evaluation Results: Conceptual Models of Groundwater Flow

The conceptual model for groundwater flow at the WIPP was discussed in Chapter 2.2.1.1 (pp. 2-98 to 2-106) of the CCA. The upper boundary for the conceptual model for groundwater flow in units above the Salado at the WIPP was identified by DOE as the ground surface. The lower boundary of the conceptual model for groundwater flow at the WIPP was identified by DOE as the top of the Salado Formation. While DOE's computer modeling assumes no flow into the Culebra, and treats the Culebra as a confined aquifer, DOE does assume that the hydraulic head increases as if there were flow into the unit. EPA concluded that the use of the ground surface and the top of the Salado as boundaries in the model was technically reasonable.

e. DOE Methodology: Units Below the Salado (2.2.1.2.1)

i. Bell Canyon Hydrology (2.2.1.2.1)

The CCA provides a description of the hydrology of the Bell Canyon in Chapter 2.2.1.2.1 (p. 2-107). The Bell Canyon was considered a single hydrostratigraphic unit about 1,000 feet (300 meters) thick. Based on tests from five boreholes in the vicinity of the WIPP Site, DOE determined the range of hydraulic conductivity in the Bell Canyon to be between $5x10^{-2}$ feet per day to $1x10^{-6}$ feet per day ($1.7x10^{-7}$ to $3.5x10^{-12}$ meters per second). In tests of two boreholes, DOE found the pressure range to be between 12.6 to 13.3 megapascals.

DOE indicated that fluid in the Bell Canyon is influenced by the isolating nature of the overlying Castile and Salado and that fluid flow directions are sensitive only to gradients established over very long distances. Brines of the Bell Canyon flow northeasterly under an estimated hydraulic gradient of 25 to 40 feet per mile (4.7 to 7.6 meters per kilometer) and discharge into the Capitan aquifer. Velocities are on the order of tenths of feet per year, and groundwater yields from wells in the Bells Canyon are 0.6 to 1.5 gallons (2.3 to 5.8 liters) per minute. Additional hydrogeologic information is provided in **Figure IV-10** of this Technical Support Document.

The following lists Appendices and cross-references for CCA Chapter 2.2.1.2.1, the Bell Canyon:

Borehole data for Bell Canyon hydrology	Appendix HYDRO, p.29-31
Bell Canyon flow directions	Chapter 2.2.1.4

ii. Castile Hydrology (2.2.1.2.2)

The CCA provided information regarding the hydrology of the Castile in Chapter 2.2.1.2.2 (pp. 2-107 to 2-108). The description of the hydraulic characteristics of the Castile had two components: the Castile and the Castile brine reservoirs. The Castile is dominated by low permeability anhydrite and halite zones and is assigned an extremely low permeability in the conceptual model. See **Figure IV-10** of this Technical Support Document for additional information regarding the hydrogeologic characteristics of the intact Castile.

DOE found the upper portion of the Castile to contain fractured anhydrite in regions of structural deformation (Figure 2-28 of the CCA). The fracturing in the upper anhydrite of the Castile has generated isolated regions with much greater permeability than the surrounding intact anhydrite. The higher permeability of the Castile contain brine pressures greater than hydrostatic and have been referred to as brine reservoirs. In one example (WIPP 12 borehole) the fluid pressure was measured at 12.7 megapascals, greater than the nominal hydrostatic pressure of 11.1 megapascals for the depth, indicating that brine could flow upward to the surface through a borehole.

DOE conducted a time-domain electromagnetic survey (TDEM) over the WIPP-12 brine reservoir and over the WIPP Site waste disposal panels, and detected a conductivity response interpreted to be the WIPP-12 brine reservoir and also indicated that similar brine occurrences may be present in the Castile under a portion of the waste disposal panels. On a geostatistical basis, DOE found the probability of a borehole encountering brine below a waste panel to be 8 percent (Powers et al. 1996)[CCA Reference 516] (Docket A-93-02, Item II-G-1).

DOE believed the Castile residual times could be on the order of several hundred thousand years. Isolated volumes of brine were estimated, based on data from two bore holes, the ERDA-6 ($3.6x10^6$ cubic feet; 100,000 cubic meters) and the WIPP-12 ($9.5x10^{+7}$ cubic feet; 2,700,000 cubic meters). Specific information regarding the hydrogeologic characteristics of the Castile brine reservoirs is provided in **Figure IV-10** of this Technical Support Document.

DOE indicated that based on geochemical investigations (Popielak et al., 1983) [CCA Reference 511] (Docket A-93-02, Item II-G-1), the brines originated from ancient sea water and that no evidence exists for fluid contribution from present meteoric waters. Based on data from the ERDA-6 and WIPP-12 reservoirs, the brines are distinct from each other and from local groundwaters. In addition, DOE indicated that the brines are saturated, or nearly so, with respect to halite and consequently have little potential to dissolve halite.

The following lists Appendices and cross-references for CCA Chapter 2.2.1.2.2, the Castile:

Castile lithology	Chapter 2.1.3
Structurally deformed areas	Chapter 2.1.6.1.1
Conceptual model for Castile brine	Chapter 6.4.8
Model parameters	Appendix PAR, Tables PAR-49, PAR-50
Derivation of model parameters	Appendix MASS.18
Chemical composition of Castile brine	Table 2-5
Brine composition as model parameter	Appendix SOTERM.2.2.1
Brine volume estimated in two wells	Popielak et al 1983 [CCA Reference 511] (Docket A-93-02, Item II-G-1)
Time-domain electromagnetic survey	The Earth Technology Corp. 1988 [CCA Reference 229] (Docket A-93-02, Item II-G-1)
Probability of a drillhole encountering brine under WIPP	Appendix MASS, Attachment 18-6

f. EPA Technical Review Results: Units Below the Salado

i. Bell Canyon Hydrology

The pressure head within the Bell Canyon is important to WIPP performance based on the potential for fluid within the Bell Canyon to migrate up a borehole which has penetrated both the Salado and Castile Formations. Based on the maximum recorded pressure of 13.3 megapascals (Cabin Baby), fluid from the Bell Canyon could migrate up a borehole into the Rustler Formation possibly to the Culebra. However, as discussed in Appendices DEL and SCR (also Beauheim, 1986) [CCA Reference 40] (Docket A-93-02, Item II-G-1), DOE took the position that dissolution of salt from an uncased borehole would result in a fluid level below the Culebra. Discussion presented on this subject in Appendices DEL, SCR and Beauheim (1986) [CCA Reference 40] (Docket A-93-02, Item II-G-1) supported this argument and recognize limitations in understanding many of the factors that could affect the density of fluid flow through a borehole from the Bell Canyon to the Rustler. Overall, EPA concluded that the information pertaining to the Bell Canyon hydrology was technically adequate.

ii. Hydrology of the Castile

DOE characterized several aspects of the hydrogeology of the Castile Formation brine pockets based on the limited direct evidence DOE had available on brine product nature and occurrence. The geochemical argument that DOE presented for the isolation of pressurized brine pockets relative to each other appeared to be technically reasonable, but was based on very limited data. According to this argument, the differences in the geochemical signatures of individual brine pockets is indicative of the lack of connectivity between the reservoirs. No contradictory evidence of connectivity between brine pockets was identified in the CCA, although the CCA also failed to present any evidence to the contrary.

The Natural Barriers Peer Review panel considered DOE's characterization of the Castile brine reservoir rock compressibility, porosity, pressure, permeability, and volume. They were able to qualify each of these parameters. However, it was observed that several aspects of the Castile Formation brine reservoirs that are considered in performance assessment modeling were not reviewed by a peer review panel and, upon inspection, these were found to not be well characterized in the CCA. These characteristics included size, orientation and repressurization potential. For instance, it could be assumed that the "estimated effective area" (CCA page 6-164, line 42) of a brine reservoir is based on the fracture thickness data presented in Table 1 of Attachment 18-3 of Appendix MASS. However, this is not necessarily the case. Also, the current understanding of the distribution of "high-angle fractures spaced widely enough that a borehole can penetrate through a volume of rock containing a brine reservoir without intersecting any fractures" (CCA page 6-162, lines 20-22) was not discussed in an organized manner, and was not well supported by data. It was therefore not clear that DOE's treatment of the consequences of encountering a brine pocket is appropriate.

EPA found that DOE's discussion of the size, orientation, and repressurization potential of the Castile brine reservoirs was not well supported by the CCA (see Chapter 2.2.1.2.2, pp. 2-107 to 2-108, and Appendices DEF.2, pp. DEF-1 to DEF-18, and DEL.7.5, pp. DEL-81 to DEL-87). The probability value for encountering a brine pocket also was poorly supported, since other DOE data imply this probability could be as high as about 60 percent (Chapter 2.2.1.2.2, pp. 2-107 to 2-108). Therefore, in a letter dated April 25, 1997 (Docket A-93-02, Item II-I-27), EPA required this parameter to be sampled between a range of 1 and 60 percent in the EPA Mandated Performance Assessment Verification Test (PAVT) (DOE, 1997l and DOE 1997m) (Docket A-93-02, Item II-G-26 and Item II-G-28). In addition, EPA modified the values for parameters such as bulk compressibility of Castile rock so that the brine reservoir used in the performance assessment would be sampled more representatively relative to larger, higher-end possible brine volumes. **More information on the review of these parameters is found in CARD 23, Models and Computer Codes, and its associated technical support documents.** The PAVT used modified Castile brine reservoir characteristics and showed that WIPP still meets the containment requirements (DOE, 1997l, Figure 7-2) (Docket A-93-02, Item II-G-26). As a result, EPA found that the original brine reservoir characteristics were, in fact, acceptable.

g. DOE Methodology: Hydrology of the Salado (2.2.1.3)

The CCA provided information regarding the hydrology of the Salado in Chapter 2.2.1.3 (pp. 2-108 to 2-113). DOE indicated that for purposes of hydrologic characterization, the Salado can be considered to consist of impure halite, pure halite, anhydrite, and marker beds. Specific information regarding the Salado is provided in **Figure IV-10** of this Technical Support Document.

DOE estimated hydraulic properties of the Salado from field and laboratory experiments and information obtained from WIPP site boreholes. DOE performed twenty-two hydraulic tests in impure halite. Permeabilities interpreted using a darcy flow model varies from $1x10^{-23}$ to $4x10^{-18}$ square meters. Interpreted formation pore pressures vary from 0.3 to 9.7 megapascals, and DOE believed the lower pressure shows effects of the Disturbed Rock Zone (DRZ). DOE indicated that two hydraulic tests conducted in pure halite have shown no observable response, indicating either extremely low permeability ($<10^{-23}$ square meters), or no flow what so ever. From fourteen tests in anhydrite, DOE interpreted Darcy model flow to vary from $2x10^{-20}$ to $7x10^{-18}$ square meters. Interpreted formation pore pressures vary from atmospheric to 12.5 megapascals, and DOE believed the lower pressure was caused by depressurization near the WIPP excavation.

DOE laboratory investigations included tests on three groups of core samples from MB 139. They are: measuring porosity, intrinsic permeability, and capillary pressure data. Threshold capillary flow pressure is indicated to be less than 1 megapascal.

Brine chemistry was considered an important factor in repository performance; Table 2-5 of the CCA summarized results of the Brine Sampling and Evaluation Program chemical determinations for Salado brines. In addition, DOE prepared a conceptual model for actinide dissolution, described in Chapter 6.4.3.5 of the CCA. DOE collected qualitative data on brine flow to underground workings since 1985. Brine content of the Salado was estimated to be 1 to 2 percent by weight, and thin clay seams contain up to 25 percent brine by volume. Natural brine of the Salado will move between areas of lower hydraulic potential and flow to the WIPP DRZ, and, for example, was characterized as complex and discontinuous. Refer to Chapter 2.2.1.3 (pp. 2-112 to 2-113) for additional information.

DOE considered the measured pressures of the Salado at the WIPP site to be a lower bound of natural pressures, though pressures cannot be higher than lithostatic pressures (lithostatic pressure calculated from density measurements in wellbore ERDA-9 is about 15 megapascals). DOE observed pore pressures in halite-rich units near Room Q on the order of 9 megapascals (the hydrostatic pressure for a column of brine at the depth of the repository is 7 megapascals). The highest pore pressure observed in anhydrite is 12.5 megapascals. DOE expected far-field pore pressures to be similar in halite-rich and anhydrite beds.

The following lists Appendices and cross-references for CCA Chapter 2.2.1.3, the Hydrology of the Salado:

Salado lithology	Chapter 2.1.3
Salado hydraulic properties	Appendix HYDRO (p. 41-42) Appendix PAR
Hydraulic parameters for performance assessment	Appendix PAR, Tables PAR-6, PAR-7
Salado brine chemistry	Appendix GCR, Section 7.5
Salado brine content	Appendix SUM, Section 3.3.1.3
Alternative conceptual flow models	Appendix MASS, Section MASS.7
Repository fluid flow model	Chapter 6.4.3.2
Brine Sampling and Evaluation Program (BSEP)	Table 2-5 Deal and Case 1987 [CCA Reference 166]

	(Docket A-93-02, Item II-G-1) Deal et al. 1989, 1991a, 1991b, 1993 [CCA References 167, 170, 171, and 172] (Docket A-93-02, Item II-G-1)
Actinide solution - conceptual model	Appendix SOTERM Chapter 6.4.3.5

h. EPA Technical Review Results: Hydrology of the Salado (2.2.1.3)

The hydrology of the Salado was discussed in Chapter 2.2.1.3 of the CCA and EPA found the characterization provided in the CCA and supporting references to be technically reasonable. Several aspects of Salado hydrology were reviewed by the Natural Barriers Peer Review Panel and each was qualified (see Appendix PEER). Although not all of the required specific information concerning the hydraulic characteristics of the Salado Formation was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

A potential concern with the characterization of the hydrogeology of the Salado, identified through review of the CCA, related specifically to the relative contributions of near- and far-field water flow into the repository. Clay minerals have been identified disseminated throughout the Salado Formation and also occurring in distinct layers, sometimes associated with Marker Beds. As a result of repository excavation, water may be released from the disturbed rock zone surrounding the repository. This near-field flow may contribute a significant volume of water to the repository. DOE concluded that Darcy flow is able to provide an adequate and conservative characterization of far-field groundwater contributions to the repository. DOE did not provide a description of the relative contributions of water to the repository from these two sources in Chapter 2 of the CCA. In EPA's December 19, 1996 and March 19, 1997 letters to DOE (Docket A-93-02, Items II-I-01, and II-I-17), EPA identified information needed to clarify the anhydrite characteristics. In supplemental information provided in letters dated January 24, 1997 and April 15, 1997 (DOE 1997k and DOE 1997e) (Docket A-93-02, Item II-I-03, and Item II-I-24), DOE provided information on anhydrite characterization and modeling implementation.

Hydrology of the Salado Formation relative to the distribution of fractures within marker beds and how it impacts fluid flow to/out of the repository was the subject of numerous DOE studies and an EPA study. EPA has concluded that while fracture distribution and subsequent fluid flow in the Salado maker beds cannot be detailed, the overall application of fracturing and subsequent fluid flow appears to be representative of site conditions. Refer to EPA's **Technical Support Document for Section 194.32: Fluid Injection Analysis (Docket A-93-02, Item V-B-22)** for additional details.

EPA concluded that while fracture distribution and subsequent fluid flow in the Salado marker beds cannot be detailed, the general application of fracturing and subsequent fluid flow appears to be an adequate representation of overall site conditions. EPA also concluded that DOE's modeling of fractures within Salado anhydrite marker beds is acceptable **(see**

CARD 23 -- Models and Computer Codes for further discussion).

i. DOE Methodology: Hydrology of the Rustler Formation (2.2.1.4.1)

The CCA provided information concerning the hydrology of the Rustler in Chapter 2.2.1.4.1 (pp. 2-117 to 2-131). DOE indicated that the units above the Salado (i.e. the Rustler, the Dewey Lake and the Santa Rosa) are classified as a single hydrostratigraphic unit for conceptual and computer modeling. Hydrology units with relatively high permeability are called conductive units and those with low permeability are called confining layers. DOE indicated that the Rustler is of particular importance for WIPP because it contains the most transmissive units above the repository. In general, fluid flow in the Rustler is characterized by very slow vertical leakage through confining layers and faster lateral flow in conductive units.

DOE found the Culebra Member, for example, to have lateral specific discharges perhaps two to three orders of magnitude greater than vertical specific discharges across the top of the Culebra.

The Rustler Formation at the WIPP is comprised of five members from bottom to top called: the Unnamed Lower Member, the Culebra, the Tamarisk, the Magenta and the Forty-niner. The hydrology of each of the Rustler members is described in the subsections below. Of the five members of the Rustler at the WIPP, the Culebra and the Magenta are considered conductive units, and the Unnamed Lower Member, the Tamarisk, and the Forty-niner are considered confining units. Specific hydrogeologic information regarding each member of the Rustler is provided in **Figure IV-10** of this Technical Support Document.

i. Unnamed Lower Member (2.2.1.4.1.1)

The CCA provided information regarding the hydrology of the Unnamed Lower Member in Chapter 2.2.1.4.1.1 (pp. 2-117 to 2-118). DOE indicated that the Basal and upper portions of the Unnamed Lower Member act as a single confining hydrostratigraphic unit. The basal portion of the Unnamed Member consists of siltstone, mudstone, claystone, and anhydrite and approximately 64 feet (19.5 meters) thick. Testing of well H-16 provided a measure of hydraulic conductivity: 4.2x10^{-6} feet per day (1.5x10^{-11} meters per second) and 3.4x10^{-6} feet per day (1.2x10^{-11} meters per second). Porosity, based on two claystone and one anhydrite sample, ranged from 26.8, 27.3, and 0.2 percent, respectively.

The upper portion of the Unnamed Member consists of mudstones, anhydrite, and variable amounts of halite. DOE indicated that the hydraulic conductivity of the upper portion was derived from tests conducted in the WIPP waste-handling shaft and varied from 2x10^{-9} feet per day (6x10^{15} meters per second) to 3x10^{-8} feet per day (1x10^{-13} meters per second). Figure 2-11 of the CCA shows total thickness of the Rustler.

The following table lists Appendices and cross-references for CCA, Chapter 2.2.1.4.1.1, Unnamed Lower Member:

Conceptual model-Unnamed Lower Member	Chapter 6.4.6.1 Appendix PAR Table PAR-31
Lower portion hydraulic conductivity	Beauheim 1987, p. 50 [CCA Reference 43] (Docket A-93-02, Item II-G-1)
Upper portion hydraulic conductivity	Saulnier and Avis 1988, p. 6-11 [CCA Reference 574] (Docket A-93-02, Item II-G-1)

ii. The Culebra

The CCA provided information regarding the hydrology of the Culebra in Chapter 2.2.1.4.1.e (pp. 2-118 to 2-127). DOE indicated that the Culebra is of interest because it is the most transmissive unit at the WIPP site and the hydrology of the unit has been studied for over a decade. Although the Culebra is relatively thin, it is treated as an entire hydrostratigraphic unit in the WIPP hydrological conceptual model and is considered the most important conductive unit in the model.

The Culebra is a fractured dolomite, that includes a few chalky lenses. The lower portion is vuggy and fractured, and has significantly higher permeability than the upper portion, which is a massive dolomite with few fractures and vugs. DOE has determined flow in the Culebra to be dominantly lateral and southward, except in discharge areas along the west or south boundaries of the basin (Figure 2-31 of the CCA).

For more than 10 years, DOE collected field data from hydraulic tests and tracer tests. The hydraulic tests included pumping, injection, and slug tests that can be used to characterize flow and fluid transport for characteristics such as transmissivity, permeability, and storativity. Long-term pumping tests provided transient pressure data between groups of test wells, located within a few tens of meters of each other. DOE used automated data acquisition systems to improve space and time resolution. The tracer tests have been conducted at six locations to evaluate the transport properties of the Culebra.

The Culebra is a fractured dolomite with non uniform properties both horizontally and vertically. The porosity within the Culebra includes fractures ranging from micro scale to potentially large, vuggy zones and inter particle and inter crystalline porosity. DOE indicated that flow within the Culebra occurs within fractures, within vugs where they are connected by fractures and to some extent within interparticle porosity where this porosity is high. Refer to CCA Chapter 6.0.2.3.6 (pp. 6-9 to 6-10) and Chapter 2.2.1.4.1.2 (p. 2-120) for additional information.

DOE stated that the Culebra is the most transmissive hydrostratigraphic unit at the WIPP site, and the Culebra acts as a “drain” for the units around it. Transmissivity of the Culebra varies spatially over six orders of magnitude from east to west in the vicinity of WIPP (CCA Figure 2-30). Over the site, the Culebra transmissivity varies over three to four orders of magnitude. Transmissivities are from about $1x10^{-3}$ square feet per day

($1x10^{-9}$ square meters per second) at well P-18 east of the WIPP site to about $1x10^{3}$ square feet per day ($1x10^{-3}$ square meters per second) at well H-7 in Nash Draw (Figure 2-2 of the CCA). Long-term hydraulic tests have also been performed by DOE for determining transport and transmissivity fields in performance assessment modeling. Refer to CCA Chapter 6.0.2.3.5 (pp. 6-8 to 6-9) and Chapter 2.2.1.4.1.2 (pp. 2-118 to 2-127) for additional information. Culebra hydraulic heads are shown in **Figure IV-11** of this Technical Support Document.

