CARD No. 25
Future State Assumptions

25.A.1 BACKGROUND

EPA's purpose in issuing the Compliance Criteria at 40 CFR 194.25 was to minimize the impact of inherently conjectural specifications of future states on the compliance application. The Agency has found no acceptable methodology that could make predictions of the future state of society, science, languages, or other characteristics of mankind. However, EPA does believe that established scientific methods can make plausible predictions regarding the future state of geologic, hydrogeologic, and climactic conditions. Therefore, Section 194.25 stipulates that the future state will resemble present conditions except for those relating to hydrogeologic, geologic and climatic conditions. For example, the population density and land ownership patterns in the WIPP's surrounding regions are assumed to remain consistent with today's conditions for the next 10,000 years. Section 194.25 also requires that performance assessments and compliance assessments include dynamic analyses of changes in the geology, hydrology, and climatic conditions during the regulatory time frame.

Changes in the hydraulic properties of rocks (such as members of the Rustler and Dewey Lake Formations) due to the natural events and processes are summarized in Section 25.B of this CARD. Geologic future states are derived from the development of features, events, and processes (FEPs). Section 25.C of this CARD provides a general review of these FEPs. Future climatic trends (precipitation and glaciation) and their likely effects are briefly discussed in Section 25.D of this CARD. Characteristics of these FEPs and criteria for screening are discussed in **CARD 32—Scope of Performance Assessments** and EPA Technical Support Document for Section 32: Scope of Performance Assessments (Docket A-93-02, Item V-B-21). The effects on the disposal system and dynamics of these processes are analyzed in **CARD 23—Models and Computer Codes**.

25.A.2 REQUIREMENT

(a) "Unless otherwise specified in this part or in the disposal regulations, performance assessments and compliance assessments conducted pursuant to the provisions of this part to demonstrate compliance with § 191.13, § 191.15 and part 191, subpart C shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions."

25.A.3 ABSTRACT

40 CFR 194.25(a) requires DOE to describe the future state assumptions based on present conditions, provided that such assumptions are not related to hydrogeologic, geologic, or climatic conditions. Future state assumptions that are relevant to Section 194.25(a) and may affect the containment of waste were identified by DOE in Chapter 6.2 and Appendices SCR and MASS of the Compliance Certification Application (CCA). Many future state assumptions are derived from

the development of FEPs potentially relevant to the performance of the waste disposal system, and are found in Appendix SCR.

EPA first determined whether all FEPs and appropriate future state assumptions were identified and developed by DOE. EPA then evaluated DOE's criteria to eliminate (screen out) inapplicable or irrelevant FEPs and associated assumptions. EPA also analyzed whether there were potential variations in DOE's assumed characteristics and determined whether the future state assumptions were in compliance with Section 194.25(a).

25.A.4 Compliance Review Criteria

As stated in EPA's Compliance Application Guidance For The Waste Isolation Pilot Plant CAG, p. 36), EPA expected the compliance application to include the following information: (1) identification and explanation of future state assumptions in reference to performance and compliance assessments; (2) a list of where future state assumptions have been applied; (3) documentation of scenarios in which exempted characteristics may interact and influence assumptions; and (4) indication of potential variations in the assumed characteristics at the time of initiation.

25.A.5 DOE Methodology and conclusions

The CCA does not contain a separate section for the discussion of future state assumptions. Instead, EPA found relevant information in Chapters 2 and 6, Appendix SCR, Appendix TFIELD, Appendix DEF, and Appendix MASS. EPA found the most efficient way to review future state assumptions was to examine the FEPs tables located in Chapters 2 and 6 and related appendices. DOE described the future state assumptions in Appendix SCR of the CCA as part of the FEPs screening and development process. DOE also provided information about future state assumptions in the FEPs lists presented in Tables 6-3, 6-4, and 6-5 in Chapter 6 of the CCA.