Transmissivity, storativity, transport properties, and diffusion properties are affected by the nature of fractures and porosity. DOE obtained porosity measurements from cores and found values ranging from 3% to 30% in fractures, vugs, chalky dolomite, and interparticle porosity. Fracture spacing, as it affects transmissivity, is thought to vary as a function of: distribution of overburden above the Culebra, distribution of halite in the Rustler, dissolution of halite in the upper portion of the Salado, and distribution of Culebra gypsum fracture fillings. DOE studied the Culebra for actinide transport properties, using a series of tracer tests and multi-well convergent flow tests. Refer to CCA Chapter 2.1.3.5.2 (pp. 2-45 to 2-50) and Appendix MASS.15 (pp. MASS-75 to MASS-81) for additional information.

DOE indicated in CCA Chapter 2.4.2.1 (pp. 2-166 to 2-169) that there is considerable variation in the groundwater chemistry of the Culebra. DOE provided information supplemental to the CCA pertaining to groundwater flow and geochemistry within the Culebra member of the Rustler in DOE's letter response dated May 14, 1997 to EPA's comments submitted March 19, 1997 (DOE, 1997d) (Docket A-93-02, Item II-I-31). In this letter, DOE explained that it modified the conceptualization of Culebra groundwater flow in the CCA relative to that supported by DOE in the past. Previously, DOE had difficulty reconciling geochemical conditions within Culebra groundwater and current groundwater flow directions and velocities (see Chapter 2.2.1.4.1.2).

The new conceptualization, referred to as the groundwater basin model, offers a three dimensional approach to treatment of Supra-Salado rock units, and assumes vertical leakage (albeit very slow) between rock units of the Rustler exists (where hydraulic head is present). Flow in the Culebra is considered transient. This differs from previous interpretations, wherein no-flow was assumed between Rustler units. The model assumes that the groundwater system is dynamic and is responding to the drying of climate that has occurred since the late Pleistocene period. DOE assumed that recharge rates during the late Pleistocene period were sufficient to maintain the water table near land surface, but has since dropped significantly. Therefore, the impact of local topography on groundwater flow was greater during wetter periods, with discharge from the Rustler to the west; flow is dominated by more regional topographic effects during drier times, with flow to a more southerly direction.

DOE identified four hydrogeochemical facies within the Culebra in the WIPP area in CCA Chapter 2.4.2.1 (p. 2-166) and Figure 2-40 (p. 2-167):

- Zone A - saline (2-3 molal) NaCl brines, Mg/Ca ratio of 1.2 to 2;

- Zone B - dilute (<0.1 molal) $CaSO_4$ - rich groundwater;
- Zone C - variable composition (0.3-1.6 molal); Mg/Ca ratio 0.3 to 1.2; and
- Zone D - high salinities (3-7 molal); K/Na weight ratios (0.2).

DOE concluded that Facies A groundwater flow is slow, has not changed over the last 14,000 years, and probably recharged more than 600,000 years ago. Vertical leakage occurs to Facies A, and both lateral and vertical groundwater flow rates are extremely low. Facies B occurs in an area with greater vertical fracturing in the Culebra, and therefore exhibits more vertical infiltration and more rapid lateral flow in the Culebra. According to DOE, flow in Facies B is currently to the south (it may mix with Facies C water to the southeast) but was more toward the west during wetter climates; vertical infiltration from the Dewey Lake to the Culebra Facies B is assumed by DOE to have occurred during wetter climates in an area south of the WIPP site. DOE theorized that Facies C water was not diluted to create Facies B water. Facies C occurs "in between" Facies A and B, and groundwater flow entered the Culebra prior to the climate change (to drier conditions) 14,000 years ago. Facies C groundwater flow is to the south at WIPP, where DOE theorized that it joins with a small amount of Facies A solute being transported from the east. Groundwater flow rate in Facies C is faster than in A but slower than in B, and the proposed recharge area from the Dewey Lake to the Culebra was to the northeast of the WIPP site. DOE theorized that Facies C groundwater infiltrated into the Dewey Lake and then interacted with anhydrite and halite along its path to the Culebra, wherein it mixed with smaller amounts of Facies A water. Within information submitted in a letter dated May 14, 1997 (DOE, 1997d) (Docket A-93-02, Item II-I-31), DOE concluded that the presence of anhydrite within Rustler units does not preclude slow downward infiltration, as had been previously argued by DOE.

In the 1992 performance assessment (Sandia National Laboratories, 1992) [CCA Reference 563] (Docket A-93-02, Item II-G-1), DOE and others believed the geochemistry of Culebra groundwater was inconsistent with flow directions. This was based on the premise that Facies C water must transform to Facies B water (e.g. become "fresher"), which is inconsistent with the observed flow direction. Within information submitted in a letter dated May 14, 1997 (DOE, 1997d) (Docket A-93-02, Item II-I-31), DOE now contends that the observed geochemistry and flow directions can be explained with different recharge areas and Culebra travel paths.

DOE noted that anomalous water level rises are apparent in some Culebra wells and that the water level rises in the vicinity of the WIPP site are caused by recovery from drainage into the shafts. DOE also indicated that water levels to the northwest of the site, in and near Nash Draw, appear to fluctuate in response to effluent discharge from potash mines, although this can not be proven due to a lack of specific data regarding the discharges. The well-operators conducted an analysis of oil and gas-related injection wells near the WIPP to determine whether any of these are malfunctioning and causing associated groundwater level anomalies. The resulting mechanical integrity tests (MITs) did not indicate well failure. The cause of water-level rises in the vicinity of the H-9 hydropad, about 6.5 miles (10.46 kilometers) south of the WIPP site, remains unexplained. DOE monitoring of groundwater levels throughout the region is being conducted; see CCA Chapter 2.2.1.4.1.2 (p. 2-124).

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.4.1.2, the Culebra:

Culebra core porosity values	Kelley and Saulnier 1990 [CCA Reference 353] (Docket A-93-02, Item II-G-1)
Culebra conceptual model	Chapter 6.4.6.2
Parameter values	Table 6-18, 6-19, 6-20 ,6-21
Background for the Culebra model	Appendix MASS.14 Appendix MASS.15
Long-term performance models	Appendix TFIELD, Section TFIELD.2
Actinide flow model parameters	Appendix PAR Chapter 6.4.6.2.2 Tables 6-20 and 6-21
Multiwell convergent flow-transport	Jones et al. 1992 [CCA Reference 343] (Docket A-93-02, Item II-G-1)
Data for Culebra Transmissivity Map	Appendix TFIELD Section TFIELD.2
Model discussion for Culebra	MASS.15 and Attachment 15-6
Data for Culebra Isopach Map	Appendix FAC, Figure 4-8
Gypsum fracture-fill discussion	Chapter 2.1.3.5.2, Figure 2-12
Culebra hydrogeochemical facies	Chapter 2.4.2
Age of Culebra waters	Lambert 1987 [CCA Reference 377] (Docket A-93-02, Item II-G-1) Lambert and Carter 1987 [CCA Reference 380] (Docket A-93-02, Item II-G-1) Lambert and Harvey 1987 [CCA Reference 378] (Docket A-93-02, Item II-G-1)
Halite presence in the Rustler	Figure 2-10
Culebra recharge and climate	Chapter 6.4.9
Groundwater basin models	Chapter 6.4.6 Appendix MASS, Section MASS.14.2

iii. The Tamarisk (2.2.1.4.1.3)

The CCA provides information regarding the hydrology of the Tamarisk in Chapter 2.2.1.4.1.3 (p. 2-127). DOE described the Tamarisk as a confining layer, consisting of claystone, mudstone, and siltstone overlain and underlain by anhydrite. The effective porosity, of two claystone samples, was found to be 21.3 and 21.7 percent. The porosity in five anhydrite samples was found to range from 0.2 to 1.0 %. DOE indicated that hydraulic tests were attempted in a 7.9 foot (2.4 meter) interval of the Tamarisk in wells H-14 and H-16. DOE indicated that the permeability was too low to measure in either well in the time allowed for testing. As a result, Beauheim (1987) [CCA Reference 43] (Docket A-93-02, Item II-G-1) estimated the transmissivity of the claystone sequence to be one or more orders of magnitude less than that of the underlying Unnamed Lower Member, and is estimated to be: $2.5x10^{-5}$ square feet per day ($2.7x10^{-11}$ square meters per second).

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.4.1.3, the Tamarisk:

Conceptual model	Appendix MASS Section MASS.14.1
Hydrological parameters	Appendix PAR, Table PAR-29

<u>iv. The Magenta (2.2.1.4.1.4)</u>

The CCA provides information pertaining to the hydrology of the Magenta in Chapter 2.2.1.4.1.4 (pp. 2-127 to 2-128). DOE described the Magenta as a conductive hydrostratigraphic unit about 26 feet (7.9 meters) thick at the WIPP site. The effective porosity as determined from four samples ranged from 2.7 to 25.2 percent . The hydraulic gradient varies from 16 to 20 feet per mile (3 to 4 meters per kilometer) on the east side of the WIPP site, to 32 feet per mile (6 meters per kilometer) along the western side near Nash Draw (Figure 2-32 of the CCA) (**Figure IV-12** of this Technical Support Document).

Based on hydraulic data from 15 wells, transmissivity ranges over five orders of magnitude between: $4x10^{-3}$ to $3.75x10^{2}$ square feet per day ($1x10^{-9}$ to $4x10^{-4}$ square meters per second). DOE indicated that in most locations, the hydraulic conductivity of the Magenta is one to two orders of magnitude less than that of the Culebra. DOE stated that the Magenta does not have hydraulically significant fractures near the WIPP.

DOE indicated that regional modeling using the groundwater basin model indicates that leakage occurs into the Magenta from the overlying Forty-niner and out of the Magenta downwards into the Tamarisk. The model also indicated that the flow direction in the magenta are dominantly westward, similar to the slope of the land surface. This flow direction is different than the underlying Culebra, but was explained as consistent with the conceptual model in that flow in the shallower units is expected to be sensitive to topography.

From data collected from wells, DOE inferred information regarding vertical flow directions in the Magenta and that flow downward out of the Magenta, consistent with the conceptual model, has been inferred from the data. However, pressure data from three boreholes (H-3, H-14 and H-16) indicated that an upward flow direction exists between the Magenta and the Forty-niner (Beauheim 1987) [CCA Reference 43] (Docket A-93-02, Item II-G-1). This was not consistent with the results of groundwater monitoring and DOE indicated the cause may be the result of local heterogeneity in rock that cannot be duplicated in the regional model.

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.4.1.4, the Magenta:

Conceptual model	Chapter 6.4.6.4
Hydrological parameters	Table 6-22
Magenta upward flow	Beauheim 1987, p. 139 [CCA Reference 43] (Docket A-93-02, Item II-G-1)

v. The Forty-niner (2.2.1.4.1.5)

The CCA provided information pertaining to the hydrology of the Forty-niner in Chapter 2.2.1.4.1.5 (p. 2-118). DOE described the Forty-niner as a confining hydrostratigraphic layer, consisting of anhydrite and siltstone, that is about 66 feet (20 meters) thick. Porosity was measured at the H-19 hydropad where three claystone samples had effective porosities ranging from 9.1 to 24.0 % and four anhydrite samples had effective porosities ranging from 0.0 to 0.4%.

DOE indicated that hydraulic tests yielded transmissivities in the H-14 and H-16 wells of about 3x10-2 to $7x10^{-2}$ square feet per day ($3x10^{-8}$ to $8x10^{-8}$ square meters per second) and $5x10^{-3}$ to $6x10^{-3}$ square feet per day ($3x10^{-9}$ to $6x10^{-9}$ square meters per second.) (Beauheim 1987) [CCA Reference 43] (Docket A-93-02, Item II-G-1).

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.4.1.5, the Forty-niner

Conceptual model	Chapter 6.4.6.5
Hydrological parameters	Appendix PAR, Table PAR-27
Transmissivity testing	Beauheim 1987, p. 119-123 [CCA Reference 43] (Docket A-93-02, Item II-G-1)

j. EPA Technical Evaluation Results: Hydrology of the Rustler Formation (2.2.1.4.1)

In general, EPA concluded that DOE's description of the hydrology of the Rustler (CCA Chapter 2.2.1.4, pp. 2-114 to 2-132) was technically adequate because it addressed the major elements required for use in performance assessment.

i. EPA Technical Evaluation Results: Hydrology of Unnamed Lower Member (2.2.1.4.1.1)

The hydrology of the unnamed lower member was discussed in Chapter 2.2.1.4.1.1 of the CCA and EPA concluded that the characterization provided in the CCA and supporting references and appendices is technically adequate. Although not all of the required specific information concerning the hydraulic characteristics of the Unnamed

Lower Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

ii. EPA Technical Evaluation Results: Hydrology of the Culebra (2.2.1.4.1.2)

The hydrology of the Culebra is discussed in Chapter 2.2.1.4.1.2 of the CCA and in supporting appendices and references. Although not all of the required specific information concerning the hydraulic characteristics of the Culebra Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

In paragraph 2 on page 2-123, the CCA indicated that geochemical data pertaining to Culebra groundwater, including isotopic data, was interpreted differently by various authors. The CCA also indicated that the groundwater basin model used in the CCA for the Culebra can explain these geochemical variations (rather than, for example, a different recharge concept). Although the CCA referenced the interpretations voiced by other workers (e.g. Chapman, 1986) [CCA Reference 118] (Docket A-93-02, Item II-G-1), it did not include a summary of these various assessments, including supporting and conflicting data/interpretations, so that a ready comparison of the Culebra basin model with alternative interpretations could be achieved. EPA initially concluded that hydrochemical facies within the Culebra were not adequately described with respect to origin in the CCA. In a letter dated May 14, 1997 (DOE, 1997d) (Docket A-93-02, Item II-I-31) DOE submitted additional information that described the Culebra hydrochemical facies with respect to potential groundwater infiltration rates, Culebra flow velocities, and geochemical facies). EPA reviewed this information and concluded that it was sufficient to explain Culebra geochemical facies within the WIPP area.

DOE stated that most anomalous water level increases in some Culebra wells (e.g., related to shaft installation activities and subsequent rebound of Culebra heads) can be explained but some remain unexplained. EPA reviewed these data and concluded that despite these unexplained water level rises, the current anomalous heads lead to water level variations that are already incorporated into performance assessment modeling. **Refer to CARD 23 -- Models and Computer Codes for further discussion.**

The CCA indicated that transmissivity variations within the Culebra are due to both primary and secondary features and also indicated that the significant spatial variability in transmissivity was apparently accounted for in TFIELD model runs (Appendix TFIELD.2, pp. TFIELD-1 to TFIELD-23). EPA found that Chapter 2.2.1.4.1.2 (pp. 2-118 to 2-127) did not provide a detailed discussion of the origin of these variations relative to fracture infill/dissolution, integration of climatic change, and loading/unloading events, which is important to understanding not only current transmissivity differences but also potential future transmissivity variations that could affect performance assessment calculations. However, EPA's review indicated that determination of the specific origin of these fractures was not necessary because conditions are not expected to change during the regulatory period. DOE provided supplemental information in letters dating January 24, 1997, March 12, 1997, May 14, 1997, June 13, 1997, and July 3, 1997 indicating that a significant mechanism that could alter fracture permeability -- dissolution of fracture fill -- will not likely have a significant impact on transmissivity (DOE, 1997a, c, d, f, and k) (Docket A-93-02, Item II-H-46, Item II-H-44,). EPA accepted DOE's argument that infiltrating waters would most likely become saturated with calcium sulfate and consequently would not dissolve anhydrite or gypsum fracture fill.

iii. EPA Technical Evaluation Results: Hydrology of the Tamarisk (2.2.1.4.1.3)

The hydrology of the Tamarisk was discussed in Chapter 2.2.1.4.1.3 of the CCA and in supporting appendices and references. EPA concluded that the characterization provided in the CCA and supporting references and appendices is technically adequate. Although not all of the required specific information concerning the hydraulic characteristics of the Tamarisk Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

The CCA indicated that attempts were made in two wells to test a 7.9-foot sequence of the Tamarisk. Results of the attempted tests showed the permeability of the sequence to be too low to measure. As a result, the transmissivity of the claystone unit within the Tamarisk is estimated to be one or two orders of magnitude less than that of the tested interval within the unnamed lower member. This conclusion appears to be technically reasonable.

iv. EPA Technical Evaluation Results: Hydrology of the Magenta (2.2.1.4.1.4)

The hydrology of the Magenta was discussed in Chapter 2.2.1.4.1.4 of the CCA and in associated appendices and references and EPA concluded that the characterization provided in the CCA and supporting references and appendices is technically adequate. Although not all of the required specific information concerning the hydraulic characteristics of the Magenta Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

v. EPA Technical Evaluation Results: Hydrology of the Forty-niner (2.2.1.4.1.5)

The hydrology of the Forty-niner was discussed in Chapter 2.2.1.4.1.5 of the CCA and in associated appendices and references and EPA concluded that the characterization provided in the CCA and supporting references and appendices is technically adequate. Although not all of the required specific information concerning the hydraulic characteristics of the Forty-niner Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as

Figure IV-10 of this Technical Support Document.

k. DOE Methodology: Hydrology of the Dewey Lake (2.2.1.4.2.1)

The CCA provided information pertaining to the hydrology of the Dewey Lake in Chapter 2.2.1.4.2 (pp. 2-128 to 2-131). DOE indicated that the Dewey Lake Redbeds contains a productive zone of saturation, probably under water table conditions, in the southwestern to south-central portion of the WIPP site. The productive zone is typically found in the middle of the Dewey Lake, 180 to 265 feet (55 to 81 meters) below ground surface and appears to derive much of its transmissivity from open fractures. Fractures below the productive zone tend to be completely filled with gypsum. DOE indicated that the Dewey Lake is the uppermost important layer in the hydrological model and that changes in the water table in the Dewey Lake in the future, due to wetter conditions, are part of the conceptual model.

DOE estimated the position of the water table in Dewey Lake in the southern half of the WIPP area (Figure 2-33 in the CCA) based on data from three potash exploration and five hydraulic test boreholes. Depth to water was estimated by identifying the first occurrence of moist cuttings, as such, DOE estimated the elevation of the water table over the WIPP waste panels to be about 3,215 feet (980 meters) above sea level. Groundwater flow was interpreted to be to the southwest at about 25 meters per mile (15.5 meters per kilometer). Water is producible from fractured portions of the Dewey Lakes; less transmissive fractures below productive zones are filled with gypsum.

Porosity of the Dewey Lake was measured at the H-19 hydropad; four samples taken above the gypsum-sealed region had measured effective porosities of 14.9 to 24.8%; four samples taken from within the gypsum-sealed region had porosities from 3.5 to 11.6%. For modeling purposes, the saturated hydraulic conductivity of the Dewey Lake was estimated to be: $3x10^{-3}$ feet per day (10^{-8} meters per second).

Dewey Lake water is used for livestock at the J.C. Mills Ranch, and short-term production rates of 25 to 30 gallons per minute (5.7 to 6.8 cubic meters per hour) were observed in boreholes P-9 WQSP-6, and WQSP-6a. At the WIPP site, DOE stated that no Dewey Lake water has produced water within the WIPP shafts or in boreholes in the immediate vicinity of the waste panels. DOE assumed that the Dewey Lake is an underground source of drinking water (USDW) in their bounding analysis in the compliance assessment. See Chapter 6.4.6.6 (pp. 6-148 to 6-149) and Appendix PAR, and Table PAR-26 (p. PAR-210) and Chapter 8 for more information. **USDWs are further discussed by EPA in CARD 53: Consideration of USDWs.**

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.4.2.1, the Dewey Lake:

Conceptual hydrological model	Chapter 6.4.6.6 Appendix MASS, Section MASS.14.2
Hydrological parameters	Table 6-23

Water production rates	Appendix USDW Jones 1978, Vol. 1., p. 167 and 168 [CCA Reference 339](Docket A-93-02, Item II-G-1)
Fractures reservoir in wells H-1, H-2, H-3	Appendix HYDRO, p. 69
Climatic changes in water table	Chapters 6.4.6 and 6.4.9
Hydraulic conductivity estimate	Davies 1989, p. 110 [CCA Reference 158] (Docket A-93-02, Item II-G-1)

l. EPA Technical Evaluation Results: Hydrology of the Dewey Lake (2.2.1.4.2.1)

The hydrology of the Dewey Lake Redbeds was discussed in Chapter 2.2.1.4.2.1 of the CCA and in the associated appendices and references. Although not all of the required specific information concerning the hydraulic characteristics of the Dewey Lake Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

m. DOE Methodology: Hydrology of the Santa Rosa (2.2.1.4.2.2)

The CCA provided information pertaining to the hydrology of the Santa Rosa in Chapter 2.2.1.4.2.2 (p. 2-122). DOE indicated that the Santa Rosa is 0 to 300 feet (0 to 91 meters) thick and present only over the eastern half of the WIPP site. DOE indicated that the Santa Rosa near the WIPP site may have a saturated thickness of limited extent. Porosity is about 13 percent and the formation has a specific capacity of 0.14 to 0.20 gallons per minute per foot (0.029 to 0.041 liters per second per meter) of drawdown where it yields water in the WIPP region.

In Appendix HYDRO, DOE indicated that the Santa Rosa was tested in two test holes, H-5 and H-10. Water was found in the lower part of the formation in test hole H-5, but no reliable information was obtained during hydraulic testing. DOE indicated that the Santa Rosa is probably recharged by precipitation in the area where it is overlain by Cenozoic deposits, especially in the eastern part of the WIPP site. DOE indicated the water moves downward until it is impeded by the relatively impermeable Dewey Lake Redbeds and then probably down the structural dip towards the east.

n. EPA Technical Evaluation Results: Hydrology of the Santa Rosa (2.2.1.4.2.2)

The hydrology of the Santa Rosa is discussed in Chapter 2.2.1.4.2.2 of the CCA and Appendix HYDRO and the characterization provided in the CCA appears to be technically reasonable. Although not all of the required specific information concerning the hydraulic characteristics of the Santa Rosa Member was provided in Chapter 2 of the CCA, DOE included this information in a table submitted to the EPA in a letter dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08). This table has been included as **Figure IV-10** of this Technical Support Document.

o. DOE Methodology: Hydrology of Other Groundwater Zones of Regional Importance (2.2.1.5)

i. Capitan Limestone (2.2.1.5.1)

The CCA provided information pertaining to the hydrology of the Capitan Limestone in Chapter 2.2.1.5.1 (p. 2-132). The Capitan Limestone was evaluated by DOE because its importance in some processes such as the formation of dissolution features. DOE indicated that in the area of the WIPP site, where the Capitan underlies the Salado Formation, breccia pipes have formed in the Salado, most likely in response to the effects of dissolution by groundwater flowing in the Castile along the base of the Salado. DOE determined a low probability of occurrence at the WIPP site because the Capitan is not present below the WIPP. Refer to Appendix DEF.3.1 (pp. DEF-18 to DEF-25) for more information.

The Capitan aquifer forms a long narrow arcuate belt composed of very permeable rocks approximately 10 - 14 miles wide. The Capitan aquifer is approximately 10 miles north of the WIPP site at its closest point. The Capitan Limestone is recharged by percolation through the northern shelf aquifers. Recharge is also by flow from the south and west from underlying basin aquifers, and by direct infiltration at its outcrop in the Guadalupe Mountains. Water table conditions are present in the Capitan aquifer southwest of the Pecos River at Carlsbad; artesian conditions are present to the north and east.

Hydraulic conductivity of the Capitan ranges from 1 to 25 feet per day ($3x10^{-6}$ to $9x10^{-5}$ meters per second) in southern Lea County and is 5 feet per day ($1.7x10^{-5}$ meters per second) east of the Pecos River at Carlsbad. Transmissivity around the northern and eastern margins of the Delaware Basin are 10,000 square feet per day (0.01 square meters per second) in thick sections and 500 square feet per day ($5.4x10^{-4}$ square meters per second) in sediments deposited in incised submarine canyons.

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.5.1, the Capitan Limestone

Breccia pipe formation	Appendix DEF, Section DEF.3.1
Regional hydraulic conductivity	Appendix HYDRO, p. 34
Regional transmissivity	Hiss 1975, p. 199 [CCA Reference 299] (Docket A-93-02, Item II-G-1)
Underlying basin aquifers	Bell Canyon, Chapter 2.2.1.2.1

ii. Rustler/Salado Contact Zone in Nash Draw (2.2.1.5.2)

The CCA provided information pertaining to the Rustler/Salado Contact Zone in Nash Draw in Chapter 2.2.1.5.2 (pp. 2-135 to 2-136). The CCA indicated that in Nash Draw, three miles (4.8 kilometers) west of the WIPP area, DOE has identified a dissolution contact zone between the Rustler and Salado formations. The contact zone is a residuum of gypsum, clay, and sandstone created by the dissolution of halite. The residuum ranges in thickness from 10.5 to 60 feet (3 to 18 meters) and averages about 24 feet (7 meters) thick. The residuum contains a "brine aquifer" (Figure 2-34 of the CCA) that has also been referred to as the Rustler-Salado residium and residuum. The Rustler/Salado residuum is absent under the WIPP site.

DOE found that the occurrence of the brine aquifer concentrated in an area in Nash Draw from 2 to 8 miles (3.3 to 13 kilometers) wide and about 26 miles (43 kilometers) long, and indicated it constitutes a continuous hydraulic system. Hydraulic properties of the brine aquifer include a calculated transmissivity of 2×10^{-4} square feet per day (2.1×10^{-10} square meters per second) at WIPP-27 to 8 square feet per day (8.6×10^{-6} square meters per second) at WIPP-29. The average hydraulic gradient within the residuum of Nash Draw is about 10 feet per mile (7.4 meters per kilometer); in contrast, the average hydraulic gradient at the Rustler/Salado contact is 39 feet per mile (7.4 meters per kilometer). The difference is due to increased transmissivity of the Nash Draw residuum, where it exhibits as much as five orders of magnitude greater transmissivity than at other WIPP site Rustler/Salado contact locations.

An increase in chloride concentration in water from the north to the south in Nash Draw may indicate water flow and solution of halite from north to south. Brine in the Rustler/Salado residuum ranges from 41,500 milligrams per liter (borehole H-1) to 412,000 milligrams per liter (borehole H-5c). Dissolved minerals include calcium, magnesium, sodium, potassium and sulfates/chlorides. DOE indicated that the brine aquifer is believed to discharge to the Pecos River near Malaga Bend.

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.1.5.2, the Rustler-Salado Contact Zone in Nash Draw:

Salado dissolution - Nash Draw	Appendix DEF, Section DEF.3.2
Area of the Nash Draw brine aquifer	Figure 2-34
Hydraulic properties - brine aquifer	Hale, et al. 1954 [CCA Reference 277] (Docket A-93-02, Item II-G-1)
Brine aquifer salinity	Appendix HYDRO, p. 55
Hydraulic gradient at WIPP	Appendix HYDRO, p. 50

p. EPA Technical Evaluation Results: Hydrology of Other Groundwater Zones of Regional Importance (2.2.1.5)

The CCA includes a brief discussion of the Capitan Limestone and Rustler/Salado ("brine aquifer") Contact Zone hydrology. EPA found the information in Chapter 2.2.1.5 (pp. 2-132 to 2-136) and Appendix HYDRO (various sections) pertaining to the Capitan aquifer to be technically adequate to describe the relevant hydrological and geochemical properties of the aquifer.

EPA's initial review of the CCA found the discussion of the Rustler/Salado contact to be confusing, particularly with respect to the possibility of the continued development of and characteristics of a dissolution front along this contact, and the impact that continued dissolution within the brine aquifer residuum would have on the overlying units of the

Rustler. DOE further discussed the rate and extent of dissolution processes in supplemental information provided in a letter dated June 13, 1997 (DOE, 1997c) (Docket A-93-02, Item II-H-44). Based upon this information, EPA concluded that while dissolution may occur along the Rustler Salado contact, it would not impact the WIPP's containment capabilities during the regulatory time period.

2. Surface Water Hydrology (2.2.2)

a. DOE Methodology: Surface Water Hydrology (2.2.2)

The CCA provided information regarding surface water hydrology in the vicinity of the WIPP site within Chapter 2.2.2 (pp. 2-136 to 2-144). DOE indicated that the WIPP site is within the Pecos River Basin (CCA Figure 2-36). The Pecos River is about 500 miles (805 kilometers) in length, and the maximum basin width is about 130 miles (209 kilometers), with a drainage area of about 44,535 square miles (115,301 square kilometers). The Pecos River does not always flow year-round; at low flow times the river percolates into its stream bed below Anton Chico and between Fort Sumner and Roswell. Five major reservoirs are located on the Pecos River (Table 2-6 of the CCA).

DOE indicated that no perennial streams flow from the WIPP site to the Pecos River, 12 miles (19 kilometers) southwest of the WIPP site boundary at the nearest point. DOE did not identify any major natural lakes or ponds within 5 miles (8 kilometers) of the WIPP site. The United States Geological Survey (USGS) initiated a low-flow investigation within the Hill Tank Draw drainage area, a prominent drainage feature near the WIPP site. The drainage area is about 4 square miles (10.3 square kilometers); the average channel slope is 1 to 100, and the drainage is westward into Nash Draw. Nash Draw is the largest surface drainage feature east of the Pecos River in the WIPP region; it is a closed depression and does not provide surface flow to the Pecos River.

The maximum recorded flood on the Pecos River occurred near the town of Malaga on August 23, 1966. Discharge was 120,000 cubic feet (3,396 cubic meters) per second and a stage elevation of about 2,938 feet (895 meters) above mean sea level. The maximum recorded 24-hour precipitation at Carlsbad was 5.12 inches (130 millimeters) in August, 1916. The maximum recorded daily snowfall at Carlsbad was 10 inches (254 millimeters) in December 1923. The minimum surface elevation at the WIPP site is over 300 feet above the elevation of the maximum historical flood.

At the WIPP site, more than 90 percent of the mean annual precipitation at the WIPP site is lost by evapotranspiration. On a mean monthly basis, evapotranspiration greatly exceeds available rainfall, though local thunderstorms may produce runoff and some percolation. About 75 percent of the total annual precipitation and 60 percent of the annual flow results from intense thunderstorms between April and September. The mean annual precipitation in the region is 13 inches (0.33 meter); the mean annual runoff is 0.1 to 0.2 inches (2.5 to 5 millimeters). The predicted maximum 6-hour, 100-year precipitation event for the site is 3.6 inches (91 millimeters).

Salinity of the Pecos River has been increased by minerals from natural groundwater discharge sources and irrigation return flows. At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1,650 tons per day (1,497 metric tons per day). Chlorides enter the river near Roswell from Salt Creek and Bitter Creek. Concentrated brine enters the Pecos River at Malaga Bend, adding an estimated 370 tons (64 metric tons) of chloride per day.

The following table lists Appendices and cross-references for the CCA, Chapter 2.2.2, Surface Water Hydrology:

Region evapotranspiration	FEIS, DOE 1980, p. 7-71 [CCA Reference 178] (Docket A-93-02, Item II-G-1)
Surface water quality	Chapter 2.3.2.2
Brine in the Pecos River at Malaga Bend	Appendix GCR, 6-7

b. EPA Technical Evaluation Results: Surface Water Hydrology

The surface water hydrology of the WIPP region was discussed in Chapter 2.2.2 of the CCA. Based on a review of this Chapter, EPA concluded that the information presented regarding present- day conditions of the surface water hydrology of the WIPP region appears to be technically reasonable.

D. Potential Pathways [194.14(a)(3)]

1. DOE Methodologies: Potential Pathways

DOE provided a description of the presence and characteristics of potential pathways for transport of waste from the disposal system to the accessible environment in CCA Chapter 2 and Appendix DEF. The potential pathways identified by DOE included: breccia pipes and Bell Canyon-Castile interface dissolution as a result of deep dissolution; lateral dissolution along the Rustler-Salado contact and within the Rustler; and shallow dissolution, including the development of karst and dissolution of fracture fill in Salado marker beds and the Rustler. The Culebra Dolomite and other members of the Rustler are other potential pathways identified by DOE. In addition, DOE addressed potential transport through shaft seals (CCA Chapter 8.1.1, pp. 8-2 to 8-3).

DOE provided information regarding the presence and characteristics of evaporite dissolution features, which are potential pathways, in CCA Chapter 2.1.6.2 (pp. 2-86 to 2-87) and Appendix DEF.3 (pp. DEF-18 to DEF-33). DOE indicated that because evaporates are known to be much more soluble than most other rocks, it was important to understand the dissolution processes and rates that occur at the WIPP and the surrounding area. DOE also indicated that there are three dissolution processes possible or identified at the WIPP: deep dissolution (including breccia pipes), lateral dissolution, and shallow dissolution (including karst).

DOE stated that breccia pipes are deep dissolution features that are vertical or near vertical cylindrical features filled with collapse debris and typically extending from near the ground surface down to the Castile; see Appendix DEF.3.1(pp. DEF-18 to DEF-25). DOE indicated that breccia pipes were known to be present in the northern part of Nash Draw, approximately 12 miles (19 kilometers) northwest of the WIPP repository. During a resistivity field program that covered about 37 square miles (93.25 square kilometers), DOE identified several potential anomalies but no breccia was encountered in the boreholes drilled to investigate the anomalies.

DOE also conducted studies of known breccia pipes to develop an understanding of the mechanisms leading to their formation. DOE indicated that deep dissolution is a possible mechanism for the formation of breccia pipes and introduced the concept of brine density flow, which allows upward flow of water through an overlying fractured/permeable unit, dissolution of evaporates, and subsequent downward flow of the ensuing, more dense brine. The overlying rocks may then collapse into the resulting solution cavity. DOE indicated that there are no known breccia pipes that are not underlain by the Capitan Limestone or Bell Canyon (where the Bell Canyon is not overlain by the Castile). Breccia pipes can form above these two formations because the hydraulic conductivity of the formations is sufficiently high to allow significant groundwater flow and transport of dissolved material, thereby allowing the formation of solution cavities. The Capitan Limestone does not occur below WIPP, and the Bell Canyon below is of low transmissivity and is overlain by the Castile.

More generalized dissolution of deeper units such as the Castile, due to the flow of unsaturated groundwater within the Bell Canyon Formation and subsequent dissolution salt along the fresher-water interface, represents another potential deep dissolution feature. DOE drilled a borehole within a feature where structural depressions in the Salado suggested slow removal of salt at depth. DOE's interpretation of the resulting data indicated that the feature was the result of deformation rather than dissolution. DOE concluded that there is no unequivocal information that supports the possibility of deep dissolution occurring anywhere other than the edges of the Capitan Reef (Appendix DEF.3.1, p. DEF-25).

DOE stated that lateral dissolution results from groundwater movement within units that lead to lateral variations in porosity and permeability. DOE indicated that lateral dissolution of the upper Salado and within the Rustler in the Region of the WIPP has been recognized and studied since at least 1970 (Appendix DEF.3.2, p. DEF-25). DOE indicated that lateral dissolution of the upper Salado (and the subsequent collapse of the overlying Rustler) formed Nash Draw, located approximately 1 to 5 miles (1.6 to 8 kilometers) west of the WIPP site. DOE indicated that the maximum eastward lateral extent of dissolution at the top of the Salado is east of Livingston Ridge. DOE concluded that the edge of halite dissolution at the top of the Salado will not reach the repository until well after the period of regulatory concern (Appendix DEF.3.2, p. DEF-29).

DOE indicated that dissolution within the Rustler also led to further development of Nash Draw and that in the vicinity of Nash Draw, halite is absent from all the units of the Rustler (Chapter 2.1.3.5, pp. 2-37 to 2-38). Further east, toward the WIPP site, halite progressively appears in younger units, which has led many investigators to conclude that halite has been dissolved from the Rustler by groundwater in a process similar to the lateral dissolution at the top of the Salado. DOE presented an alternative interpretation, based on shaft mapping and core logging, stating that the Rustler was formed in variable depositional environments and that the current distribution of halite in the Rustler is similar to that when the unit was deposited. DOE concluded, however, that neither interpretation of the Rustler would appear to threaten the integrity of the disposal system during the regulatory time period (Appendix DEF.3.2, p. DEF-29).

DOE also discussed shallow dissolution, including karst development and dissolution of Culebra fracture fills. Karst topography is developed through dissolution of soluble rock units. DOE indicated that karst features such as dolines, collapse sinks, karst valleys, blind valleys, and other solution/subsidence-related features are present in Nash Draw, which is a dissolution feature approximately one mile west of the LWA boundary. DOE indicated that east of Nash Draw, "only a few small clusters of shallow dolines on the Mescalero caliche have been identified" (Appendix DEF.3.3, p. DEF-30). DOE indicated that dissolution of fracture fill within the Culebra would significantly impact the transmissivity of this unit. DOE stated that "there is no evidence for progressive change in this pattern [of fracture fill] across the area although some dissolution and precipitation of gypsum as fracture infills will inevitably occur in the next 10,000 years." DOE submitted supplemental information in letters dated June 13, 1997, May 14, 1997, March 12, 1997, February 26, 1997, February 7, 1997 and January 24, 1997 (DOE, 1997 c, d, f, g, j, and k) (Docket A-93-02, Item II-H-44, Item II-I-31, Item II-H-22, Item II-I-10, Item II-I-07, and Item II-I-03) concerning fracture fill dissolution in response to questions raised in EPA's December 19, 1997 letter requesting additional information (Docket A-93-02, Item II-I-01) and public comments received on EPA's ANPR for the certification decision. In this information, DOE concluded that the possibility of fracture fill dissolution is very low because infiltrating waters that would cause the dissolution would be saturated with respect to calcium sulfate. Because infiltrating water is saturated with fracture fill mineral, the likelihood that these waters could dissolve and remove existing fracture fill is remote.

DOE concluded that while these dissolution mechanisms may have occurred to varying degrees in the Delaware Basin, "there is a high level of confidence that dissolution sufficient to affect the performance of the disposal system is physically unreasonable and will not occur over the regulatory time frame" (Appendix DEF, p. DEF-33). Appendix SCR (Section 1.1.5.1) provides a summary of the screening of these dissolution mechanisms with respect to the PA.

DOE also considered actinide movement through marker beds in the undisturbed case and presented an overview of results in CCA Chapter 8.1.1 (pp. 8-2 to 8-3). DOE assigned porosity and gas-pressure sensitive permeability to the Salado marker beds and modeled actinide movement through the beds. Of the 300 CCA performance assessment model realizations, nine showed releases of actinides at the LWA boundary through lateral movement in Salado marker beds. However, DOE noted that the release concentrations were well below the limits of regulatory concern. In addition, DOE screened fluid injection from the performance assessment based on low consequence. DOE concluded that it addressed and described actinide transport in Salado marker beds, and that little, if any, transport would occur along these beds. Refer to Appendix SCR.2 and SCR.3 (pp. SCR-33 to SCR-144) for more information regarding fluid injection.

DOE also recognized the importance of the Rustler (i.e., Culebra member) as an important potential pathway. The presence and characteristics of this pathway were discussed in CCA Chapter 2, Sections 2.1.3.5.2 (pp. 2-45 to 2-49) and 2.2.1.4.1 (pp. 2-117 to 2-127), and Appendix HYDRO (pp. 55-62).

In summary, DOE identified and described numerous potential pathways within the CCA. DOE concluded that the potential for significant fluid migration to occur through most of these pathways is low. However, DOE also concluded that fluid migration could occur within the Rustler and Salado marker beds and so included this possibility in performance assessment calculations.

2. EPA Technical Evaluation Results: Potential Pathways

The CCA discussed numerous potential radionuclide transport pathways, including: deep dissolution resulting in either movement through breccia pipes, or through conduits developed through deep seated dissolution; shallow dissolution horizontal pathways; dissolution-enhanced transmissivity through supra-Salado units; karst features; and brine movement through anhydrite marker beds in the Salado (see, for example, CCA Executive Summary, CCA Chapters 2.2.1, 6.0.2, and 6.3.2). EPA concurred with DOE's conclusion that karst features and breccia pipes are not potential pathways at the WIPP. However, EPA's preliminary review found that DOE could not reasonably conclude that the mechanism for breccia pipe formation presented in the CCA is the only breccia pipe formation mechanism that could be present within the WIPP area without additional discussion of potential non-Capitan related breccia pipes.

EPA's review identified questions about karst, shallow dissolution, and breccia pipe development. These questions were transmitted to DOE in an EPA letter dated December 19, 1996 (A-93-02, Item II-I-01). DOE submitted supplemental information in a letter dated January 24, 1997 (Enclosure 2, p. 7) (DOE, 1997k) (Docket A-93-02, Item II-I-03) regarding non-Capitan related breccia pipes (i.e., those associated with the Bell Canyon where it is relatively shallow). EPA reviewed this information and concurred that the geologic evidence indicates that the breccia pipes are not likely to occur under the repository. EPA also concluded that the marker beds of the Salado contain brine that has limited ability to dissolve additional halite, and these marker beds, while more permeable that the halite, exhibit very low permeabilities. EPA also concluded that deep, lateral, and shallow dissolution pathways will not serve as significant potential radionuclide pathways and that the potential for significant fracture fill dissolution during the regulatory time period is low.

EPA found that the potential for fluid migration through Salado marker beds and the Culebra member of the Rustler was acknowledged by DOE (Chapter 6.4.5.2, pp. 6-116 to 6-118, Chapter 6.4.6.2, pp. 6-123 to 6-136, Chapter 6.5, pp. 6-214 to 6-234) and included in performance assessment calculations. The characteristics (e.g., hydraulic conductivity) of the different geologic units (provided in Chapter 2 and in a table included in a letter response dated February 14, 1997 (DOE, 1997i) (Docket A-93-02, Item II-I-08) indicate that most of the geologic units cannot transmit water and DOE appropriately identified the geologic units to the level necessary for performance assessment calculations.

<u>E. Projected Geophysical, Hydrogeologic, and Geochemical Conditions [194.14(a)(4)]</u>

1. DOE Methodologies: Projected Geophysical, Hydrogeologic and Geochemical Conditions

DOE discussed how it considered the effects of waste presence (including heat and gas generation on geophysical, hydrological, and geochemical conditions of the repository) in CCA Chapters 4 and 6 and Appendices SCR, SOTERM, WCA, and BRAGFLO. Related discussions of DOE's analysis are included in **CARD 23 -- Models and Computer Codes**, **CARD 24 - Waste Characterization, and CARD 32 -- Scope of Performance Assessments**. Within Appendix SCR.2.2.2 (p. SCR-40), DOE considered and screened out the impact that radioactive decay-related heat generation would have on the disposal system as a result of the low consequence of the generated heat. Heat generated via nuclear criticality was also screened out in Appendix SCR.2.2.3 (p. SCR-43) based on the low probability that a criticality event would occur. Based on the low probability of occurrence, DOE also screened out the following: thermal effects on materials and waste properties, thermally induced stress changes, thermal expansion of WIPP geologic material, and exothermic reactions, which include concrete and backfill hydration and aluminum corrosion, that may raise the temperature of the disposal system. For additional discussion regarding DOE's consideration of heat on geophysical, hydrological, and geochemical conditions within the WIPP repository, see Appendices SCR.2.3.6 (p. SCR-50), SCR.2.4.3 (p. SCR-56), SCR.2.5.7 (p. SCR-76), and SCR.2.7.3 (p. SCR-84).