Chapter 6 describes DOE's overall approach to demonstrating compliance with Section 194.25(a). Chapter 6.2 identifies the assumptions associated with the FEPs that DOE considered in the CCA, as well as the criteria DOE used to eliminate certain FEPs. DOE used three criteria to screen FEPs either into or out of performance assessment. These criteria were regulatory exclusion, low probability exclusion, and low consequence exclusion. The primary criterion that DOE used to screen FEPs in accordance with Section 194.25(a) was regulatory exclusion. The primary criteria that DOE used to screen FEPs in accordance with Section 194.25(b) were low probability exclusion and low consequence exclusion. Exclusions due to low probability or low consequence were also applied during the screening of FEPs under Section 194.25(a). Screened-in FEPs and their associated future state assumptions were subsequently categorized as undisturbed or disturbed FEPs. These FEPs were described in Chapters 6.3.1 and 6.3.2 and listed in Tables 6-6 and 6-7. Appendix SCR provides the details of the future state assumptions related to the FEPs.

The human-initiated events and processes (EPs) that were not excluded on the basis of low probability or low consequence assume that near-future and future human activities are

typical of current activities. In both disturbed and undisturbed categories, human-initiated EPs and their associated future state assumptions are explicitly limited to current mining and drilling practices. For example, potash mining is assumed to continue within or in the vicinity of the WIPP controlled area. DOE described the mining-induced subsidence effects on groundwater flow in Chapter 6.4.6.2.3, 6.4.12.8, and 6.4.13.8. In Chapter 6.4.6.2, 6.4.7, 6.4.12.2, 6.4.12.7, and 6.4.13, DOE discussed the potential geochemical effects and fluid or waste constituent transport due to drill holes. Additional assumptions, approximations, and simplifications that were used in the WIPP performance assessment models were identified by DOE in Appendix MASS.

25.A.6 EPA Compliance Review

In determining DOE's compliance with Section 194.25(a), EPA examined the FEPs and related future state assumptions, as listed in Appendix SCR and Tables 6-3, 6-4, and 6-5 of Chapter 6, and the general modeling assumptions listed in Table MASS-1, in order to determine their accuracy. EPA determined that these Tables contain all of the future state scenarios and related assumptions that were formally documented in the CCA, regardless of whether they were rejected or retained for incorporation in performance and compliance assessment modeling.

EPA reviewed FEPs and any associated assumptions that were screened out (i.e., not considered in performance assessment) on a regulatory basis to determine if the requirements of Section 194.25(a) were properly applied. DOE cited regulatory language in 40 CFR Part 191 and Part 194 as a justification for exclusion. EPA also examined the FEPs and related assumptions that DOE retained for consideration in the performance assessment. For the retained undisturbed and disturbed FEPs, EPA confirmed in Tables 6-6 and 6-7 of the CCA that the future state assumptions used in performance and compliance assessments were adequately explained and cross-referenced.

In addition, EPA reviewed the development process of the initial list of FEPs and related future state assumptions in Appendix SCR, Attachment 1. EPA found that the preliminary list of potentially relevant future scenarios was much larger than the final list included in Appendix SCR. In the process of developing the final list of FEPs, DOE excluded inapplicable or irrelevant scenarios as well as duplicate descriptions of the FEPs and related assumptions from the preliminary list. EPA did not discover any incorrect assumptions in the final list (Chapter 6, Tables 6-6 and 6-7).

EPA found no potentially significant omissions in the lists of FEPs, and no major inadequacies in the CCA's descriptions of FEPs and related future state assumptions. EPA concluded that DOE adequately described all the future state assumptions that are applicable under 194.25(a).

Further details and supporting documentation of EPA's review of DOE's future state assumptions and FEPs that are applicable to this requirement are provided in **CARD 23—Models and Codes**. EPA's evaluation of FEPs screening and how the retained FEPs were incorporated into the performance assessment is discussed in **CARD 32—Scope of Performance Assessments**.

25.B.1 REQUIREMENT

(b) "In considering future states pursuant to this section, the Department shall document in any compliance application, to the extent practicable, effects of potential future hydrogeologic, geologic and climatic conditions on the disposal system over the regulatory time frame. Such documentation shall be part of the activities undertaken pursuant to § 194.14, Content of compliance certification application; § 194.32, Scope of performance assessments; and § 194.54, Scope of compliance assessments.

(1) In considering the effects of hydrogeologic conditions on the dispos al system, the Department shall document in any compliance application, to the extent practicable, the effects of potential changes to hydrogeologic conditions."