DOE acknowledged that the presence of waste within the WIPP impacts the geochemistry of the WIPP disposal system (CCA Chapter 6.4.3, pp.6-92 to 6-111, and Appendix SCR.2, pp. SCR-33 to SCR-90). For this reason, DOE included the presence of waste in the PA. The oxidation conditions within the repository are altered by the corrosion of steel waste containers, and DOE linked the changing oxidation conditions to the oxidation state of actinides considered in solubility analysis. The presence of complexants in waste, including colloids and organic ligands, impacts solubility of actinides as well. Furthermore, degradation of cellulosic, plastic, and rubber waste could result in carbon dioxide generation that decreases brine pH and hence increases actinide solubility. DOE indicated that MgO emplaced among WIPP transuranic waste would mitigate the solubility-enhancing effects of carbon dioxide from waste degradation. DOE's analysis of geochemical conditions due to the presence of waste was discussed in Appendices WCA and SOTERM, as well as in the supplementary information submitted by DOE (Sandia National Laboratories, 1997) (Docket A-93-02, Item II-A-39).

In addition to considering the generation of carbon dioxide's impact on the disposal system, DOE stated that gas generation would be a critical factor to consider in the PA. For example, gas generation would increase pressure within the WIPP repository, and this increased pressure could impact creep closure, permeability of fractured units, brine inflow, spallings releases, etc. DOE considered that gas will be generated through two primary processes: corrosion of steel to generate hydrogen gas and degradation of organic material to create carbon dioxide and methane. DOE calculated steel corrosion rates under humid and inundated conditions, and assumed the inundated conditions' rates for PAs. DOE determined that inundated gas generation rates are higher than humid corrosion rates. DOE modeled the cumulative impact of gas generation on repository pressure throughout the 10,000 year regulatory period and included this estimate in modeled room closure, porosity surface calculations, pressure-sensitive permeability calculations for Salado marker beds, spallings particle releases. DOE discusses the modeling of gas generation and repository response in Chapter 6, Appendices MASS, WCA, SOTERM, PORSURF, and BRAGFLO. **For a detailed discussion of DOE's gas generation studies, refer to CARD 24 - Waste Characterization, Section 194.24(b). For discussion of DOE's**

modeling approach for inclusion of gas generation in the PA, refer to CARD 23 -- Models and Computer Codes.

2. EPA Technical Evaluation Results: Projected Geophysical, Hydrogeologic and Geochemical Conditions

EPA reviewed DOE's consideration of waste-related impacts on WIPP geophysical, geochemical, and hydrogeological conditions (CCA Chapter 6.4.3, pp.6-92 to 6-111, and Appendix SCR.2, pp.SCR-33 to SCR-90). EPA concluded that DOE's exclusion of heat-generating mechanisms from the performance assessment was appropriate since the impact that heat generation would have on the disposal system hydrogeology and geochemistry is minimal. EPA determined that DOE identified the waste components and characteristics that impact repository performance and integrated them into the performance assessment appropriately. **For EPA's review of waste-related conditions in the WIPP repository as they pertain to gas generation and actinide solubility, refer to CARD 24 - Waste Characterization**. EPA also concluded that DOE appropriately integrated gas generation into performance assessment models. **For additional information on integrating gas generation into performance assessment models, refer to CARD 23 -- Models and Computer Codes.**

F. Materials of Construction [194.14(b)(1)]

1. DOE Methodologies: Materials of Construction

DOE provided a description of the design and materials of construction of the disposal system in CCA Chapter 3, Chapter 2, Sections 2.1.3 (pp. 2-12 to 2-63) and 2.2.1 (pp. 2-97 to 2-136), Chapter 7, Section 7.4 (pp. 7-89 to 7-96), and Appendices BACK, DEL, PCS, and SEAL.

DOE provided a general description of the WIPP facility and the waste disposal system, including the general arrangement and approximate dimensions, in Chapter 3, Sections 3.0, 3.1, and 3.2 (pp. 3-1 to 3-14). DOE indicated that the ground surface area of the WIPP facility has been divided into the following four areas:

- The WIPP Land Withdrawal Area, a 16-section (41.4-square-kilometer) Federal land area under DOE's jurisdiction and bounded by the WIPP site boundary. The LWA land withdrawal area is the controlled area for purposes of demonstrating compliance to 40 CFR Part 191.

- The off-limits area -- approximately 1,454 acres (5.9 square kilometers) -- which is posted and managed as off-limits by DOE.

- The exclusive use area -- approximately 277 acres (112 hectares) -- which is restricted exclusively for the use of DOE and its contractors and subcontractors and is posted against trespass by the general public.

- The property protection area -- approximately 34 acres (13.7 hectares) -- which is enclosed by a chain-link security fence that protects all major surface structures.

The surface facilities at the WIPP accommodate personnel, equipment, and support services required for the safe receipt and transfer of TRU waste from the surface to the underground. These facilities are all located within the property protection area. The principal surface structure is the Waste Handling Building. Other structures include hoist houses, the exhaust filter building, the support building, office trailers, water pump house, engineering building, safety and emergency services building and the guard and security building. DOE indicated that the surface structures will be in service during the operation of the WIPP and are not considered part of the disposal system. See CCA Chapter 3.1 (p. 3-7 to 3-11) for more information.

The CCA indicated (p. 3-1) that DOE has employed a system of berms and ditches to divert storm-water runoff away from the surface facilities. DOE indicated that as documented in the Final Safety and Analysis Report (DOE, 1995) [CCA Reference 202] (Docket A-93-02, Item II-G-1), the WIPP facility drainage system is designed so that storm runoff caused by the probable maximum precipitation event will not flood the WIPP facility. DOE also indicated that the WIPP facility does not lie within a 100-year floodplain and that there are no major surface-water bodies within five miles (8 kilometers) of the site. DOE also indicated that the collars of the repository shafts are elevated at least 6 inches (15.2 centimeters) above the surrounding ground surface to prevent surface water from entering the shafts.

The WIPP facility design includes four vertical shafts to connect the waste disposal area with the ground surface: the waste shaft, the salt handling shaft, the air intake shaft, and the exhaust shaft. All but the exhaust shaft have permanently installed hoists capable of moving personnel, equipment, and materials between the surface and the repository. Each shaft includes a shaft collar, a shaft lining, and a shaft key section. The shaft collars are constructed of reinforced concrete and serve to retain unconsolidated materials and prevent surface water runoff from entering the shaft. The shaft linings extend from the base of the collar to the top of the Salado and serve to retain loose rock and inhibit water seepage from water-bearing formations such as the Magenta and Culebra members of the Rustler. The shaft linings are concrete except in the salt handling shaft, where it is made of steel.

The shaft key section is a circular reinforced concrete section emplaced below the lining of each shaft, in the base of the Rustler, that extends approximately 100 feet into the Salado. The shaft key section supports the weight of the lining and contains water seal rings to prevent water from seeping into the shaft. Two separate water seals are incorporated into each shaft key and the performance of the seals is monitored by inspecting the bottom of each key for seepage. If groundwater is detected flowing past the upper ring, the condition is corrected by injecting chemical sealants or cement grouts to stop the leakage. Each shaft, except the salt handling shaft, is equipped with three water collection rings design to collect any water that may seep into the shaft through the liner.

All of the shafts will eventually be sealed using the seal design described below (see CCA Chapter 3, Sections 3.1.3 (pp. 3-11 to 3-12) and 3.2 (p. 3-13)).

The waste disposal area of the WIPP repository is located 2,150 feet (655 meters) below ground surface (bgs) (Chapter 3.2, pp. 3-12 to 3-14). The waste disposal area consists of eight panels, each of which contains seven rooms, and the access drifts and crosscuts adjacent to the disposal panels. The access drifts and crosscuts have been labeled Panels 9 and 10. See Figure 3-2 (p. 3-5) of the CCA for a plan view of the WIPP underground facility. Each of the disposal rooms in Panels 1 through 8 will have nominal dimensions of 300 feet (91 meters) long, 33 feet (10 meters) wide, and 13 feet (4 meters) high. The pillars between each room will be 100 feet wide. The access drifts and crosscuts designated as Panels 9 and 10 will typically have smaller cross-sections than the disposal rooms and will range from 14 to 25 feet (4.25 to 7.6 meters) wide and 12 to 13 feet high (3.6 to 4 meters) high. The overall size of the waste disposal area is approximately 1,970 feet (600 meters) by 2,625 feet (800 meters) and is designed to hold a combined total of 6.2 million cubic feet (175,600 cubic meters) of contact-handled and remote-handled transuranic (TRU) waste. Only Panel 1 and portions of drifts have been constructed to date. See Chapter 3 (pp. 3-1 and 3-2), Section 3.2 (pp. 3-12 to 3-14), and Figure 3-2 for more information.

DOE provided information regarding the geologic media in Chapter 2, Sections 2.1.3.4 (pp. 2-29 to 2-37) and 2.2.1.3 (pp. 2-108 to 2-113). DOE stated that the Salado, a regionally extensive evaporite, provides the primary natural containment for potential radionuclide releases from the WIPP. According to DOE, the existence of a large salt deposit such as the Salado demonstrates isolation from circulating groundwater for long periods of time. In addition, creep closure of the salt in the Salado will encapsulate the emplaced waste after closure.

The Salado is part of the Permian age Ochoan Series, is approximately 2,000 feet (609 meters) thick in the WIPP area, and is divided into an unnamed upper member, the middle McNutt Potash Zone, and an unnamed lower member. There are 10 potash zones within the McNutt Member, of which the 4th and 10th zones are of potential significance in the vicinity of the WIPP. Also, there are numerous sulfate beds (primarily anhydrite) within the Salado. The anhydrite layers are designated as marker beds (MB) and have been numbered MB100 (near the top of the formation) to MB 144 (near the base). DOE provided information regarding the characteristics of the geologic media above and below the Salado in Chapter 2, Sections 2.1.3 and 2.2.1 (pp. 2-97 to 2-136).

Chapter 3.2 (pp. 3-13 to 3-14) indicated that mining of shafts and underground passages within the repository gives rise to a disturbed rock zone (DRZ) that is important to repository performance. The DRZ forms as a consequence of unloading of the rock in the vicinity of the excavation. Increased permeability is created by microfractures along grain boundaries and by bed separation along lateral seams. The DRZ development begins immediately after excavation and continues as salt creeps into the opening. DOE indicated (p. 3-14) that the DRZ surrounding the shafts is symmetrical and has been characterized and incorporated into the shaft seal design in Appendix SEAL. As shaft seal elements resist inward creep, the stress state becomes compressive and gives rise to fracture healing, and a return of the disturbed salt to it's original extremely low permeability.

DOE further indicated (CCA p. 3-14) that the lateral DRZ along passages in the underground includes fractures in nonhalitic rock, such as anhydrite, and bed separation along clay seams. These zones will not naturally heal in a manner similar to the healing of halite. DOE indicated that the panel closure systems discussed below will prevent further development of the DRZ in the panel entries, thereby restricting flow from the panels to the DRZ existing at the time of panel closure construction.

Engineered Features

DOE provided information regarding the design and materials of construction for engineered features incorporated into the disposal system design in CCA Chapter 3.3 (pp. 3-14 to 3-45) and Appendices SEAL, PCS, BACK, and DEL. DOE incorporated three types of engineered features into the design of the disposal system: shaft seals, panel closures, and borehole plugs. DOE also determined that an engineered barrier, consisting of emplacement of magnesium oxide (MgO) backfill around the waste containers, would be required to meet the assurance requirements of § 194.44.

Shaft Seals

DOE described the seals to be used in each of the four shafts in Chapter 3.3.1 (pp. 3-15 to 3-27). Appendix SEAL included the design plans and the material and construction specifications for the seals. The purpose of the shaft seal system is to limit fluid flow within the shafts after the WIPP is decommissioned and to ensure that the shafts will not become pathways for radionuclide release.

DOE indicated (CCA p. 3-15) that material specifications and construction techniques for the shaft seal system were provided in Appendix SEAL (Chapters 5 and 6). Chapter 5 of Appendix SEAL also provided the rationale and quantification methods used to develop parameter distribution functions. The materials specifications and construction techniques were described in Appendices A and B of Appendix SEAL. Appendix PAR provided a summary of the shaft seal system parameters used as inputs to the performance assessment codes.

CCA Chapter 3.3.1.2 (p. 3-16) provided a description of the design objectives for the shaft seal system and DOE summarized the design objectives as:

- limit radionuclides from reaching regulatory boundaries,
- restrict groundwater flow through the sealing system,
- use engineered materials possessing good long-term stability
- protect against structural failure of system components
- minimize subsidence and prevent accidental entry, and
- use available construction methods and materials.

DOE indicated (p. 3-16) that the shaft seal system design was completed under the Quality Assurance program described in Chapter 5 of the CCA and included review by independent, qualified experts. The reviewers examined the complete design including conceptual, mathematical, and numerical models, and computer codes. DOE further indicated that the shaft seal design reduces uncertainty associated with any particular element by using multiple sealing system components constructed from different materials.

The shaft seal system has 13 elements that fill the shaft with engineered materials possessing high density and low permeability, including concrete, clay, compacted salt, cementitious grout, and earthen fill. DOE provided a schematic drawing of the shaft seal system in Figure 3-4 (p. 3-17) of the CCA. The compacted salt column component of the system within the Salado is intended to serve as the primary long-term barrier by limiting fluid transport along the shaft during the 10,000-year regulatory period. The other components of the shaft seal within the Salado are intended to prevent migration of radionuclides in the short term and protect the compacted salt column until it becomes effective as a long-term barrier. Components of the seal system within the Rustler are intended to limit the commingling of groundwater between the water bearing members. The seal system overlying the Rustler will consist of compacted earthen fill (Chapter 3.3.1 and Appendix SEAL).

A shaft station monolith will be placed at the bottom of each shaft to fill the station excavations and the sumps in the salt-handling and waste-handling shafts. The shaft station monoliths will be constructed of salt-saturated concrete called the Salado mass concrete (SMC).

Clay columns consisting of a commercial well-sealing-grade sodium bentonite clay, will be placed in two places within the Salado and one place in the Rustler. The purpose of the clay columns is to limit groundwater movement from the time they are placed and provide an effective barrier to fluid migration throughout the 10,000-year regulatory period. The clay will be emplaced as compressed blocks to provide stiffness sufficient to promote early healing of the DRZ surrounding the shaft within the Salado to remove the DRZ as a pathway for gases or brine. The locations of the Salado compacted clay columns were selected to limit brine migration and potential gas migration into the consolidating compacted salt column. The Rustler compacted clay column is intended to limit groundwater communication between the Magenta and the Culebra.

Within the Salado, DOE indicated (CCA p. 3-20) that there will be upper, middle, and lower concrete components. Each concrete component will be composed of an upper concrete plug, a central asphalt water stop, and a lower concrete plug. The concrete plugs are intended to fill irregularities in the shaft wall, and provide a rigid component to promote early healing of the DRZ due salt creep. The concrete plugs will be constructed of SMC to ensure good bonding with the salt. Prior to placement on the asphalt water stops, a cut will be made into the shaft wall that is one shaft radius deep in order to cut through the existing shaft DRZ. The asphalt water stop will intersect the shaft cross section and will extend into the cut. The intent is that the new DRZ around the cut will heal quickly, and that the asphalt will provide a seal of the existing shaft DRZ.

The compacted salt column component of the system within the Salado is intended to serve as the primary long-term barrier by limiting fluid transport along the shaft during the 10,000-year regulatory period. The compacted salt column will be constructed of crushed Salado salt with about 1.5 weight-percent water added during construction. DOE indicated (CCA p. 3-20) that demonstrations have shown that mine-run WIPP salt can be dynamically compacted to a density equivalent to approximately 90 percent of the average density of intact Salado salt. The intent of the compacted salt column is for consolidation due to salt creep to increase the density of the compacted salt over time, which will further reduce the permeability. DOE indicated that the salt column offers little resistance to brine migration immediately after placement, but becomes less permeable as density increases. Within Chapter 3.3.1.3.4 (p. 3-20) and Appendix SEAL (Sections 7.5 and 8.4), DOE indicated that analyses indicate that the salt column becomes an effective long-term barrier in less than 100 years.

An asphalt column consisting of an asphalt-aggregate mixture will be placed to span the Rustler and Salado contact. The intent of the asphalt column is to provide an essentially impermeable seal for the shaft cross section and along the shaft wall interface. The existing shaft linings and keys will be removed prior to placement of the asphalt column.

The shaft seal design calls for the placement of two concrete plugs, which will be approximately 20-foot (6-meter) long Salado mass concrete sections. The first plug will be located directly on top of the asphalt column to allow the immediate construction and dynamic compaction of the Rustler clay column before the asphalt has completely cooled. The second concrete plug will be located near the surface, extending downward from the top of the Dewey Lake.

The last element of the shaft seal design will be compacted earthen fill that will be placed above and below the concrete plug at the top of the Dewey Lake. The compacted earthen fill below the Dewey Lake concrete plug will extend throughout the Dewey Lake and will be dynamically compacted in an attempt to achieve a density approaching the surrounding materials. The uppermost earthen fill will be placed from the shaft collar, down to the top of the Dewey Lake concrete plug.

Panel Closure System

Section 3.3.2 (pp. 3-27 to 3-33) and Appendix PCS of the CCA provided a description of the panel closure system that DOE intends to emplace in the panel access drifts of the waste disposal panels after waste is emplaced in each panel. The CCA (Figure 3-5, p. 3-29, and Appendix PCS) provided four panel closure system design options identified as Options A through D. Each of the design options consists of a two component composite system. The first component consists of a rigid concrete component emplaced either with removal of the DRZ (Options C and D), or without removal of the DRZ (Options A and B). The second component is either an explosion-isolation wall (Options B and D) or a construction-isolation wall (Options A and C). The concrete barrier component is intended as the primary barrier for the flow of air, volatile organic compounds and brine through the panel access drift after closure of the waste disposal panel. DOE proposed (Appendix PCS, p. 2-29) that the concrete barrier be composed of standard concrete with a plain cement mix. The CCA indicated (Appendix PCS, pp. ES-8 and 3-4) that the construction isolation wall is intended to comply with Mine Safety and Health Administration regulations to safely isolate abandoned areas from active workings using barricades of substantial construction and will be constructed of concrete block keyed into the salt. The CCA (Appendix PCS, p. ES-8) indicated that the explosion-isolation wall will be used for those panel closures where there is a potential for the occurrence of an explosive mixture of methane within the closed panel. The explosion-isolation wall will also be constructed of concrete block, but will be thicker than the construction isolation wall to mitigate the effects of a postulated methane explosion.

Within Section 3.3.2 (pp. 3-27 to 3-33) of the CCA, DOE did not explicitly state which of the four proposed panel closure system design options would be used at the time of panel closure. The CCA indicated (pp. 3-28 and 3-33) that DOE will choose the appropriate panel closure system design at the time a panel closure is needed based on several criteria including: the age of the panel excavation at the time of panel closure; the potential for the concentration of methane within the closed panel, generated due to waste degradation, to exceed flammable concentrations during the operational period; the particular ground conditions (stability of the roof, walls, and floor of the excavation) at the time of installation; and the extent of the disturbed rock zone (DRZ) at the time of panel closure.

Section 3.3.2 (p. 3-27) of the CCA indicated that the original intention of the panel closure system was to support Resource Conservation and Recovery Act (RCRA) closure of the waste disposal panels and to prevent the release of potentially unacceptable levels of volatile organic compounds from the filled waste disposal panels during waste management operations in the remainder of the repository (up to 35 years). The CCA indicated (p. 3-33) that although the design of the panel closure system was based on it's need to protect human health and the environment during the operations period, the use of these systems will also influence fluid connections between panels during the postclosure phase. The CCA also indicated (p. 3-23) that although the panel closures are neither intended nor designed for long-term repository compliance, they provide a solid within the panel access drifts which prevent the preexisting DRZ from increasing in permeability after closure system installation. The CCA (p. 3-27) referenced Appendix PAR and Appendix MASS (MASS Attachment 7-1) for the supporting rationale for the DRZ permeability value used in performance assessment.

Chapter 3.3.2 (p. 3-33) indicated that flow of fluids into or out of the panels will be controlled by the permeability of the panel closure and the surrounding DRZ. The CCA further stated that consideration of the current panel closure designs indicated that they will maintain their structural integrity for the regulatory period. The CCA (p. 3-33) acknowledged that degradation of the freshwater concrete barrier component may occur by interaction with brine flowing through the barrier component or with brines flowing along the interface between the concrete barrier component and the salt or through the DRZ. However, the CCA stated (p. 3-33) that calculations show that insufficient brine transport is available to begin the degradation processes (Appendix MASS, MASS Attachment 7-1) and that the concrete barrier element of the panel closure system will continue to provide resistance to inward deformation of the surrounding salt and will thereby prohibit growth of the DRZ from it's initial state. The CCA then stated (p. 3-33) therefore, concrete components are not intended to degrade to a condition that is more permeable than the DRZ in the regulatory period of 10,000 years.

Although DOE provided information showing that insufficient brine transport is available to begin degradation processes (Appendix MASS, MASS Attachment 7-1), the actual panel closure system design document, Appendix PCS (Section 2.2.1.2, pp. 2-26 to 2-29), acknowledged that Wakeley (Wakeley et al., 1994) [CCA Reference 663] (Docket A-93-02, Item II-G-1) researched various concrete mixtures for use in the panel closure system design, and studied the susceptibility of various concrete mixtures to chemical degradation by brines, and created what was called the Salado Mass Concrete for use in the panel closure system. However, within Section 2.2.1.5 (p. 2-29) of Appendix PCS, DOE states "Previous studies suggest the application of the SMC (Salado Mass Concrete) to the design of the panel-closure system.... Because of the trace amounts of brine and the impermeable nature of the concrete, a standard concrete with a low heat of hydration and similar workability was considered acceptable. Therefore, the design specifies a plain cement concrete mix that must be verified with testing."