25.B.2 ABSTRACT

40 CFR 194.25(b)(1) requires DOE to consider the effects of potential changes to hydrogeologic conditions on the disposal system. DOE identified and described the FEPs and related future state assumptions retained for further evaluation and inclusion in performance assessment calculations in Chapter 6.3 of the CCA. DOE described the effects of potential changes to hydrogeologic conditions on the disposal system in Chapter 6.4.6 and 6.4.9 and Appendices SCR, TFIELD, and MASS.

EPA reviewed DOE's discussions of the effects of potential future changes of hydrogeologic conditions on the disposal system and evaluated the descriptions of characteristics of potential changes, such as increased precipitation, hydraulic gradient, and recharge locations in the Culebra Member and Dewey Lake Formation. EPA also reviewed DOE's descriptions of the uncertainty associated with the characteristics of these potential changes.

25.B.3 COMPLIANCE REVIEW CRITERIA

As stated in the CAG (p. 37), EPA expected the compliance application to include the following information: (1) the potential impact of increased precipitation on recharge location and capacity, hydraulic gradient and characteristics in the Culebra member of the Rustler Formation and the Dewey Lake Formation; (2) the likely uncertainties associated with analyses conducted in accordance with Section 194.25(b)(1); and (3) other potential changes related to hydrogeologic conditions. EPA also expected that the effects of hydrogeologic conditions would be included in the performance and compliance assessments.

25.B.4 DOE METHODOLOGY AND CONCLUSIONS

DOE described potential future hydrogeologic conditions at the WIPP in Chapter 6.2, 6.4.6, and 6.4.9 and Appendices SCR and TFIELD. In Chapter 6.2, DOE described the natural FEPs screening process and listed the subsurface hydrogeologic, geologic, and climatic FEPs and their associated future state assumptions that were retained or rejected in Table 6-3. In Tables 6-

6 and 6-7, DOE listed all the disturbed and undisturbed FEPs and related assumptions retained for future analyses or modeling in compliance and performance assessment calculations.

DOE developed several hydrogeological condition assumptions in the process of modeling the WIPP waste disposal system. DOE discussed its assumptions of potential future subsidence created by potash mining and fracture mechanisms in the Culebra Formation in Chapter 6.4.6.2.3. DOE assumed that subsidence may alter the recharge rates in the WIPP area over time. DOE explained the future state assumptions for the shaft and shaft seals, as well as for the disturbed rock zone (DRZ) in the Salado, in Chapter 6.4.4 and Appendix MASS. In Table MASS-1, DOE developed a comprehensive list of modeling assumptions that were used in performance assessment. DOE also discussed its numerous future hydrogeological condition assumptions related to halite impurity (Chapter 6.4.5.1), Salado interbeds (Chapter 6.4.5.2), and the DRZ (Chapter 6.4.5.3). For the halite-rich Salado rock units and the units above the Salado, DOE described the high threshold pressure and related assumptions in Chapter 6.4.6 and Appendix MASS 13.4 and 14. DOE analyzed the possibility of actinide transport in the Salado in Chapter 6.4.5.4 and Appendix MASS. In Chapter 6.4.6, DOE discussed future state assumptions related to the units above the Salado, the unnamed lower member, and the Culebra. DOE described assumptions related to the Castile brine reservoir in Chapter 6.4.8.

DOE discussed potential impact to hydrogeologic future assumptions related to human intrusion scenarios, including cuttings, cavings, and spallings, in Chapter 6.0.2.3.1 and 6.0.2.3.2. In Chapter 6.2.5.1, DOE further discussed future human activities that could potentially have an impact on the waste disposal system. For modeling purposes, DOE assumed a future drilling rate of 46.8 boreholes per square kilometers per 10,000 years. As part of the intrusion scenario, DOE modeled the effects of long-term flow of brine into a borehole. In Chapter 6.4.7, DOE presented additional assumptions related to intrusion boreholes such as long-term releases that occur both during and after drilling.

DOE also considered the potential impact or influence that possible changing hydrogeologic assumptions can have on performance assessment over time (Chapter 6). DOE found that in most instances the hydrogeological assumptions do not change with time, though in a few exceptions future hydrological conditions can change with time and possibly affect performance assessment. For example, groundwater flow in the Culebra was modeled by DOE as a steady-state process, but two mechanisms were considered in the performance assessment that are not steady-state processes and could affect flow in the future. These mechanisms are fracturing in the Culebra (due to subsidence resulting from mining the McNutt Potash Zone) and climate change during the next 10,000 years, which may affect groundwater flow by altering recharge to the Culebra.