Borehole Plugs

DOE described the borehole plug materials that will be installed in existing unplugged borings within the controlled area in CCA Chapter 3.3.4 (pp. 3-39 through 3-45). Appendix DEL.6.2.4 (pp. DEL-72 to DEL-73) listed the applicable State oil and gas well plugging requirements. The purpose of the borehole plugs is to mitigate the potential for migration of contaminants toward the accessible environment. DOE also indicated that the plugs are designed to limit the volume of water that could be introduced to the repository from the overlying water bearing zones and to limit the volume of contaminated brine released from the repository to the accessible environment.

DOE indicated that shallow unplugged boreholes within the controlled area will be plugged in accordance with current State or Federal regulations. Existing deep unplugged boreholes within the controlled area will be plugged in according to the State of New Mexico, Oil Conservation Division, Order R-111-P. DOE concluded that boreholes within the controlled area, which were previously plugged in accordance with appropriate State and Federal regulations in effect at the time of plugging, will mitigate the potential for migration of fluids to the accessible environment.

DOE indicated (p. 3-40) that solid cement plugs will go through the salt section and any water bearing horizon to prevent liquids or gases from entering the hole above or below the salt section. DOE indicated that cements will be mixed with salt-saturated fluids made with salts from the horizon being plugged (Appendix DEL.6.2.4). The CCA (p. 3-39) indicated that DOE has completed a significant amount of research to optimize the concrete mixtures for the conditions expected in the Salado and identified materials (i.e., Salado mass concrete) that will provide suitable plugs for boreholes.

MgO Backfill

DOE also plans to employ an engineered barrier of MgO backfill around the waste. The purpose of the MgO backfill is to buffer the chemical composition of brine that may enter the waste disposal area over the 10,000-year regulatory period. For a detailed discussion of MgO backfill as an engineered barrier, see **CARD 44 -- Engineered Barriers**. For information concerning how MgO was incorporated into performance assessment calculations, refer to the discussion of the Chemical Conditions model in **CARD 23--Models and Computer Codes**.

2. EPA Technical Evaluation Results: Materials of Construction

EPA verified whether the information required at § 194.14(b)(1) was provided and the descriptions of construction material and general design were accurate, appropriate, and consistent throughout the CCA. EPA compared the references for Section 194.14(b)(1) with parts of the CCA dealing with other Compliance Criteria sections (e.g., Section 194.23 and Section 194.44), EPA found that the CCA did not provide a separate description of the materials for construction of the disposal system. Most of the information referenced by DOE as demonstrating compliance with Section 194.14(b)(1) was principally used to demonstrate compliance with other sections of the Compliance Criteria. EPA reviewed all of the disposal system information to verify that there were no inconsistent, extraneous, or contradictory descriptions of materials or dimensions.

Based on the review of the information in Chapter 3, Sections 2.1.3 (pp. 2-12 to 2-63) and 2.2.1 (pp. 2-97 through 2-136) of Chapter 2, Chapter 7.4 (pp. 7-89 through 7-96), and Appendices BACK, DEL, PCS, and SEAL, EPA concluded that the documentation provided by DOE to describe the design and materials of construction of the disposal system and to demonstrate that they can be implemented and will function in the intended manner to be consistent and technically sufficient.

The purpose of borehole plugs is to mitigate the potential for migration of contaminants toward the accessible environment. DOE indicated that they will abide by the applicable State oil and gas well plugging requirements listed in Appendix DEL 6.2.4 (State of New Mexico, Oil Conservation Division, Order R-111-P). While there are four deep research wells drilled in the disposal system, DOE identified that (Appendix DVR 12.2.3 Design Configuration) "the ERDA-9 exploratory hole was the only hole within the underground development area which was permitted to penetrate the Salado formation to the underground facility horizon." ERDA-9 did not penetrate what will be a waste panel area and DOE indicated (Appendix SCR.3.3.1.4.2) that abandoned boreholes less than a meter away from the waste can be screened out due to low consequence. EPA agreed with DOE's assessment that these boreholes are not significant to performance of the disposal system and can screened out of PA.

EPA concurred with DOE's predictions regarding the consolidation and subsequent decrease in permeability of the compacted salt components of the proposed shaft seals. The compacted salt component will serve as the "primary" long-term shaft seal component, since it will be the largest single component (approximately 560 feet in vertical length) and has an inherent compatibility with the host rock material. The salt will be compacted during seal construction to 90 percent of the density of undisturbed halite. Moreover, approximately 100 to 200 years after construction, the pressure from overlying materials and inward creep of the surrounding Salado should further consolidate the salt plug and reduce its permeability to within an order of magnitude of undisturbed halite. The shaft seal design in Appendix SEAL of the CCA received extensive technical review by DOE, and was also subjected to an independent design review. EPA concludes that the shaft seal design is adequate because the system can be built and is expected to function as intended.

EPA was concerned about the potential for seepage of brine into the shafts from the surrounding Salado in the zone to be occupied by the compacted salt plug. DOE was been unable to quantify the brine seepage, although seepage locations were observed and documented (Appendix SEAL, Table 2-1). This is essentially an operational problem because seepage zones would be plugged before emplacement of shaft seal materials.

Nevertheless, EPA investigated the seepage of brine in the salt column interval by reviewing the original shaft stratigraphic mapping reports, viewing bore logs, reviewing the interim shaft geologic inspection report, interviewing the lead geologist (Dr. Dennis Powers) who prepared the shaft mapping and inspection reports, and performing an independent inspection of the air intake shaft. On January 28, 1997, EPA inspected the shaft from Marker Bed 101 to the repository level by stopping the lift cage repeatedly at intervening marker beds, observing the shaft face with the assistance of video lighting equipment, and correlating these observations with previous records of brine seepage. Dr. Powers was available for questioning and clarification during the inspection. EPA's inspection indicated that there is no apparent current brine seepage between Marker Beds 117 and 135. See EPA's Air Intake Shaft Inspection Trip Report, included as Attachment 1 to this Technical Support Document, and additional DOE references (DOE, 1995 and Holt and Powers, 1990) (Docket A-93-02, Item II-G-1) for information regarding brine seepage in the air intake shaft.

EPA's review of the panel closure system indicated that the original purpose of the panel closure system was to reduce VOC emissions from the repository during the operational period and control possible explosions. The primary long-term effect of the seal will be to block the flow of brine between panels. Gas flow (for post-closure performance assessment modeling) between panels would be relatively unaffected by the design choice. DOE indicated that the panel closure system is designed so that components can be added or removed, or their shapes adjusted, based on the particular ground conditions (stability of the roof, walls, and floor of the excavation) at the time of installation.

DOE provided four options for panel seal closures but did not specify which panel closure option would be used at WIPP. This lack of a specificity was pointed out in public comments. (Docket A-93-02, Item II-H-10) After review of the four panel closure system options proposed by DOE, and consideration of the intended purpose of the panel closure system in preventing the existing DRZ in the panel access drifts from increasing in permeability after panel closure, EPA concludes that the panel closure system design identified as "Option D" in Figure 3-5 (p. 3-29) of the CCA is the most robust panel closure design and is the panel closure system design that DOE must use when closing each underground waste panel. EPA has chosen the most robust design option since for performance assessment purposes, DOE has assumed a fixed value for the permeability of the DRZ around the panel closure system. Option D in Figure 3-5 of the CCA includes significant removal of the DRZ prior to construction of the concrete barrier portion of the panel closure system, thereby ensuring consistency in the initial characteristics of the interface between the Salado formation host rock and the concrete barrier component of the panel closure system and the resulting permeability of the DRZ surrounding the panel closure system. The consistency in the initial characteristics of the interface between the Salado formation host rock and the concrete barrier component of the panel closure system will support DOE's assumption of the fixed DRZ permeability assumed in performance assessment.

EPA determined that such a design is adequate to achieve the long-term performance modeled in PA, since DOE provides information in Appendix PCS that shows that the use of a concrete barrier component is capable of providing resistance to inward deformation of the surrounding salt and prohibiting growth of the DRZ from its initial state. EPA therefore finds that DOE complies with §194.14(b), but is requiring DOE to implement the Option D design, with Salado mass concrete replacing fresh water concrete. EPA is requiring the use of Salado mass concrete for the construction of the concrete barrier component of the panel closure due to the potential for degradation and decomposition of fresh water concrete. The degradation of the freshwater concrete barrier component could occur because of infiltration of brine into the block of concrete or along the interface between the salt and the concrete. These processes could potentially reduce the strength of the concrete and potentially increase the permeability of the concrete.

Although EPA's sensitivity analysis indicated that the panel seal permeability is not a sensitive parameter [see EPA's Technical Support Document for Section 194.23: Sensitivity Analysis (EPA, 1998d) (Docket A-93-02, Item V-B-13), especially with the disturbed rock zone at the same or higher permeability, the Agency believes it is important to ensure that the proposed design on which compliance was based is actually implemented at the site. Therefore, EPA is requiring that DOE use panel closure seal design Option D.

G. Computer Codes and Standards for Design and Construction [194.14(b)(2)]

1. DOE Methodologies: Computer Codes and Standards for Design and Construction

DOE indicated in Chapter 3.1.1 (p. 3-7) of the CCA that Federal facility acquisition policies were applied to the design and construction of the WIPP facility and that WIPP structures were designed to meet DOE design and quality assurance (QA) requirements as documented in the Final Safety and Analysis Report (DOE, 1995) [CCA Reference 202] (Docket A-93-02, Item II-G-1). The Final Safety and Analysis Report provided identification of the design criteria and QA requirements used for the design and construction of the WIPP facility. Chapter 3.1.1 (p. 3-7) also indicated that structures, systems, and components were designed to meet the requirements applicable to Design Class II structures, systems, and components for nonreactor nuclear facilities. Chapter 3.2 (pp. 3-12 to 3-14) indicated that the Site and Preliminary Design Validation (SPDV) program was implemented in 1981 to validate the WIPP site geology and provide preliminary validation of the underground excavation. The data obtained during the SPDV program were analyzed to determine the suitability of the design criteria and the design bases and to provide confirmation of the underground opening reference design. DOE stated (p. 3-13) that "Information in Appendix DVR (Section DVR.6.4.2) meets the criterion specified in 40 CFR § 194.14(b)(2)" for demonstrating that the designs can be implemented and that they will function in the manner for which they were designed.

CCA Chapter 3.1.2 (p. 3-8) describes how the design standards for the WIPP are documented and maintained through a Configuration Control System. Under this system, any changes to the current design must be fully reviewed and approved to avoid compromising the Safety Analysis Report for the facility. DOE indicated that the primary standards used in design and construction of the WIPP are the American Society of Mechanical Engineers NQA-1 nuclear facility quality assurance standards (Chapter 3.1.2, p. 3-8).

DOE identified computer codes used in design of the disposal system in CCA Chapter 3.3.3 and Appendices DVR, PCS, and SEAL. Chapter 3.3.3 (p. 3-39) indicated that DOE estimated the chemical effects of MgO backfill using a commercially available code named EQ3/EQ6. The 1986 WIPP Design Validation Report in Appendix DVR, Section 2.6.3 (p. 2-15), Section 5.4 (pp. 5-13 through 5-16), and Section 7.3.3 (pp. 7-47 to 7-67) described the Model Simulation activities used to assess structural behavior around the disposal rooms and shafts. DOE provided descriptions of a model for air flow through a panel closure in Appendix A of Appendix PCS. Appendix C of Appendix PCS discusses another model (FLAC) for analyzing stress of the panel closure, while a third model developed for determining the heat transfer effects resulting from (potential) methane explosions within a panel after closure is contained in Appendix F of Appendix PCS. Appendix SEAL describes three models (SPECTROM-32, SPECTROM-41, and SALT_SUBSID used in evaluating the structural performance of the shaft seals and surrounding rock mass. Two additional models (SWIFT II and TOUGH28W) were used in a total of four different configurations to evaluate the fluid-flow performance of the shaft seal design; see Appendix SEAL, Section 8.2 (p. 63) and Appendix C.

2. EPA Technical Evaluation Results: Computer Codes and Standards for Design and Construction

EPA verified whether the information required at § 194.14(b)(2), including the descriptions of design standards and computer codes that have been applied to the design and construction of the disposal system, were provided. Based on the review of the information in CCA Chapter 3, Appendix DVR, and the Final Safety and Analysis Report (DOE, 1995) [CCA Reference 202] (Docket A-93-02, Item II-G-1), EPA determined that the identification of the design standards used in the design and construction of the disposal system provided by DOE was appropriate since the regulation did not specify that a detailed description of the individual design standards were required. Based on the review of information provided in Chapter 3.3.3, and Appendices DVR, PCS, and SEAL, EPA determined that DOE's identification of the computer codes and standards that were applied to the design and construction of the disposal system is adequate since the regulation does not specify that a detailed description of the individual computer codes was required.

H. Results of Assessments [194.14(c)]

1. DOE Methodologies: Results of Assessments

Chapter 6 summarizes the results of the performance assessment and Chapter 8 summarizes the results of the compliance assessment. Major Appendices that support conclusions drawn in these chapters include, but are not limited to, Appendix MASS, modeling and computer code-related Appendices such as CCDFGF, SOTERM, GTMP, and WCA.

DOE presented the results of performance and compliance assessment activities in accordance with the disposal regulations (CCA Chapter 6.5, pp. 6-214 to 6-234, and Chapter 8, pp. 8-1 to 8-19). DOE concluded that the results of the performance assessment indicate that the cumulative releases via all mechanisms over the 10,000 year regulatory period are well below EPA release standards. DOE concluded that the results of the compliance assessment indicate that the maximum potential dose will be one-thirtieth of the individual protection standard and that radionuclide concentrations in a hypothetical underground source of drinking water would be less than half of the EPA groundwater protection standard.

2. EPA Technical Evaluation Results: Results of Assessments

EPA reviewed CCA Chapter 6, Chapter 8, and numerous supporting appendices and references to determine DOE's compliance with Section 194.14(c). EPA raised questions in letters to DOE dated December 19, 1996, March 19, 1997, April 17, 1997, and April 25, 1997

(Docket A-93-02, Items II-I-01, II-I-25, and II-I-27) regarding the technical validity of the information, which DOE addressed by providing supplementary information in letters dated July 3, 1997, June 27, 1997, June 13, 1997, May 14, 1997, April 15, 1997, March 12, 1997, February 26, 1997, February 21, 1997, February 14, 1997, February 7, 1997, January 24, 1997, July 25, 1997 and August 8, 1997 (DOE, 1997a, b, c, d, e, f, g, i, j, k, l and m) (Docket A-93-02, Item II-H-46, Item II-H-45, Item II-H-44, Item II-I-31, Item II-I-24, Item II-H-22, Item II-I-10, Item II-I-08, Item I-I-07, Item II-I-03, Item II-G-26 and II-G-27). DOE also presented additional technical information in memorandum dated August 8, 1997 (WPO No. 046766) and September 10, 1997 (WPO No. 047544). EPA's requests for additional information and the technical adequacy of DOE's supplements are treated fully in the following CARDs: **CARD 23 -- Models and Computer Codes, CARD 24 - Waste Characterization, CARD 34 -- Results of Performance Assessment, CARD 42 -- Monitoring, CARD 44 -- Engineered Barriers, and CARD 55 -- Results of Compliance Assessments.**

EPA concluded that, with the provision of supplementary information, DOE had provided sufficient information regarding the results of its performance assessments. The CCA documentation included the evaluations necessary to support performance assessment calculations pursuant to disposal regulations. The CCDFs in Chapter 6.5 portray the results required by Section 194.34. In addition, the Performance Assessment Verification Testing (DOE, 1997l and m) (Docket A-93-02, Item II-G-26 and II-G-28) verified the original CCA performance assessment results.

EPA concluded that, with the provision of supplementary information, DOE provided sufficient information regarding the results of its compliance assessments, which included evaluations necessary to support the bounding calculations used by DOE to address the disposal regulations. Radioactive releases in the undisturbed scenario are essentially zero; any releases reported were more likely due to numerical dispersion in the modeling than to measurable radionuclide activities.

I. Description of Parameters [194.14(d)]

1. DOE Methodologies: Description of Parameters

DOE presented descriptions of input parameters to the performance assessment within Appendix PAR and associated references (see Chapter 6.5, pp. 6-214 to 6-235). The 57 Latin Hypercube Sampled (LHS) parameters were discussed individually, while the remaining 1,400+ parameters were presented in tabular format. Appendix PAR included, for each LHS parameter, a parameter description, material/parameter names, related computational codes, mean, median, min, max and standard deviation, units, distribution type, experimental data (as applicable), discussion, Sandia National Laboratories Records Center WPO record number(s), and additional references. The LHS parameters include parameters such as inundated steel corrosion rate, Castile brine reservoir initial pressure, and waste particle diameter for the computer code CUTTINGS_S. **Refer to CARD 23 -- Models and Computer Codes and related technical support documents for a complete discussion of parameters.**

2. EPA Technical Evaluation Results: Description of Parameters

EPA thoroughly reviewed DOE's parameter selection and justification as presented in Appendix PAR and conducted a detailed independent analysis of the parameter selection process. EPA assessed over 300 parameters for traceability of data and availability of documentation supporting parameters selected. **Refer to CARD 23 -- Models and Computer Codes** and EPA's Technical Support Document for Section 194.23: Parameter Justification Report (EPA, 1998c) (Docket A-93-01, Item V-B14). EPA found that parameter traceability and support in the CCA required some clarification, including better data base compilation, improvements in data "road maps," documentation of legacy parameters, and documentation as to why parameters based on professional judgement do not require use of the expert elicitation process. EPA requested in a letter dated December 19, 1996 (Enclosure 1, page 10, 194.23(c)(4) and Enclosure 1, page 13, 194.23(c)(4) (Docket A-93-02, Item II-I-01)) and in a letter dated March 19, 1997 (Enclosure 1, pp. 3 and 4, 194.23(c)(4) (Docket A-93-02, Item II-I-17)) that DOE provide additional information, which DOE sent with letters dated February 26, 1997 (DOE, 1997g), April 15, 1997 (p. 11 of response) (DOE, 1997e), and May 14, 1997 (p. 24 of response) (DOE, 1997d) (Docket A-93-02, II-I-10, Item II-I-24, and Item II-I-31). DOE also responded adding to records in the Sandia National Laboratories (SNL) Record Center. EPA found that this supplementary information adequately addressed EPA's concerns, as discussed in the Technical Support Documents for **CARD 23.**

Additionally, EPA noted that the particle diameter value selected by DOE was not based on adequate data nor expert judgement, and required DOE to convene an expert judgement panel to assess the selected value. **Refer to EPA's Technical Support Document for Section 194.23: Parameter Justification Report (EPA, 1998c) (Docket A-93-02, Item V-B-14) for a complete discussion of this parameter. See also CARD 26 -- Expert Judgment for a discussion of the procedure by which the expert judgment was conducted.**

EPA also conducted a technical evaluation of the parameter values used in the PA. EPA's technical review of parameter values indicated that several parameters required modification (see Table 1 below). EPA required that modifications of these parameter values be used in Performance Assessment Verification Testing in lieu of the parameter values used by DOE. Table 1 lists the parameters and values that EPA directed DOE to use in the Performance Assessment Verification Testing. **Refer to CARD 23 -- Models and Computer Codes for a complete discussion information of modified parameters and values.**

Table 1. **EPA Mandated Performance Assessment Verification Testing Parameters**

ID No.	Material	Parameter	Distribution Type/Unit	Min	Max	Med	Mean	Standard Dev.
198	DRZ_1	PRMX_LOG	Loguniform/m^2	3.98E-20	3.16E-13	1.12E-16	1.99E-14	5.24E-14
3184	BH_SAND	PRMX_LOG	Loguniform/m^2	5.01E-17	1.00E-11	2.24E-14	8.19E-13	7.85E-12
8001	CONC_PLG	PRMX	Uniform/m^2	1.0E-19	1.0E-17	5.05E-18	--	--
663	WAS_AREA	PRMX_LOG	Constant/m^2	2.4E-13	2.4E-13	2.4E-13	2.4E-13	0.00
2131	REPOSIT	PRMX_LOG	Constant/m^2	2.4E-13	2.4E-13	2.4E-13	2.4E-13	0.00
2907	STEEL	CORRMCO2	Uniform/ M/S	0.00	3.17E-14	1.585E-14	1.585E-14	9.151E-15
61	CASTILER	COMP_RCK	Triangular/log (Pa^{-1})	2.00E-11	1.00E-10	4.00E-11	5.333E-11	1.6997E-11
3493	GLOBAL	PBRINE	Uniform/None	0.01	0.60	0.305	0.305	0.1703
27	BOREHOLE	DOMEGA	Cumulative/ rad/s	4.20	23.0	7.77	8.63	3.16
3482	AM+3	MKD_AM	Loguniform/ m^3/kg	0.020	0.500	0.100	0.1491	0.1286
3480	PU+3	MKD_PU	Loguniform/ m^3/kg	0.020	0.500	0.100	0.1491	0.1286
3481	PU+4	MKD_PU	Loguniform/ m^3/kg	0.900	20.0	4.243	6.1591	5.141
3479	U+4	MKD_U	Loguniform/ m^3/kg	0.900	20.0	4.243	6.1591	5.141
3475	U+6	MKD_U	Loguniform/ m^3/kg	3.00E-5	3.00E-2	9.487E-4	4.339E-3	6.808E-3
3406	SOLMOD3	SOLSIM	Constant/ moles/liter	1.2E-7	1.2E-7	1.2E-7	1.2E-7	0.00
3402	SOLMOD3	SOLCIM	Constant/ moles/liter	1.3E-8	1.3E-8	1.3E-8	1.3E-8	0.00
3407	SOLMOD4	SOLSIM	Constant/ moles/liter	1.3E-8	1.3E-8	1.3E-8	1.3E-8	0.00
3403	SOLMOD4	SOLCIM	Constant/ moles/liter	4.1E-8	4.1E-8	4.1E-8	4.1E-8	0.00
3408	SOLMOD5	SOLSIM	Constant/ moles/liter	2.4E-7	2.4E-7	2.4E-7	2.4E-7	0.00
3404	SOLMOD5	SOLCIM	Constant/ moles/liter	4.8E-7	4.8E-7	4.8E-7	4.8E-7	0.00

ID No.	Material	Parameter	Distribution Type/Unit	Min	Max	Med	Mean	Standard Dev.
3478	TH+4	MKD_TH	Loguniform/ m3/kg	0.900	20.0	4.243	6.1591	5.141
2254	BOREHOLE	TAUFAIL	Loguniform/Pa	0.05	77	--	--	--
8004	WAS-AREA	VOL SPALL	Uniform/m^3	0.50	4.00	2.25	2.25	1.01

J. Documentation of Measures to Meet Assurance Requirements [194.14(e)]

1. DOE Methodologies: Documentation of Measures to Meet Assurance Requirements

DOE provided documentation of the assurance requirements in Chapter 7 and numerous appendices. A complete discussion of DOE's compliance with the assurance requirements can be found in the following CARDs: **CARD 41 -- Active Institutional Controls, CARD 42 -- Monitoring, CARD 43 -- Passive Institutional Controls, CARD 44 -- Engineered Barriers, CARD 45 -- Consideration of the Presence of Resources, and CARD 46 -- Removal of Waste.**

2. EPA Technical Evaluation Results: Documentation of Measures to Meet Assurance Requirements

EPA thoroughly reviewed DOE's documentation of assurance requirements in the CCA. In certain cases EPA requested additional information from DOE, which DOE provided. Refer to the following CARDs for a complete discussion of EPA's requests for additional information and an evaluation of the technical adequacy of the CCA and supplementary materials: **CARD 41, CARD 42 -- Monitoring, CARD 43 -- Passive Institutional Controls, CARD 44 -- Engineered Barriers, CARD 45 -- Consideration of the Presence of Resources, and CARD 46 -- Removal of Waste.**

K. Waste Acceptance Criteria [194.14(f)]

1. DOE Methodologies: Waste Acceptance Criteria

To demonstrate compliance, DOE provided the current Waste Acceptance Criteria for the WIPP (DOE, 1996) [CCA Reference 201] (Docket A-93-02, Item II-G-1), Appendix WAP, and the Transuranic Waste Characterization Quality Assurance Program Plan (DOE, 1995) [CCA Reference 208] (Docket A-93-02, Item II-G-1). The latter two documents describe procedures that DOE will follow to ensure that the waste acceptance criteria are met. DOE's methodologies include those for generator site waste characterization (non-destructive examination and assay, real-time radiography, and acceptable knowledge), data transfer mechanisms (e.g., WIPP Waste Information System (WWIS)), and waste verification and emplacement activities.

DOE also identified waste limits that must be met by the WIPP, which were presented in Appendix WCL. Appendix WCL specified, for example, the minimum quantity of steel to be emplaced in the WIPP. Steel promotes reducing conditions and provides metals (via corrosion) that will preferentially combine with organic ligands or colloids, thus reducing actinide mobility. In addition, DOE identified a maximum allowable quantity of cellulosics to ensure that the quantity of MgO emplaced around waste containers as an engineered barrier is sufficient to mitigate carbon dioxide generation due to degradation of cellulosics.

2. EPA Technical Evaluation Results: Waste Acceptance Criteria

EPA reviewed the documentation provided by DOE and concluded that DOE provided satisfactory descriptions of actions that will be followed to ensure adherence to the waste acceptance criteria. In addition, EPA audited generator sites, examined performance demonstration programs, and attended WWIS demonstrations, from which it concluded that overall procedures are in place to ensure that waste acceptance criteria and waste limits will be met. **Refer to CARD 24 -- Waste Characterization for a complete discussion of EPA's review of waste acceptance criteria.**

L. Background Environmental Conditions: Environmental Radioactivity (2.4)[194.14(g)]

1. DOE Methodology: Background Environmental Conditions - Environmental Radioactivity (2.4)

General Background Environmental Conditions

In CCA Chapter 2.4 (pp. 2-161 to 2-162), DOE indicated that it designed the WIPP to have minimal impact on the ecology due to construction and operation. The CCA indicated that the final Environmental Impact Statement (FEIS) (DOE, 1980) [CCA Reference 178] (Docket A-93-02, Item II-G-1) concluded that adverse impacts on the ecology were expected to be slight for the following reasons:

- no natural areas proposed for protection are on or near the site;
- no endangered species of plants or animals inhabit the site (and no critical habitats are known to exist on or near the site);
- water requirements are low;
- soil types and vegetation associations are common in the region; and
- access is readily available (thus recreational use is not likely to increase).

In Chapter 2.4 (pp. 2-161 to 2-162), DOE indicated that background environmental conditions form the baseline for determining if releases to the environment have occurred during the operational period or the post-operational period. DOE currently collects physical environmental data with emphasis on ecological conditions, water quality, and air quality, using a system of sampling locations, sampling frequencies, sample management practices, and analytical procedures (where appropriate). The CCA referenced the WIPP Environmental Monitoring Plan (Appendix EMP) for the specifications for implementing and operating the WIPP Environmental Monitoring Program. The studies organized by DOE were as follows:

- Ecological conditions:

- Vegetation
- Mammals
- Reptiles and amphibians
- Birds
- Arthropods
- Aquatic ecology
- Endangered Species

♦ Quality of Environmental Media
- Surface water
- Groundwater
- Air

Environmental Radioactivity

Chapter 2.4.4 (pp. 2-170 to 2-175) of the CCA and Appendices EMP, RBP and SER provided explicit information regarding background radiation in air, soil, and water in the vicinity of the disposal system and the procedures used to determine the background radiation. DOE indicated that background radiation in the vicinity of the WIPP site are influenced by natural sources of radiation, fallout from nuclear tests, and one local research project called Project Gnome. Project Gnome resulted in the underground detonation of a nuclear device on December 10, 1961, at a site approximately 8 miles (13 kilometers) southwest of the WIPP site.

DOE indicated that the WIPP Radiological Baseline Program (RBP) was initiated in July 1975 to describe background levels of radiation and radionuclides in the WIPP environment prior to the emplacement of radioactive waste. The RBP consisted of five subprograms including: atmospheric baseline; ambient radiation baseline; terrestrial baseline (soils); hydrologic baseline (surface water, sediments and groundwater); and biotic baseline. The RBP was succeeded by the Environmental Monitoring Plan. The final report on the RBP was provided as Appendix RBP and the Environmental Monitoring Plan was provided as Appendix EMP. Chapter 2.4.4 (pp. 2-170 to 2-175) of the CCA provided a summary of the results of the radiological monitoring and Appendices RBP, EMP and SER [Sections 1.3, (pp. 1-6 to 1-8), 5 (pp. 5-1 to 5-24), 8 (pp. 8-1 to 8-9), and Appendix A], provided information regarding the locations in which the measurements were made, the dates on which the measurements were made, the standard statistics used on the data, identification of the instrument used and the lower detection limit for the instrumentation, and documentation that the measurements were quality assured. The reports containing background radiation information provided as Appendix RBP and Appendix SER did not provide specific sections describing whether any problems were encountered during the measurement process, but problems encountered were discussed within the body of each report (e.g., the description of the impact of the Chernobyl accident on gross alpha results for airborne particulate samples in Appendix RBP, Section 3.1, p. 3-1).

Chapter 2.4.4.1 (p. 2-171) of the CCA described the atmospheric radiation baseline and indicated that historically, most gross alpha activity in airborne particulates has shown little variation and is within the range of 1 x 10^{-15} to 3 x 10^{-15} microcuries per milliliter. Mean gross beta activity in airborne particulates fluctuates but is typically within the range of 1 x 10^{-14} to 4 x 10^{-14} microcuries per milliliter. The average level of gamma radiation in the environment is approximately 7.5 microroentgens per hour.

Chapter 2.4.4.2 (p. 2-171) of the CCA described the ambient radiation baseline and indicated that using the average rate of gamma radiation of 7.5 microroentgens per hour, the estimated annual dose is approximately 66 millirem. DOE indicated that a seasonal rise in ambient radiation has been observed in the first and fourth quarters each year. DOE speculated that this fluctuation may be due to variations in the emission and dispersion of radon-222 from the soil surrounding the WIPP site, possibly caused by meterological conditions.

Chapter 2.4.4.3 (p. 2-172) of the CCA described the terrestrial baseline and indicated that data were collected in December 1985 and July 1987. Soil samples from 37 locations within a 50-mile (80-kilometer) radius of the WIPP were collected and analyzed for 19 radionuclides. DOE indicated that 16 sample locations were collected in a ring around the WIPP site with a 5-mile (8-kilometer) radius and the remaining samples were either collected at the WIPP site, or outside the 5-mile ring. The results indicated that the mean values for ^{60}Co, ^{90}Sr, ^{228}RA, ^{233}U, ^{237}Np, the plutonium isotopes, ^{241}Am and ^{244}Cm fell below detection limits. The range of measured mean values for 40K, 137Cs, 226 Ra, three thorium isotopes, and three uranium isotopes were provided in Table 2-10 of the CCA.

Chapter 2.4.4.4 (pp. 2-172 to 2-174) of the CCA described the hydrologic baseline and indicated that samples were collected from 12 surface water locations, six sediment locations, and 37 groundwater wells. The surface water and groundwater samples were analyzed for 19 radionuclides and the sediment samples were analyzed for 18 radionuclides (tritium was not analyzed in the sediments).

Five surface water samples were collected from stock tanks near the WIPP, four samples were collected from the Pecos River, and three samples were collected from a series of playa lakes at the lower end of Nash Draw. Only ^{60}Co, ^{137}Cs, ^{228}Ra, ^{234}U, and ^{238}U were found to be above detection limits.

DOE indicated that 23 groundwater samples were collected from wells completed by DOE in the Culebra, four samples were collected from wells completed by DOE in the Magenta, and 10 samples were collected from privately owned wells completed in various units. DOE indicated that only ^{60}Co, ^{137}Cs, ^{226}Ra, ^{234}U, and ^{238}U were found to have an average concentration (average of all wells) that was above detection limits. DOE indicated that elevated levels of ^{40}K were found in the in the Magenta, private wells and the Culebra wells at levels ranging from 2.0 x 10^{-7} to 5.4 x 10^{-7} microcuries per gram. DOE indicated that the increased levels of ^{40}K can be attributed to the generally high levels of dissolved solids in groundwater in these formations.

Chapter 2.4.4.5 (p. 2-174) of the CCA described the biotic baseline and indicated that vegetation, rabbits, quail, beef, and fish were sampled to characterize background radioactivity levels in key organisms along possible food-chain pathways to man. DOE made no attempt to interpret the data from this program due to the small sample sizes, but indicated that the results of the program are presented in Appendix RBP.

The following table lists Appendices and cross-references for the CCA, Chapter 2.4, Background Environmental Conditions:

WIPP Environmental Monitoring Plan	Appendix EMP

2. EPA Technical Evaluation Results: Background Environmental Conditions - Environmental Radioactivity (2.4.4) [194.14(g)]

The background radiation conditions in the vicinity of the WIPP were discussed in Chapter 2.4.4 (pp. 2-170 to 2-175) of the CCA which included a description of background radiation in air, soil and water in the vicinity of the disposal system and the procedures employed to determine such radiation. The CCA indicated that DOE programs established to monitor environmental radioactivity in the vicinity of the WIPP were the Radiological Baseline Program (RBP) and the Environmental Monitoring Plan (EMP).

The CCA presented a summary of the two DOE programs established to monitor environmental radioactivity in the vicinity of the WIPP and a detailed description of the programs, including the majority of the information required under 40 CFR §194.14(g), within Appendix RBP, Appendix EMP and Appendix SER. In general, the information regarding the background radiation in air, soil and water provided in the CCA and associated appendices appeared to be technically reasonable.

For each of the baseline programs, the Appendices RBP or SER provided a description of the:

- ♦ location in which the measurements were made;
- ♦ dates on which the measurements were made;
- ♦ standard statistics, such as mean and standard deviation;
- ♦ Identification of the instrument used and lower limit of detection for the instrumentation;
- ♦ discussion of problems (if any) encountered in the measurement process; and
- ♦ documentation that the measurements were quality assured.

EPA reviewed the background radiation conditions in the vicinity of the WIPP as discussed in Section 2.4.4, including DOE's description of background radiation in air, soil, and water and the procedures employed to determine such radiation. DOE programs established to monitor environmental radioactivity in the vicinity of the WIPP are the RBP and the EMP. EPA found that DOE provided sufficient discussion of these background levels and associated procedures to monitor these media for radiation.

M. Topographic Maps [194.14(h)]

1. DOE Methodology: Topographic Maps

The CCA indicated in Chapter 2.1.4.2 (page 2-67, lines 21-22), that Figure 2-18 is a topographic map of the area and that detailed topographic maps are attached at end of Volume 1.

DOE provided four topographic contour maps within the CCA:

- Figure 2-18 (p. 2-69), which shows an area 60 miles by 44 miles (96.5 kilometers by 70.8 kilometers) at a contour interval of 100 feet;
- Figure 2-25 (p. 2-99), which shows an area 36 miles by 42 miles (58 kilometers by 65.6 kilometers) at a contour interval of 50 feet; and
- Two USGS 15 minute quadrangle topographic maps of Livingston Ridge and Los Medanos (attached to Volume I of the CCA), each of which covers an area of 7.5 miles by 8.5 miles (12 kilometers by 13.7 kilometers) at a contour interval of 10 feet.

DOE provided CCA Figures 2-1 (p. 2-7), 2-25 (p. 2-99) and 3-1 (p. 3-3) to show the locations of the controlled area within the U.S. Public Land Survey coordinate system. DOE also provided a map showing the location of active, inactive and abandoned injection and withdrawal wells in the controlled area and in the vicinity of the disposal system in Appendix DEL, Plate DEL-6.

The following lists Appendices and cross-references for [194.14(h)], Topographic Maps

60x44 mile-area Topographic Map	Chapter 2.0, Figure 2-18
36x42 mile-area Topographic Map	Chapter 2.0, Figure 2-25
USGS Topographic Maps	Pocket Maps - Volume 1
WIPP Site Area	Chapter 3.0, Figure 3-1
	Appendix DEL
	Figures DEL-5 and DEL-6

2. EPA Technical Evaluation Results: Topographic Maps

The combination of scale and coverage provided in CCA Figure 2-18 and the topographic maps included at the end of Volume 1 of the CCA appear to be technically reasonable and provided detail sufficient to show the surface water drainage pattern in the vicinity of the disposal system, as recommended in 40 CFR §194.14. The maps which were most useful for this purpose include the two U.S. Geological Survey (USGS) 7.5 Minute Topographic Maps that are included with the CCA. The 10 feet contour interval on these two maps allowed for the identification of surficial drainage features on multiple scales and also the identification of features, interpreted as aeolian blowouts, that are present in the area.

A limitation imposed by the scale of the USGS maps was aerial coverage. CCA Figure 2-18, as well as Figure 2-25, were additional maps with coverage of the WIPP area which provide topographic information. Enlarged versions of Figures 2-18 and 2-25 were included at the end of Volume 1 of the CCA. An indication of the pattern of surface water flow in the vicinity of the WIPP on a larger scale than available in the USGS maps was available in Figures 2-18 and 2-25.

CCA Figures 2-16 and 2-25 showed the approximate boundaries of the controlled area. Figures such as 2-2 and 3-1 provided a more precise location of the controlled area within the State of New Mexico Township and Range grid coordinate system. Plate DEL-6, included in Appendix DEL, showed the location of active, inactive and abandoned injection and withdrawal wells in the controlled area and in the vicinity of the disposal system.

N. Climate and Meteorological Conditions (2-5, CLI) [194.14(i)]

1. DOE Methodology: Historic Climatic and Meteorological Conditions (2.5.1)

DOE derived the discussion of historic climatic conditions included in Chapter 2.5.1 of the CCA from Swift (1992) (Docket A-93-02, Item II-G-1), which was included in the CCA as Appendix CLI. Appendix CLI reviewed evidence of past climate changes that may have affected the WIPP region and presented limits on future precipitation based on interpreted past extremes. The studies that are discussed in Appendix CLI primarily consider oxygen isotopic data collected through the analysis of marine and lacustrine sediments, glacial ice and vein filling calcite. Carbon dioxide concentrations in air bubbles trapped in glacial ice and hydrogen (deuterium) isotopic data are also considered. Local geologic, and other, deposits were described in Section 6 of Appendix CLI as they relate to climate change in the southwestern New Mexico area. The studies that were referenced in Appendix CLI relied on established methodologies that are often used in climate studies.

CCA Chapter 2.5.1 and Appendix CLI (i.e. Section 6), provided a discussion of past glaciation events and climatic changes and included information on past precipitation and temperature averages. The variability of climatic changes as inferred through isotopic data display periodicity through time. Graphics were included in Appendix CLI to show global climate variation, as deduced through isotopic studies.

CCA Chapter 2.5.1 and Appendix CLI described the historic climatic conditions that were assessed by DOE to understand how climatic conditions can influence the WIPP site 10,000 years in the future. Although DOE indicated that accurate prediction was not possible, DOE reported that it is unlikely the WIPP site will experience future climatic extremes that will exceed those of the late Pleistocene, 1.4 million years ago, to the present. DOE indicated that periodicity of glacial conditions suggests that a return to cooler, wetter periods characteristic of those times is unlikely within the next 10,000 years.

After study of multiple lines of physical and biological evidence, DOE made three conclusions about climate in the WIPP region in Chapter 2.5.1 (p. 2-178):

- Maximum precipitation coincided with the maximum advance of the North American ice sheet (22,000 to 18,000 years ago); minimum precipitation occurred after the ice sheet had retreated to its present limits;

- Past maximum long-term average precipitation was roughly twice the present level; past minimum precipitation may have been 90% of the present level; and

- Short-term fluctuations in precipitation have occurred during the present relatively dry, interglacial period (from 18,000 years ago), though the long-term average precipitation has not exceeded upper limits of the glacial maximum (22,000 to 18,000 years ago).

DOE stated that wetter and cooler conditions prevailed in the WIPP region 1.4 million and 600,000 years ago, based on Gatuna fluvial development of evidence. Drier conditions were present 510,000 years ago, based on the presence and the Mescalero Caliche. At least six climatic cycles are indicated by alternating soil and eolian sand horizons of the Blackwater Draw Formation which is present in the southern High Plains of eastern New Mexico and western Texas.

Using carbon-14 dating techniques, DOE established a more detailed record for climatic conditions prior to 22,000 years b.p. Lines of evidence included:

- Plant communities preserved in packrat middens;

- Pollen from lacustrine (lake) deposits of southwestern New Mexico;

- Gastropods (snails) from western Texas;

- Ostracod assemblages (small, bivalve crustaceans) from western New Mexico;

- Lake levels throughout the Southwest; and

- Faunal remains from caves in southern New Mexico.

DOE indicated that evidence gathered generally indicates a relatively dry climate prior to the last glacial advance 22,000 years ago, and cooler, wetter conditions during the glacial peak from 22,000 to 18,000 years b.p. Continental glaciation closest to the WIPP site occurred in South Dakota, approximately 750 miles (1,200 kilometers) to the north. Alpine glaciation is represented by evidence in the Sacramento Mountains of New Mexico, approximately 135 miles (220 kilometers) to the northwest.

During the last glaciation peak, gastropod evidence suggested a mean annual temperature 5 degrees Celsius below present values; floral and faunal evidence suggested annual precipitation throughout the region 1.6 to 2.0 times greater than today's values. The driest conditions prevailed from 7,000 to 5,000 years ago, with precipitation estimated to be 0.89 times the present value, and mean annual temperature was 2.5 degrees Celsius higher than at present.

The following table lists Appendices and cross-references for the CCA, Chapter 2.5.1, Historical Climatic Conditions:

Historical records of climate	Swift (1992) (Docket A-93-02, Item II-G-1)

2. EPA Technical Review Results: Historic Climatic and Meteorological Conditions

EPA reviewed Chapter 2 of the CCA, related supporting references, and Appendix CLI and determined that the discussion of how climatologic and meterologic conditions at the WIPP site are expected to change during the 10,000-year regulatory time period is adequate. EPA also reviewed the information provided in Section 6.4.9 of the CCA and determined that the method used by DOE to incorporate climatologic and meterologic changes into the conceptual models was appropriate, and that the climate index parameter presented in Appendix PAR and derived from historic meteorological climatic condition data was sufficiently justified. EPA concluded that DOE's assumption in the performance assessment that the range of precipitation levels in the future would be no less than current levels, and up to 225% is adequate and conservative, and that the description of past and present climatic changes and associated impacts on the WIPP disposal system were adequately addressed. **For a detailed discussion of the potential for increased/decreased recharge to the disposal system, refer to CARD 25 -- Future State Assumptions.** The Natural Barriers Data Qualification Peer Review Panel considered the characterization of climate presented in the CCA and determined that the value and distribution of the climate index parameter used in the performance assessment is adequate and conservative.