25.B.5 EPA Compliance Review

EPA reviewed DOE's list of hydrogeologic conditions and potential changing conditions in Table 6-3 of the CCA, the referenced screening discussions in Appendix SCR, and the general modeling assumptions in Table MASS-1. EPA also reviewed the events and processes (EPs) that are related to the future state assumptions, including both human-initiated and natural EPs. Human-initiated EPs related to drilling were reviewed in Chapter 6.0.2, 6.2.5, 6.3.2, and 6.4.7

and Appendix MASS.16. EPA reviewed the effects of mining and its resulting subsidence and fracturing on the Culebra's transmissivity in Chapters 6.3.2.1, 6.4.6, and Appendix MASS.15.4. A detailed evaluation of drilling and mining is included in **CARD 32—Scope of Performance Assessments**. Natural EPs (i.e., climate changes) that can alter hydrogeologic conditions, with time and groundwater flow in particular, were reviewed in Chapters 2.2.1, 6.4.9, Appendices PAR (Parameter 48), MASS 14, MASS 15, and MASS 17. EPA reviewed DOE's discussions of potential changes in the Culebra's hydrogeology and overlying strata (including the Dewey Lake Formation) in Chapters 6.4.6.2, 6.4.6.6, and 6.4.9 of the CCA. EPA found that the following potential hydrogeologic changes were assumed to represent potential future climate change: groundwater recharge, Culebra flow rate variations, and water table elevation.

EPA also reviewed other potential changes to hydrogeologic conditions that were suggested or described in the preliminary list of FEPs (Appendix SCR, Attachment 1), as well as those potential changes that were rejected (Appendix SCR and Chapter 6, Tables 6-3, 6-4, and 6-5). EPA did not identify any inappropriate exclusions or missing scenarios of hydrogeological conditions that may be important to waste containment in the long-term future.

EPA also examined the screening arguments and considered the possibility of different or additional future state assumptions that may have been rejected or not included in the list of FEPs to be screened. After reviewing the initial list of FEPs (Table 6-3 of the CCA), EPA determined that no FEPs with the potential to affect performance adversely were inappropriately excluded from consideration. For further discussion, see **CARD 32—Scope of Performance Assessments**.

EPA found that the CCA included an impact assessment of increasing precipitation in the Culebra, but DOE did not assess the Dewey Lake Formation. EPA required DOE to assess the Dewey Lake Formation in a letter dated December 19, 1996 (Docket A-93-02, Item II-I-01). In a February 26, 1997, memorandum to EPA, DOE discussed vertical inflow to the Dewey Lake Formation and three-dimensional groundwater flow modeling (Docket A-93-02, Item II-I-10). EPA concluded that this supplementary information provided adequate documentation to address this issue.

EPA's review of hydrogeologic conditions is discussed further in **CARD 14—Content of Compliance Certification Application, CARD 32—Scope of Performance Assessments, CARD 33—Consideration of Drilling Events in Performance Assessments, and CARD 54—Scope of Compliance Assessments.**

EPA verified that the CCA acknowledges and quantifies uncertainties in hydrogeologic conditions. EPA found these uncertainties in hydrogeologic conditions in the site characterization data descriptions and modeling assumptions in Chapter 2 and Chapter 6 of the CCA, respectively. For example, in Chapter 2.1.3.5.2 EPA found that available data from site characterization and the known and potential variations in thickness, porosity, and transmissivity of this stratum were clearly described and discussed. Boundary conditions were referenced in Chapter 6.4.6.2 and described in Chapter 6.4.10.2 and Appendices MASS, SECOFL2D, SECOTP2D, and TFIELD. EPA's technical evaluation of these codes is discussed in **CARD 23—Models and Computer Codes**.

EPA reviewed the adequacy of DOE's description of the uncertainty of key parameter assumptions, such as the impacts of mine subsidence on Culebra transmissivity and the potential frequency with which mining may occur in the vicinity of the WIPP. DOE assumed in the performance assessment that mining of all potash in the vicinity of the WIPP site but outside the controlled area will occur in the near future, and that mining within the controlled area will occur with a probability of 1 in 100 per century (adjusted for the effectiveness of passive institutional controls during the first 700 years following closure). Due to the uncertainty of the effects of mining subsidence on the transmissivity of the Culebra, DOE increased the transmissivity of the Culebra by randomly sampling a factor increase that is uniformly distributed between 1 and 1,000 for those areas of the Culebra that are underlain by mining. EPA found that DOE adequately addressed the effects of mining induced subsidence on the Culebra transmissivities.

EPA found that DOE modeled the effects of climate change on the groundwater flow in the Culebra during the next 10,000 years by increasing the flow velocities in the Culebra by a factor of between 1 and 2.25. The uncertainty is incorporated in performance assessment by sampling from a cumulative distribution between 1 and 2.25. EPA found that DOE considered the resulting increase in water table elevation and recharge rates due to wetter climates, but did not consider the potential increase in Culebra transmissivity that may occur due to fracture infilling dissolution.

DOE used Culebra field transmissivity values to conduct groundwater modeling in wetter climate conditions using SECOFL codes (Corbet and Knupp 1996). In the modeling analysis, DOE considered the resulting increase in water table elevation and recharge rates due to wetter climates. This model does not reflect the changes in the Culebra permeability due to climatic conditions. DOE addressed the overall effects of wetter climate and groundwater flow velocities in Corbet's SECOFL3D analyses of the regional groundwater basin model (CCA Reference #147). However, this model did not explicitly consider the potential increase in the dissolution of the fracture infillings in the Culebra due to the introduction of less saturated water with gypsum and the resultant impact on the permeability of Culebra. At the request of EPA (Docket A-93-02, Item II-I-01), DOE provided in a January 24, 1997 memorandum additional information regarding uncertainty in permeability due to fracture infilling dissolution (Docket A-93-02, Item (II-I-03). Memoranda prepared by Dennis Powers (1997) and Corbet et al. (1997) were included in this additional information. The Corbet, et al., memorandum stated that it is "not possible, at this time, to absolutely rule out some change to the hydraulic properties of the Culebra over 10,000 years." However, the memorandum concluded that "for any climatic scenario, it is likely that groundwater is saturated with respect to gypsum before it reaches the Culebra and will not dissolve additional gypsum from the Culebra." The memorandum further stated that "although flow in the Culebra responds rapidly to changes in recharge at the water table, perhaps in hundreds of years, recharge takes tens of thousands of years to reach the Culebra." Based on this conclusion, DOE decided that it was not necessary to increase permeability due to dissolution as the result of higher precipitation. For further information see **CARD 23—Models and Computer Codes**. Even if Culebra hydraulic conductivities across the WIPP vicinity were to increase naturally, which EPA does not believe will occur, then it is likely that the result in Culebra flow transport would be similar to that modeled for the mining case.

DOE adjusted the transmissivities in the Culebra to account for the potential effects of mining subsidence. DOE assumed that mining would only occur within the controlled area with a probability of 1 in 100 per century during the first 700 years following closure. Considering the previous discussions regarding uncertainties in Culebra transmissivity, EPA concluded that DOE's explanation of uncertainty associated with the potential impacts of fracture infilling dissolution on Culebra transmissivities is acceptable. For further discussion of this topic, see **CARD 23—Models and Codes, CARD 32—Scope of Performance Assessments**, and EPA's Response to Comments Document under Section 23, comments 143b and 877 (Docket A-93-02, Item V-C-1).

EPA determined that DOE's approach to addressing future uncertainty and the examples of conservative assumptions used to compensate for uncertainty, as described in Chapter 6.5.4, is consistent with the FEPs list, screening arguments, and model descriptions.

25.C.1 REQUIREMENT

(b) "In considering future states pursuant to this section, the Department shall document in any compliance application, to the extent practicable, effects of potential future hydrogeologic, geologic and climatic conditions on the disposal system over the regulatory time frame. Such documentation shall be part of the activities undertaken pursuant to § 194.14, Content of compliance certification application; § 194.32, Scope of performance assessments; and § 194.54, Scope of compliance assessments.