3. DOE Methodology: Recent Climatic Conditions (2.5.2)

DOE described recent climatic conditions in the WIPP area in CCA Chapter 2.5.2 (pp. 2-178 to 2-191) and various supporting documents, including: Appendix SER and the WIPP Site Environmental Reports for 1990 through 1994 (Westinghouse Electric Corporation, 1991 [CCA Reference 690]; DOE, 1992 [CCA Reference 191] (Docket A-93-02, Item II-G-1); DOE, 1993 [CCA Reference 192]; Westinghouse Electric Corporation, 1994 [CCA Reference 691]; and, Westinghouse Electric Corporation, 1995 [CCA Reference 692] (Docket A-93-02, Item II-G-1). Summaries of recent rainfall, temperature, and wind data were presented in Chapter 2.5.2 (pp. 2-178 to 2-191). DOE provided an estimate of evapotranspiration in Appendix CLI (Section 2, p.3). DOE provided a description of how the climate changes were incorporated in conceptual models in Chapter 6.4.9 (pp. 6-165 to 6-168).

The following table lists Appendices and cross-references for the CCA, Chapter 2.5.2, Recent Climatic Conditions:

Environmental monitoring data	DOE 1992, 1993 [CCA References 191 and 192] (Docket A-93-02, Item II-G-1)

Westinghouse 1991, 1994, 1995 [CCA References 690, 691, and 692] (Docket A-93-02, Item II-G-1)

4. EPA Technical Review Results: Recent Climatic Conditions

An important aspect of the climate conditions at the WIPP lies in assessing the recharge component of the hydrologic cycle. The current climate at the WIPP may be characterized as semi-arid, with generally mild temperatures, low precipitation and humidity and a high evaporation rate. This combination of climatic conditions results in a relatively small component of recharge. This characterization appeared to be supported by available data on recent climate conditions at the WIPP. EPA reviewed CCA Chapter 2.5.2 (pp. 2-178 to 2-191), Appendix SER, and CCA references 191, 192, 690, 691, and 692 and determined that the information provided regarding records of recent annual and monthly precipitation averages, monthly temperature averages and extremes, wind speed and wind direction, and estimates of evapotranspiration were adequately detailed.

O. Additional Information [194.14(j)]

1. DOE Methodologies: Additional Information

Supplementary information sent by DOE in response to EPA's formal requests is listed in "EPA Compliance Review" below. DOE's responses contained clarifications of information in the CCA and the results of analyses and tests conducted subsequent to the preparation of the final CCA, dated October 29, 1996. All supplementary documents formally sent to EPA are available in the EPA docket. Additional supplementary documentation that was not formally sent to EPA but was reviewed by the Agency is available in the Sandia National Laboratories Records Center in Albuquerque, New Mexico (e.g., calculations of actinide solubility for americium, plutonium, thorium and uranium). Documentation of peer review exercises conducted after receipt of the CCA has been placed in the EPA docket.

2. EPA Technical Evaluation Results: Additional Information

In regard to information required by sections other than § 194.14, EPA did not conduct a separate evaluation of compliance with § 194.14(j). Rather, EPA's consideration of DOE's compliance is addressed in the CARDs for those sections.

The CARDs for other sections of the Compliance Criteria discuss in greater detail DOE's responses to EPA's formal requests for additional information and any other supplementary information reviewed by EPA after receipt of the CCA dated October 29, 1996. EPA formally requested additional information from DOE in seven letters dated December 19, 1996 (Docket A-93-02, Item II-I-01), February 18, 1997 (Docket A-93-02, Item II-I-09), March 19, 1997 (Docket A-93-02, Item II-I-17), April 17, 1997 (Docket A-93-02, Item II-I-25), April 25, 1997 (Docket A-93-02, Item II-I-27), June 6, 1997 (Docket A-93-02, Item II-I-33), and July 2, 1997 (Docket A-93-02, Item II-I-37). The information requested by these letters was necessary for EPA's completeness determination and technical review.

EPA staff and contractors also reviewed records maintained by DOE or DOE's contractors (e.g., records kept at the Sandia National Laboratories Records Center in Albuquerque, New Mexico). No additional laboratory or field tests were conducted by DOE at EPA's specific direction; however, DOE did conduct and document laboratory tests after October 29, 1996, in order to present additional data to the Conceptual Model Peer Review Panel. Additional supplementary documentation that was not sent to EPA but was reviewed by the Agency is available in the Sandia National Laboratory's Record Center in Albuquerque, New Mexico (e.g., calculations of actinide solubility for americium, plutonium, thorium and uranium). Documentation of peer review panel meetings conducted after receipt of the CCA has been placed in the EPA docket.

V. REFERENCES

A. References in Support of 40 CFR § 194.14(a)(1)-(4)

1. CCA Appendices

Appendix BH
Appendix DEF
Appendix DEL
Appendix FAC
Appendix FEP
Appendix GCR
Appendix HYDRO
Appendix MASS.13.3
Appendix MASS.14
Appendix MASS.15
Appendix MASS.18
Appendix PAR
Appendix PORSURF
Appendix SCR
Appendix SOTERM
Appendix SUM
Appendix TFIELD
Appendix USDW

2. References

Anderson, R.Y., 1978. Report to Sandia Laboratories on Deep Dissolution of Salt, Northern Delaware Basin, New Mexico [CCA Reference 12] (Docket A-93-02, Item II-G-1).

Anderson, R.Y., and Powers, D.W., 1978. "Salt Anticlines in the Castile-Salado Evaporite Sequence, Northern Delaware Basin, New Mexico." In Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas, G.S. Austin, ed., Circular 159. Pp. 79 - 83. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM [CCA Reference 18] (Docket A-93-02, Item II-G-1).

Bachman, G.O., 1973. Surficial Features and Late Cenozoic History in Southeastern New Mexico. Open-File Report 4339-8. U.S. Geological Survey [CCA Reference 20] (Docket A-93-02, Item II-G-1).

Bachman, G.O., 1974. Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico, Open-File Report 74-194, Denver, CO, U.S. Geological Survey [CCA Reference 21] (Docket A-93-02, Item II-G-1).

Bachman, G.O., 1976. Cenozoic Deposits of Southeastern New Mexico and an Outline of the

History of Evaporite Dissolution, Journal of Research, U.S. Geological Survey, Vol. 4, No. 2, pp. 135-149 [CCA Reference 22] (Docket A-93-02, Item II-G-1).

Bachman, G.O., 1980. Regional Geology and Cenozoic History of Pecos Region, Southeastern New Mexico, Open-File Report 80-1099, Denver, CO, U.S. Geological Survey [CCA Reference 23] (Docket A-93-02, Item II-G-1).

Bachman, G. O., 1985. Assessment of Near-Surface Dissolution at and Near the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico, SAND84-7178, Albuquerque, NM, Sandia National Laboratories [CCA Reference 26] (Docket A-93-02, Item II-G-1).

Barr, G.E., W.B. Miller, and D.D. Gonzalez, 1983. Interim Report on the Modeling of the Regional Hydraulics of the Rustler Formation, SAND83-0391, Albuquerque, NM: Sandia National Laboratories [CCA Reference 32] (Docket A-93-02, Item II-G-1).

Beauheim, R.L., 1986. Hydraulic-Test Interpretations for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site.SAND86-1364, Albuquerque, NM, Sandia National Laboratories [CCA Reference 40] (Docket A-93-02, Item II-G-1).

Beauheim, R.L., 1987. Interpretations of Single-Well Hydraulic Tests Conducted At and Near the Waste Isolation Pilot Plant (WIPP) Site, 1983-1987, SAND87-0039, Albuquerque, NM, Sandia National Laboratories [CCA Reference 43] (Docket A-93-02, Item II-G-1).

Borns, D.J., L.J. Barrows, D.W. Powers, and R.P. Snyder, 1983. Deformation of Evaporites Near the Waste Isolation Pilot Plant (WIPP) Site, SAND82-1069, Albuquerque, NM, Sandia National Laboratories [CCA Reference 79] (Docket A-93-02, Item II-G-1).

Borns, D.J., 1987. The Geologic Structures Observed in Drillhole DOE-2 and Their Possible Origins: Waste Isolation Pilot Plant. SAND86-1495. Albuquerque, NM: Sandia National Laboratories [CCA Reference 76] (Docket A-93-02, Item II-G-1).

Brookins, D.G. and S.J. Lambert, 1987. Radiometric dating of Ochoan (Permian) evaporites, WIPP site, Delaware Basin, New Mexico, USA, 84: Materials Research Society. Ed. 771-780 [CCA Reference 87] (Docket A-93-02, Item II-G-1).

Brookins, D.G., 1980. "Polyhalite K-Ar Radiometric Ages from Southeastern New Mexico." In Isochron/West, No. 29, 29 - 31 [CCA Reference 88] (Docket A-93-02, Item II-G-1).

Brookins, D.G., J.K. Register, and H. Krueger, 1980. Potassium-argon dating of polyhalite in southeast New Mexico, Geochimica et Cosmoshimica Acta 44, 635-637. Pergamon Press, Journals Div., Maxwell House, Fairview Park, Elmsford, NY 10523, (914)-592-7700 [CCA Reference 88] (Docket A-93-02, Item II-G-1).

Brookins, D.G., 1981. "Geochronologic Studies Near the WIPP site, Southeastern New Mexico." In Environmental Geology and Hydrology in New Mexico, S.G. Wells, and W.

Lambert, ed., Special Publication 10, pp. 147-152. New Mexico Geological Society [CCA Reference 689] (Docket A-93-02, Item II-G-1).

Calzia, J.P., and Hiss, W.L., 1978. "Igneous Rocks in Northern Delaware Basin, New Mexico, and Texas." In Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas, G.D. Austin, ed., Circular 159, pp. 39 - 45. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM [CCA Reference 18] (Docket A-93-02, Item II-G-1).

Chapman, J.B., 1986. Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area, EEG-35, DOE/AL/10752-35. Santa Fe, NM, Environmental Evaluation Group [CCA Reference 118] (Docket A-93-02, Item II-G-1).

Chugg, J.C., Anderson, G.W., Kink, D.L., and Jones, L.H., 1952. Soil Survey of Eddy Area, New Mexico. pp. 82, plus figures. U.S. Department of Agriculture [CCA Reference 132] (Docket A-93-02, Item II-G-1).

Corbet, T.F. and Knupp, P.M., 1996. The Role of Regional groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico., SAND96-2133, Sandia National Laboratories, Albuquerque, NM [CCA Reference 147] (Docket A-93-02, Item II-G-1).

Davies, P.B., 1989. Variable-Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico, U. S. Geological Survey Open-File Report 88-490, Albuquerque, NM, U. S. Geological Survey [CCA Reference 158] (Docket A-93-02, Item II-G-1).

Deal, D.E., and J.B. Case, 1987. Brine Sampling and Evaluation Program Phase I Report. DOE-WIPP-87-008. Carlsbad, NM: Sandia National Laboratories [CCA Reference 166] (Docket A-93-02, Item II-G-1).

Deal, D.E., and R.J. Abitz, D.S.Belski, J.B.Case, M.E. Crawley, R.M. Deshler, P.E. Drez,C.A. Givens, R.B. King, B.A. Lauctes, J. Myers, S. Niou, J.M. Peitz, W.M. Roggenthen, J.R. Tyburski, and M.G. Wallace, 1989. Brine Sampling and Evaluation Program, 1988 Report, DOE/WIPP 89-015, Section 4.1, 1989 [CCA Reference 167] (Docket A-93-02, Item II-G-1).

Deal, D.E., R.J. Abitz, D.S. Belski, J.B. Clark, M.E. Crawley and M.L. Martin, 1991a. Brine Sampling and Evaluation Program 1989 Report. DOE_WIPP_91-009. Carlsbad, NM: U.S. Department of Energy Waste Isolation Pilot Plant [CCA Reference 170] (Docket A-93-02, Item II-G-1).

Deal, D.E., R.J. Abitz, J. Myers, J.B. Case, D.S. Belski, M.L. Martin and W.M. Roggenthen, 1991b. Brine Sampling and Evaluation Program 1990 Report. DOE-WIPP 91-036. Carlsbad, NM: U.S. Department of Energy Waste Isolation Pilot Plant [CCA Reference 171] (Docket A-93-02, Item II-G-1).

Deal, D.E., R.J. Abitz, J. Myers, M.L. Martin, D.J. Milligan, R.W. Sobocinski, P.P.J. Lipponer, and D.S. Belski, 1993. Brine Sampling and Evaluation Program, 1991 Report, DOE/WIPP93-026, Carlsbad, NM, Westinghouse Electric Corporation [CCA Reference 172] (Docket A-93-02, Item II-G-1).

DOE, 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS-0026. Vol. 1-2. Washington D.C. WPO 38835, 38838 - 38839 [CCA Reference 178](Docket A-93-02, Item II-G-1).

DOE, 1997a. Response to Comments Made to EPA by CARD on DOE's CCA. July 3, 1997 (Docket A-93-02, Item II-H-46).

DOE, 1997b. Response to Comments Made to EPA by EEG on DOE's CCA Dated March 14, 1997. June 27, 1997 (Docket A-93-02, Item II-H-45).

DOE, 1997c. Response to Comments made to EPA by the NMAG on DOE's CCA Dated March 14, 1997. June 13, 1997 (Docket A-93-02, Item II-H-44).

DOE, 1997d. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. May 14, 1997 (Docket A-93-02, Item II-I-31).

DOE, 1997e. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. April 15, 1997 (Docket A-93-02, Item II-I-248).

DOE, 1997f. DOE Response to comments made by the CCA on Southwest Research and Information Center. March 12, 1997 (Docket A-93-02, Item II-H-22).

DOE, 1997g. Response to EPA's December 19, 1996 Request for Supplemental Information. February 26, 1997 (Docket A-93-02, Item II-I-10).

DOE, 1997i. Response to EPA's December 19, 1996 Request for Supplemental Information. February 14, 1997 (Docket A-93-02, Item II-I-08).

DOE, 1997j. Response to EPA's December 19, 1996 Request for Supplemental Information. February 7, 1997 (Docket A-93-02, Item II-I-07).

DOE, 1997k. Response to EPA's December 19, 1996 Request for Supplemental Information. January 24, 1997 (Docket A-93-02, Item II-I-03).

DOE, 1997l. Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison with Compliance Certification Application Calculations. July 25, 1997 (Docket A-93-02, Item II-G-26).

DOE, 1997m. Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with Compliance Certification Application Calculations. August 8, 1997. WPO# 46702 (Docket A-93-02, Item II-G-28).

Earth Technology Corporation, 1988. Final Report for Time Domain Electromagnetic (TDEM) Surveys of the WIPP Site, SAND87-7144, Albuquerque, NM, Sandia National Laboratories

[CCA Reference 229] (Docket A-93-02, Item II-G-1).

EPA, 1998b. Technical Support Document for Section 194.14: Assessment of K_ds used in the CCA. Prepared under EPA Contract No. 68-D5-0174. 1997 (Docket A-93-02, Item V-B-4).

EPA, 1998e. Technical Support Document for Section 194.32: Fluid Injection Analysis. Prepared under EPA Contract No. 68-D5-0174. 1997 (Docket A-93-02, Item V-B-22).

Foster, R.W., 1974. Oil and Gas Potential of a Proposed Site for the Disposal of High-Level Radioactive Waste, ORNL/SUB-4423/1, New Mexico Bureau of Mines and Mineral resources, Socorro, NM, New Mexico Institute of Mining and Technology. Open-File Report, Contract No. AF(40-1)-4423. Oak Ridge National Laboratory, Oak Ridge, TN [CCA Reference 253] (Docket A-93-02, Item II-G-1).

Hale, W.E., Hughes, L.S., and Cox, E.R., 1954. Possible Improvement of Quality of Water of the Pecos River by Diversion of Brine at Malaga Bend, Eddy County, NM. Pecos River Commission New Mexico and Texas, in cooperation with United States Department of the Interior, Geological Survey, Water Resources Division, Carlsbad, NM [CCA Reference 277] (Docket A-93-02, Item II-G-1).

Haug, A., V.A. Kelley, A.M. LaVenue, and J.F. Pickens, 1987. Modeling of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Interim Report, SAND86-7167, Albuquerque, NM, Sandia National Laboratories [CCA Reference 288] (Docket A-93-02, Item II-G-1).

Hiss, W.L., 1975. Stratigraphy and Ground-Water Hydrology of the Capitan Aquifer, Southeastern New Mexico and West Texas, Ph.D. dissertation, Boulder, CO, University of Colorado [CCA Reference 299] (Docket A-93-02, Item II-G-1).

Holt, R.M., and Powers, D.W., 1986. Geotechnical Activities in the Exhaust Shaft. DOE-WIPP-86-008. U.S. Department of Energy, Carlsbad, NM [CCA Reference 309] (Docket A-93-02, Item II-G-1).

Holt, R.M., and D. W. Powers, 1988. Facies Variability and Post-Depositional alteration withing the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant, Southereastern New Mexico. DOE/WIPP 88-004. U.S. Department of Energy, Carlsbad, NM [CCA Appendix GCR].

Holt, R.M., and D. W. Powers, 1990. Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant, DOE-WIPP 90-051, Carlsbad, NM, Westinghouse Electric Corporation. [CCA Reference 311] (Docket A-93-02, Item II-G-1).

Izett, G.A., and Wilcox, R.E., 1982. Map Showing Localities and Inferred Distribution of the Huckleberry Ridge, Mesa Falls, and Lava Creek Ash Beds in the Western United States and Southern Canada. Misc. Investigations Map I-1325, scale 1:4,000,000. U.S. Geological Survey [CCA Reference 332] (Docket A-93-02, Item II-G-1).

Jones, C.L., M.E.Cooley, and G.O., Bachman, 1973. Salt Deposits of the Los Medaños Area, Eddy and Lea Counties, New Mexico, USGS-4339-7, Denver, CO, U.S. Geological Survey. This document has been superseded by USGSOFR 73-135 [CCA Reference 342] (Docket A-93-02, Item II-G-1).

Jones, C.L., 1978. Test Drilling for Potash Resources: Waste Isolation Pilot Plant Site, Eddy County, New Mexico, U.S. Geological Survey Open-File Report 78-592, Denver, CO, U.S. Geological Survey. Vols 1 and 2 [CCA Reference 339] (Docket A-93-02, Item II-G-1).

Jones, T.L., Kelly, V.A., Pickens, J.F., Upton, D.T., Beauheim, R.L., and Davies, P.B., 1992. Integration of Interpretation Results of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site. SAND92-1579. Sandia National Laboratories, Albuquerque, NM [CCA Reference 343] (Docket A-93-02, Item II-G-1).

Kelley, V.A., and G.J. Saulnier, Jr., 1990. Core Analyses for Selected Samples from the Culebra Dolomite at the Waste isolation Pilot Plant, SAND90-7011, Albuquerque, NM, Sandia National Laboratories [CCA Reference 353] (Docket A-93-02, Item II-G-1).

LaVenue, A.M., A. Haug, and V.A. Kelley, 1988. Numerical Simulation of Groundwater Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site; Second Interim Report, SAND88-7002, Albuquerque, NM, Sandia National Laboratories [CCA Reference 393] (Docket A-93-02, Item II-G-1).

LaVenue, A.M., Caufmann, T.L., and Pickens, J.F., 1990. Ground-Water Flow Modeling of the Culebra Dolomite: Volume 1-Model Calibration. SAND89-7068/1, Sandia National Laboratories, Albuquerque, NM [CCA Reference 393] (Docket A-93-02, Item II-G-1).

Lambert, S.J. and J.A.Carter, 1987. Uranium-Isotope Systematics in Groundwaters of the Rustler Formation, Northern Delaware Basin, Southeastern New Mexico. I: Principles and Preliminary Results, SAND87-0388, Albuquerque, NM, Sandia National Laboratories [CCA Reference 380] (Docket A-93-02, Item II-G-1).

Lambert, S.J. and J.A. Carter, 1984. Uranium-Isotope Disequilibrium in Brine Reservoirs of the castile formation, Northern Delaware Basin, Southeastern New Mexico. I:Principles and Methods, SAND83-0144, Albuquerque, NM, Sandia National Laboratories [CCA Reference 379] (Docket A-93-02, Item II-G-1).

Lambert, S.J., 1987. Feasibility Study: Applicability of Geochronologic Methods Involving Radiocarbon and other Nuclides to the Groundwater Hydrology of the Rustler Formation, Southeastern New Mexico. SAND86-1054. Sandia National Laboratories, Albuquerque, NM [CCA Reference 377] (Docket A-93-02, Item II-G-1).

Lambert, S.J. and D.M. Harvey, 1987. Stable-Isotope Geochemistry of Groundwaters In the Delaware Basin of Southeastern New Mexico, SAND87-0138, Albuquerque, NM, Sandia National Laboratories [CCA Reference 378] (Docket A-93-02, Item II-G-1).

Lowenstein, T.K., 1988. Origin of depositional cycles in a Permian saline giant: the Salado

(McNutt Zone) evaporites of New Mexico and Texas. Geological Society of America Bulletin, Vol. 100, #4, April 1988, pp. 592–608 [CCA Reference 409] (Docket A-93-02, Item II-G-1).

Lucas, S.G., and Anderson, O.J., 1993a. "Triassic Stratigraphy in Southereastern New Mexico and West Texas." In Carlsbad Region, New Mexico and West Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993. D.W. Love, et al., eds., pp. 231–235. New Mexico Geological Society, Socorro, NM [CCA Reference 408] (Docket A-93-02, Item II-G-1).