(2) In considering the effects of geologic conditions on the disposal system, the Department shall document in any compliance application, to the extent practicable, the effects of potential changes to geologic conditions, including, but not limited to: dissolution; near surface geomorphic features and processes; and related subsidence in the geologic units of the disposal system."

25.C.2 ABSTRACT

40 CFR 194.25(b)(2) requires DOE to consider the effects of potential changes to geologic conditions on the disposal system. DOE described the effects of potential changes to geologic conditions on the disposal system in Chapters 6.2, 6.4.6, 6.5.4, and Appendices SCR and MASS of the CCA.

EPA reviewed DOE's descriptions of the characteristics of potential geological changes such as dissolution, surface subsidence, and geomorphic features. EPA also reviewed the uncertainty descriptions associated with the potential geological changes' characteristics.

25.C.3 COMPLIANCE REVIEW CRITERIA

As stated in the CAG (p. 37), EPA expected the compliance application to include the following information: (i) a list that describes the geologic conditions or processes considered in the CCA; (ii) a description of the effects to the disposal system from the following potential changes in geologic conditions in both disturbed and undisturbed cases: igneous intrusion,

anhydrite bed fracturing as a result of excavation, dissolution, geomorphic features and processes, and related subsidence in the geologic system; and (iii) a discussion of how the uncertainties associated with the effects of potential changes will be projected in the geologic conditions. The Compliance Criteria state that DOE must ensure that the descriptions pertinent to Section 194.25(b)(2) are included in Sections 194.14, 194.32, and 194.54.

25.C.4 DOE METHODOLOGY AND CONCLUSIONS

DOE described potential future geologic conditions at the WIPP in Chapter 6.2, 6.4.6, and 6.5.4 and Appendix SCR of the CCA. In Chapter 6.4.2, DOE described the stratigraphy and physiography of undisturbed geologic FEPs and related assumptions. DOE discussed salt creep and excavation-induced stress changes in Chapter 6.4.3.1. In Chapter 6.4.3.4 and 6.4.6.2, DOE explained the geochemistry of the WIPP site. In Chapter 6.4.5.3, DOE discussed the seismic activity and the DRZ. DOE discussed dissolution in Chapter 6.4.6.2, Appendix DEF, and Appendix SCR 1.1.5.1. DOE addressed the uncertainties associated with the existing variability in the Culebra transmissivities in Appendix TFIELD. DOE addressed mining in the McNutt potash zone above the repository in Chapter 6.4.6.2.3, 6.4.12.8, and 6.4.13.8. In Chapter 6.4.7, 6.4.8, and 6.4.12.2, DOE addressed the disturbed geologic FEPs and related assumptions including the following scenarios: drill hole intrusions (Scenarios E1 and E2), brine reservoirs, and number and time of drilling intrusions. DOE also addressed the possibility of deep dissolution in Appendix DEF.3.1 of the CCA. DOE provided additional information at EPA's request (Docket A-93-02, Item II-I-01) regarding the potential impacts of shallow and deep dissolution on hydrogeologic conditions in its January 24, 1997 letter to EPA (Docket A-93-02, Item II-I-03).

25.C.5 EPA COMPLIANCE REVIEW

EPA examined the listed geologic conditions in Tables 6-3, 6-4, and 6-5 of the CCA, as well as the general modeling assumptions listed in Table MASS-1. EPA also examined the following assumptions of geologic conditions found in Appendix SCR:

- Tectonics and Deformation assumptions (Appendices SCR.1.1.2 and SCR. 1.1.3.1).
- Fracture development and Fault movement assumptions (Appendices SCR.1.1.3.2 and SCR.1.1.3.3).
- Ground shaking and Seismic risk assumptions (Appendices SCR.1.1.3.4.2 and SCR.1.1.3.4.3).
- Volcanic and Magmatic activity assumptions (Appendix SCR.1.1.4.1.1 and SCR 1.1.4.1.2).
- Metamorphic activity assumptions (Appendix SCR.1.1.4.2).

- Shallow, Lateral, and Deep dissolution assumptions (Appendices SCR.1.1.5.1.1, SCR.1.1.5.1.2, and SCR.1.1.5.1.7).

- Mineralization assumptions (Appendices SCR.1.1.5.2).