Muehlberger, W.R., Belcher, R.C., and Goetz, L.K., 1978, Quarternary Faulting on Trans-Pecos, Texas. Geology, Vol. 6, pp. 338 [CCA Reference 446] (Docket A-93-02, Item II-G-1).

New Mexico Bureau of Mines and Mineral Resources (NMBMMR), 1995. FINAL REPORT Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site, Vol. 1-4, March 31, 1995 [CCA Reference 460] (Docket A-93-02, Item II-G-1).

Palmer, A.R., 1983. The Decade of North American Geology 1983 Geologic Time Scale. Geology, Vol. 11, pp. 503–504 [CCA Reference 409] (Docket A-93-02, Item II-G-1).

Peake, Tom, January 31, 1996. WIPP--Examination of Mining and Hydraulic, Technical Memorandum to EPA Docket A-92-56.

Popielak, R.S., R.L. Beauheim, S.R. Black, W.E. Coons, C.T. Ellingson, and R.L. Olsen, 1983. Brine Reservoirs in the Castile Formation, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3153, Albuquerque, NM, U.S. DOE [CCA Reference 511] (Docket A-93-02, Item II-G-1).

Powers, D.W., and Holt, R.M., 1993. "The Upper Cenozoic Gatuna Formation of Southeastern New Mexico." In Carlsbad Region, New Mexico and West Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993. D.W. Love, et al., eds., pp. 271–282. New Mexico Geological Society, Roswell, NM [CCA Reference 408] (Docket A-93-02, Item II-G-1).

Powers, D.W., and Holt, R.M., 1995. Regional Geological Processes Affecting Rustler Hydrogeology, Westinghouse Electric Corp, Carlsbad, NM [CCA Reference 514] (Docket A-93-02, Item II-G-1).

Powers, D.W., J.M. Sigda, and R.M. Holt, 1996. "Probability of Intercepting a Pressurized Brine Reservoir Under the WIPP." Unpublished report, July 10, 1996. Albuquerque, NM: Sandia National Laboratories. (Copy on file in the SWCF) [CCA Reference 516] (Docket A-93-02, Item II-G-1).

Rosholt, J.N., and McKinney, C.R., 1980. Uranium Series Disequilibrium Investigations Related to the WIPP Site, New Mexico, Part II Uranium Trend Dating of Surficial Deposits and Gypsum Spring Deposit Near WIPP Site, New Mexico. Open-File Report 80-879. U.S. Geological Survey, Denver, CO [CCA Reference 555] (Docket A-93-02, Item II-G-1).

Sandia National Laboratories, 1992. Preliminary Performance Assessment for the Waste Isolation Pilot Plant. SAND 92-0700/1-5, Albuquerque, NM. December 1992 [CCA Reference 563](Docket A-93-02, Item II-G-1).

Sandia National Laboratories, 1997. Chemical Conditions Model: Results of the MgO Backfill Efficacy Investigation. Prepared for the U.S. DOE Carlsbad Area Office by Sandia National Laboratories. April 23, 1997 (Docket A-93-02, Item II-A-39).

Saulnier, G.J., Jr., and J.D. Avis, 1988. Interpretation of Hydraulic Tests Conducted in the Waste-Handling Shaft at the Waste Isolation Pilot Plant (WIPP) Site, SAND88-7001,, Albuquerque, NM, Sandia National Laboratories [CCA Reference 574] (Docket A-93-02, Item II-G-1).

Schiel, K.A., 1988. The Dewey Lake Formation: End Stage Deposit of a Peripheral Foreland Basin [M.S. thesis]. University of Texas at El Paso, El Paso, TX [CCA Reference 578] (Docket A-93-02, Item II-G-1).

Siegel, M.D.,Lambert, S.J. and Robinson, K.L. eds., 1991. Hydrochemical Studies of the Rustler Formation and Related Rocks in the WIPP Area, Southeastern New Mexico, SAND88-7096, Albuquerque, NM, Sandia National Laboratories. WPO 25624 [CCA Reference 590] (Docket A-93-02, Item II-G-1).

Sipes, Williamson and Aycock, Inc., J.J., 1976. Hydrocarbon Evaluation, Proposed Southeastern New Mexico Radioactive Material Storage Site, Eddy County, New Mexico, SAND77-7033. Vols. I and II. Sipes, Williamson, and Aycock, Inc., Midland, TX. [CCA Reference 593] (Docket A-93-02, Item II-G-1).

Slemmons, D. Burton, E.R. Engdahl, Mark D. Zoback, and David D. Blackwell, Eds., 1991. Neotectonics of North America. Geological Society of America. 1991 [CCA Reference 595] (Docket A-93-02, Item II-G-1).

Stein, C.L., 1985. Mineralogy in the Waste Isolation Pilot Plant (WIPP) Facility Stratigraphic Horizon. SAND85-0321. SNL [CCA Reference 604] (Docket A-93-02, Item II-G-1).

B. References in Support of 40 CFR § 194.14(b)(1)-(2)

DOE, 1995. Summary of Brine Investigation at the Waste Isolation Pilot Plant, Southeastern New Mexico. DOE/WIPP 96-2161. 1995. (Document available at the Sandia National Laboratories Nuclear Waste Management Library, Albuquerque, N.M.

DOE, 1995. Waste Isolation Pilot Plant Safety Analysis Report. DOE/WIPP/95- 2065, Revision 0, November 1995. [CCA Reference 202] (Docket A-93-02, Item II-G-1).

EPA, 1998d. Technical Support Document for 40 CFR Section 194.23: Sensitivity Analysis Report. Prepared under EPA Contract 68-D5-0174 (Docket A-93-02, Item V-B-13).

Holt and Powers, 1990. Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot

Plant. DOE/WIPP 90-051. 1990. [CCA Reference 311] (Docket A-93-02, Item II-G-1)

Wakeley, L.D., Poole, T.S., and Burkes, J.P., 1994, Durability of Concrete Materials in High-Magnesium Brine, SAND93-7073, Sandia National Laboratories, Albuquerque, New Mexico [CCA Reference 663] (Docket A-93-02, Item II-G-1).

C. References in Support of 40 CFR § 194.14(c)

DOE, 1997a. Response to Comments Made to EPA by CARD on DOE's CCA. July 3, 1997 (Docket A-93-02, Item II-H-46).

DOE, 1997b. Response to Comments Made to EPA by EEG on DOE's CCA Dated March 14, 1997. June 27, 1997 (Docket A-93-02, Item II-H-45).

DOE, 1997c. Response to Comments made to EPA by the NMAG on DOE's CCA Dated March 14, 1997. June 13, 1997 (Docket A-93-02, Item II-H-44).

DOE, 1997d. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. May 14, 1997 (Docket A-93-02, Item II-I-31).

DOE, 1997e. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. April 15, 1997 (Docket A-93-02, Item II-I-24).

DOE, 1997f. DOE Response to comments made by the CCA on Southwest Research and Information Center. March 12, 1997 (Docket A-93-02, Item II-H-22).

DOE, 1997g. Response to EPA's December 19, 1996 Request for Supplemental Information. February 26, 1997 (Docket A-93-02, Item II-I-10).

DOE, 1997h. Response to EPA's December 19, 1996 Request for Supplemental Information. February 21, 1997.

DOE, 1997i. Response to EPA's December 19, 1996 Request for Supplemental Information. February 14, 1997 (Docket A-93-02, Item II-I-08).

DOE, 1997j. Response to EPA's December 19, 1996 Request for Supplemental Information. February 7, 1997 (Docket A-93-02, Item II-I-07).

DOE, 1997k. Response to EPA's December 19, 1996 Request for Supplemental Information. January 24, 1997 (Docket A-93-02, Item II-I-03).

DOE, 1997l. Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison with Compliance Certification Application Calculations. July 25, 1997. (Docket A-93-02, II-G-26).

DOE, 1997m. Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with Compliance Certification Application Calculations. August

8, 1997 (Docket A-93-02, II-G-28).

D. References in Support of 40 CFR § 194.14(d)

DOE, 1997d. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. May 14, 1997 (Docket A-93-02, Item II-I-31).

DOE, 1997e. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. April 15, 1997 (Docket A-93-02, Item II-I-24).

DOE, 1997g. Response to EPA's December 19, 1996 Request for Supplemental Information. February 26, 1997 (Docket A-93-02, Item II-I-10).

EPA, 1998c. Technical Support Document for Section 194.23: Parameter Justification Report. Prepared under EPA Contract No. 68-D5-0174. 1997 (Docket A-93-02, Item V-B-14).

E. References in Support of 40 CFR § 194.14(e)

None

F. References in Support of 40 CFR § 194.14(f)

DOE, 1995. Transuranic Waste Characterization Quality Assurance Program Plan, Rev. 0. DOE/CAO-94-1010. April 30, 1995. [CCA Reference 201] (Docket A-93-02, Item II-G-1).

DOE, 1996. Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 5. DOE/WIPP-96-069. April, 1996. [CCA Reference 208] (Docket A-93-02, Item II-G-1).

G. References in Support of 40 CFR § 194.14(g)

1. CCA Appendices

Appendix EMP
Appendix RBP
Appendix SER

H. References in Support of 40 CFR § 194.14(h)

1. CCA Appendices

Appendix DEL

I. References in Support of 40 CFR § 194.14(i)

1. CCA Appendices

Appendix CLI
Appendix SER

2. References

Swift, P.N., 1992. Long-Term climate Variability at the Waste Isolation Pilot Plant, Southeastern New Mexico, USA. SAND91-7055. Sandia National Laboratories, Albuquerque, NM.

DOE, 1992. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1991. DOE/WIPP 92-007. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM [CCA Reference 191] (Docket A-93-02, Item II-G-1).

DOE, 1993. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1992. DOE/WIPP 93-017. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM [CCA Reference 192] (Docket A-93-02, Item II-G-1).

Westinghouse Electric Corporation, 1991. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1990. DOE/WIPP 91-008. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM [CCA Reference 690] (Docket A-93-02, Item II-G-1).

Westinghouse Electric Corporation, 1994. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1993. DOE/WIPP 94-2033. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM [CCA Reference 691] (Docket A-93-02, Item II-G-1).

Westinghouse Electric Corporation, 1995. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1994. DOE/WIPP 95-2094. June 1995, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM [CCA Reference 692] (Docket A-93-02, Item II-G-1).

J. References in Support of 40 CFR § 194.14(j)

DOE, 1997a. Response to Comments Made to EPA by CARD on DOE's CCA. July 3, 1997 (Docket A-93-02, Item II-H-46).

DOE, 1997b. Response to Comments Made to EPA by EEG on DOE's CCA Dated March 14, 1997. June 27, 1997 (Docket A-93-02, Item II-H-45).

DOE, 1997c. Response to Comments made to EPA by the NMAG on DOE's CCA Dated March 14, 1997. June 13, 1997 (Docket A-93-02, Item II-H-44).

DOE, 1997d. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA. May 14, 1997 (Docket A-93-02, Item II-I-31).

DOE, 1997e. Responses to EPA's Request in EPA's March 19, 1997 Letter on the WIPP CCA.

April 15, 1997 (Docket A-93-02, Item II-I-24).

DOE, 1997f. DOE Response to comments made by the CCA on Southwest Research and Information Center. March 12, 1997 (Docket A-93-02, Item II-H-22).

DOE, 1997g. Response to EPA's December 19, 1996 Request for Supplemental Information. February 26, 1997 (Docket A-93-02, Item II-I-10).

DOE, 1997h. Response to EPA's December 19, 1996 Request for Supplemental Information. February 21, 1997.

DOE, 1997i. Response to EPA's December 19, 1996 Request for Supplemental Information. February 14, 1997 (Docket A-93-02, Item II-I-08).

DOE, 1997j. Response to EPA's December 19, 1996 Request for Supplemental Information. February 7, 1997 (Docket A-93-02, Item II-I-07).

DOE, 1997k. Response to EPA's December 19, 1996 Request for Supplemental Information. January 24, 1997 (Docket A-93-02, Item II-I-03).

DOE, 1997l. Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison with Compliance Certification Application Calculations. July 25, 1997 (Docket A-93-02, II-G-26).

DOE, 1997m. Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with Compliance Certification Application Calculations. August 8, 1997 (Docket A-93-02, II-G-28).

VI. FIGURES

ATTACHMENT 1

TRIP REPORT
WIPP AIR INTAKE SHAFT INSPECTION

WASTE ISOLATION PILOT PLANT
CARLSBAD, NM
JANUARY 28, 1997

Introduction

At the request of EPA ORIA, A.T. Kearney performed a visual inspection of the WIPP air intake shaft in order to characterize any brine inflow evidence and other visible conditions in the Salado Formation above the WIPP repository. The inspection also included review of the original detailed mapping of the Salado stratigraphy in the WIPP shafts and a visual inspection of the geological rock cores of the stratigraphy of the entire shaft.

The purpose of the inspection was to verify statements in the preliminary and final Shaft Sealing System Design Reports concerning the lack of observable brine inflow (i.e., visible moisture) in the lower Salado, where the compacted salt seal components are to be placed. Original shaft mapping reports were to be reviewed to determine if there is stratigraphic correlation between the four shafts at the WIPP (air intake shaft, exhaust shaft, salt handling shaft and waste shaft), as the shaft seal design performance is based on the air intake shaft (AIS) and the seal system will be applied to all four shafts. Representative from EPA, A.T. Kearney, DOE-CAO and WIPP employees attended. The agenda is attached to this trip report.

Trip Summary

The morning session (9:00 to 11:30) consisted of a safety briefing and an overview of the air intake shaft geology. Mr. Craig Snider, CAO Compliance Engineer, met Greg Starkebaum and Paige Walter of A.T. Kearney and Jim Oliver of EPA at the Holiday Inn in Carlsbad, and drove us to the WIPP site. After a safety briefing conducted by security, we were taken to the core storage library. We were met by Ray Carrasco, Waste Isolation Division (WID) Geotechnical Principal Engineer, Dennis Powers, Geological Consultant to WID, and Liane Terrell, Geological Consultant to WID. Mr. Powers was the principal geologist responsible for the original stratigraphic mapping of the air intake shaft in 1988, and has published several reports on this subject. Dennis Powers walked us through geological cores of the WIPP stratigraphy, including cores of the Salado, Rustler, Culebra, Magenta, Tamarisk, and the Dewey Lake. Mr. Powers pointed out sedimentary textures, and other structures and lilthofacies noted in the cores. He also discussed the continuity of the stratigraphy throughout the entire WIPP region. The overall stratigraphy is fairly consistent in the WIPP area.

After lunch, Mr. Powers, Mr. Starkebaum, Ms. Walter, Mr. Oliver, and Mr. Carrasco reconvened in the core library for discussions regarding the logistics of the Air Intake Shaft tour. We walked to the lunchroom, where Mr. Powers, Mr. Starkebaum, Ms. Walter, and Mr. Oliver were equipped with the necessary safety equipment and underground access passes. After a one-half hour delay, to remove ice within the air shaft at the cracked liner section near the surface, Mr.

Teddy Garcia, Shaft Operations Supervisor, led us down the shaft at inspection speed. From the bottom of the shaft at the repository level, we ascended, stopping at various marker beds to observe seepage evidence. Most of the time was spent observing the shaft interval between marker bed 117 and 135. Several photographs were taken at various levels, of precipitate from brine evaporation and salt encrustations. Although a 100-watt video lamp and 1000 asa film were used, the photographs did not turn out well and have not been included in this report.

After returning to the surface, we returned all safety equipment and underground passes to the lamproom. A Ground Control Monitoring system review was conducted by Mr. Dennis Matthew. The review consisted of observing the computer monitoring of various areas within the WIPP repository. We observed stress and motion monitoring data from instruments installed on rock bolts.

At approximately 2:30 pm, Mr. Starkebaum, Ms. Walter, Mr. Oliver, Mr. Powers, Mr. Carrasco, and Mr. Stan Patchet, Manager of Geomechanical Engineering, and Mr. Snyder met at the Guard and Security Building for a close-out meeting. The following documents were requested:

- Geologic Mapping of the Air Intake shaft at the Waste Isolation Pilot Plant, December 1990, DOE/WIPP 90-051, Holt and Powers, 1990 [CCA Reference 311] (Docket No. A-93-02, Item II-G-1);

- Sedimentary Texture, Structures and Lithofacies in the Salado Formation: A Guide for Recognition, Classification, and Interpretation, September 1993, DOE/WIPP 93-056;

- Summary of Brine Investigation at the Waste Isolation Pilot Plant, Southeastern New Mexico, December 1995, DOE/WIPP 96-2161; and

- Geologic Mapping of the Exhaust Shaft, Salt Handling Shaft and Waste Shaft at the Waste Isolation Pilot Plant.

The first three documents were provided to A.T. Kearney on a temporary loan. The geologic mapping reports for the other shafts (exhaust handling, salt and water shaft) were not received by A.T. Kearney.

<u>Conclusions</u>

The shaft sealing system performance plays a critical role in meeting regulatory radionuclide and hazardous constituents containment requirements. The shaft sealing system performance is in part dependant upon the lack of brine seepage which could saturate compacted salt seal materials. Based upon previous studies of the air intake shaft, it has been found that brine weeps and seeps have occurred in the lower part of the Salado, specifically where the salt components of the sealing system will be located. The purpose of this investigation was to examine the air intake shaft to see if brine weeps and seeps are currently “active” or, if there is evidence of extensive recent seepage of brine, in the form of evaporite or salt encrustations.

The primary regions of brine weeps and seeps in the past have been noted in the zones of the marker beds, from Marker Bed (MB) 103 through Zone J, of the lower Salado Formation. In the original mapping of the air intake shaft, active weeps and seeps have been noted, specifically at MB 103, MB 124, Vaca Triste silstone, and the Union Anhydrite. Only MB 103 was noted as an active seepage zone in the last DOE shaft inspection in July, 1994. These zones were inspected (south wall only) during this site visit.

Based upon the inspection of the air intake shaft, several zones were noted as exhibiting characteristics of past brine seepage. Several areas were observed with salt encrustations, or brine evaporite. the areas of salt encrustations were almost exclusively related to the Marker Beds, with the exception of areas surrounding rock bolts. Apparently dry salt encrustations due to previous seepage were noted from a depth of 2040 feet (MB 105) to a depth of 960 feet (MB 101).

The air shaft inspection did not result in observations of any current brine seepage, as no areas appeared to be wet and no brine was observed. However, due to lighting conditions, and occasionally heavy build-up of salt encrustations, it was impossible to determine how much brine had wept and over what period of time. Mr. Powers indicated that the shaft wall does not appear to have accumulated much additional salt encrustation since July, 1994. If an accurate determination of how much brine weeps over a given period of time is needed, or to actually determine if brine is presently weeping, then further investigations are warranted.

The final objective of the inspection and review of literature was to determine if there was stratigraphic correlation between the four shafts of the WIPP: the AIS, the exhaust shaft, the salt handling shaft and the waste shaft. The shaft sealing system and performance evaluation is based upon the AIS. Consistency between the four shafts is crucial, as the sealing system as designed for the AIS will be applied to all four shafts. The shaft seal design report assumes that the shafts do not significantly differ stratigraphically and that the performance as demonstrated in the AIS will be mimicked in the other shafts. Since geologic mapping reports for all four shafts were not available for this report, conclusions are based upon generalized stratigraphic summaries provided in the shaft sealing system design report (DOE/WIPP 95-3117), which is included in the Compliance Certification Application (CCA) as Appendix SEAL. Although several marker beds are not present in all four shafts (MB 100, MB 119, MB 120, MB 125, MB 133, MB 137, Anhydrite b and MB 139) there is general stratigraphic consistency between the four shafts. The sealing system performance should be similar in all four shafts.

Transcripts of the Logbook of Greg Starkebaum
January 28, 1997

WIPP Air Intake Shaft Inspection

January 28, 1997

<u>9:00 am -9:40 am</u>

Drove to site-by Craig Snyder
- Jim Oliver
- Paige Walter
- Greg Starkebaum

Check in at Safety office, 15 minute safety video. Meetings with Ray Carrasco and Dennis Powers - introductions/explanation of agenda

<u>10:15 am</u>

Walk to core library - next to AIS, met Liane Terrell, geologist

Cores - transition zones
Salado/Rustler/Culebra/Magenta/TAM/DL

Powers - explained deposition/dissolution/evidence

<u>Approximately 1:00 pm</u>

Teddy Garcia, Shafts Operation Supervisor, Powers, Oliver, Walter & Starkebaum

After 1/2 hour delay to allow removal office at cracked liner section (near surface) - started descent at "inspection speed". After slow descent to repository level, started up, stopping at various marker beds to observe seepage evidence (salt encrustations on wall). Spent most of the time in the interval between MB 117 and 135.

<u>2:30 pm</u>

Show 'n Tell - Ground Control
Dennis Matthew

3:00 pm

Closeout Meeting -

Powers, Stan Patchet, Manager of Geomechanical Engineering, and Snyder Requested DOE/WIPP 95-057-Geo Mapping of the Air Intake Shaft of the WIPP and similar documents for exhaust and WH shafts

Sedimentary Textures, Structures and Lithofacies in the Salado DOE/WIPP 93-056; Geochemical of Salado Brines; BSED '94 Inspection Report 94-0100

Patchet - says due to the lack of things to do-- BSEP closed down approximately 1 year ago.

94-001 0 one of the last reports.

Left site about 3:30. Snyder took us to DOE/CAO for Oliver to meet Mewhinney, dropped Starkebaum and Walter at their car, returned to DOE.

Original logbook signed by Greg Starkebaum 1/28/97.