In addition, EPA evaluated the screening arguments in Appendix SCR to determine if the FEP geological screening rejection decisions were adequately substantiated. EPA also examined whether the assumptions underlying the screening decisions were reasonable and explicitly stated. EPA determined that DOE's screening arguments adequately justified the exclusion of the majority of the geological FEPs and related future state assumptions from the modeling. EPA specifically assessed the list of geologic FEPs and their associated future state assumptions for inclusion of the potential changes in geologic conditions identified in CCA Tables 6-6 and 6-7 (undisturbed and disturbed screening FEPs). EPA also reviewed the descriptions of potential changes of geological and mechanical FEPs (such as excavation-induced fracturing and subsidence) and geological FEPs (such as excavation activities in the Appendix SCR). EPA did not discover any significant discrepancies or inaccuracies. After reviewing Appendix MASS and the assumptions listed in Table MASS-1, EPA concluded that DOE adequately addressed the future state assumptions related to the geologic units and conditions that may potentially affect the performance assessment.

EPA reviewed DOE's discussion of the uncertainty associated with the effects of potential changes in deep dissolution in Appendices DEF.3.1, SCR.1.1.5.1.3 through SCR.1.1.5.1.7, and in the additional information DOE provided in the Tom Corbet et al. (1997) and Powers (1997) memoranda. DOE concluded in Appendix DEF.3.1 that "Localized deep dissolution and collapse features are only known to be present along the margin of the Delaware Basin above the Capitan Reef. Theoretical considerations indicate that localized deep dissolution could occur away from the margin, but extensive geophysical surveys, field mapping, and drilling in the vicinity of the WIPP have failed to confirm that breccia pipes or slow dissolution pose a threat to the WIPP." EPA considers this a reasonable conclusion.

While DOE made many geologic condition assumptions, EPA found that most of these were eliminated from performance assessment calculations, either on the basis of low consequence to the disposal system's performance or on the low probability of occurrence over the next 10,000 years. EPA found that the one significant exception to this trend is shallow dissolution, referenced in Appendix SCR.1.1.5.1.1. DOE addressed the potential uncertainty associated with shallow dissolution in the Corbet et al. (1997) memorandum that was included in DOE's January 24, 1997 response (Docket A-93-02, Item II-I-03) to EPA's December 19, 1996 request for additional information (Docket A-93-02, Item II-I-01). In this memorandum DOE concluded that shallow dissolution would not occur due to the slow groundwater travel times and the expected gypsum saturated groundwater, which is not conducive to dissolving additional gypsum in the Culebra. The issue of hydrogeological transmissivity uncertainty associated with potential shallow dissolution was previously addressed in Section 194.25(b)(1) above. EPA found that DOE satisfactorily addressed the geologic shallow dissolution uncertainty issue.

25.D.1 REQUIREMENT

(b) "In considering future states pursuant to this section, the Department shall document in any compliance application, to the extent practicable, effects of potential future hydrogeologic, geologic and climatic conditions on the disposal system over the regulatory time frame. Such documentation shall be part of the activities undertaken pursuant to § 194.14, Content of compliance certification application; § 194.32, Scope of performance assessments; and § 194.54, Scope of compliance assessments.

(3) In considering the effects of climatic conditions on the disposal system, the Department shall document in any compliance application, to the extent practicable, the effects of potential changes to future climate cycles of increased precipitation (as compared to the present conditions)."

25.D.2 ABSTRACT

40 CFR 194.25(b)(3) requires DOE to consider the effects of potential changes to climatic conditions on the disposal system. DOE identified and described the effects of potential changes to future climate cycles of increased precipitation on the repository in Chapter 6.4.9 of the CCA.

EPA reviewed DOE's descriptions of characteristics of such potential changes as increased precipitation and recharge rates. EPA also examined the uncertainty descriptions associated with climatic changes.

25.D.3 COMPLIANCE REVIEW CRITERIA

As stated in the CAG (p. 38), EPA expected the compliance application to include the following information: (i) a list of potential scenarios that are likely to be affected by climate change over the 10,000-year regulatory period; (ii) a description of how these scenarios are likely to be affected; (iii) a description of the effects to the disposal system from the following potential changes of climate cycles: increased precipitation and increased recharge rates; (iv) a discussion of the potential impact of climatic changes on the geologic conditions identified in accordance with Section 194.25(b)(2); (v) a description of the uncertainties and impacts associated with effects of potential changes to the future climate cycles; and (vi) identification of other potential changes to climatic conditions. EPA expected the effects of climatic conditions to be included in analyses related to the performance and compliance assessments.

25.D.4 DOE METHODOLOGY AND CONCLUSIONS

DOE considered the effects of potential climate changes on the disposal system performance over the next 10,000 years in Chapter 6.4.9 of the CCA. DOE incorporated the uncertainty of the effects of climate change in performance assessment by considering the effects of various possible future climates on dissolution, groundwater flow, and potential radionuclide transport in groundwater. DOE described climate change due to potential natural causes (excluding anthropogenic changes), and the resulting changes in recharge rates, groundwater flow velocity, and flow direction, in Chapter 6.4.9. DOE did not include the direct effects of climate

change such as changes in wind patterns and thermal effects related to changes in surface temperature in the groundwater flow modeling, because the WIPP facility is located in the deep underground, and the near-surface direct effects of climate change will not affect the WIPP's long-term performance.

In Appendix MASS, DOE included models of the impact of potential climate changes on groundwater flow in the Culebra over the regulatory period. DOE used an approach that is bounded by the extremes of late Pleistocene glaciation. For the purposes of performance assessment, DOE considered two possible patterns of uncertainties in the future climate. The first possible Holocene pattern assumes that weather conditions are predominately dry with alternating wet conditions that become continuously wetter. The second possible weather pattern assumes that the climate will become continuously wetter.

DOE developed climate index parameter values ranging from 1.0 to 1.25 (for the Holocene pattern) with a probability of 0.75. For the second weather pattern, DOE developed climate index parameter values ranging from 1.5 to 2.25, with a probability of 0.25. DOE obtained these values from the numerical modeling results using the three-dimensional SECOFL3D computer code. The climate index parameter values are the ratios of lateral flow velocities in the Culebra after 10,000 years versus the current lateral flow velocities. DOE then used this ratio as a velocity magnification multiplier in the two-dimensional SECOFL2D analysis of the groundwater flow in the Culebra for performance assessment.

25.D.5 EPA Compliance Review

EPA's review of climatic conditions and potential changes in climatic conditions focused on the applicable FEPs and their associated future state assumptions, and the potential scenarios that may be affected by these FEPs. EPA reviewed the screening classifications of these FEPs and related future state assumptions, as described in Chapter 6.4.9 and listed in Table 6-3. EPA also reviewed the detailed screening arguments for the applicable FEPs and related assumptions that are contained in Section SCR.1.6 of Appendix SCR.

EPA found detailed discussions of the current and previous climate at the WIPP site in Chapter 2.5 of the CCA and Appendix CLI. EPA found that DOE addressed in Chapter 6.4.9 and Section SCR.1.6 of Appendix SCR the impacts that potential future climate change related scenarios would have on the disposal system. This review showed that DOE addressed the effects that changing climate scenarios would potentially have on geologic dissolution and its subsequent impacts on hydrogeologic conditions such as Culebra transmissivities and possible radionuclide transport in groundwater. These scenarios and their associated hydrogeological and geological uncertainties are addressed further in Sections 25.B.5 and 25.C.5 of this CARD.

EPA reviewed DOE's modeling assumptions on the future climate change found in the CCA in Chapter 6.4.9, Appendix MASS, and Appendix CLI. EPA found that DOE considered such climate-related factors as precipitation, temperature, and evapotranspiration that might affect groundwater flow in the regional three-dimensional groundwater basin model. Varying recharge rates and groundwater velocity magnification factors (Climate Index Parameter) were adopted in DOE's SECOFL2D model simulation to reflect the wetter climate change. EPA examined DOE's

three-dimensional regional analyses with the values of higher potential recharge in SECOFL3D. EPA evaluated DOE's explanation of exclusion of direct effects such as changing wind patterns, changing near-surface temperature, and the long term effects of climate change on the near surface portion of the shaft seal system in the BRAGFLO modeling. EPA found that DOE excluded anthropogenic climate changes in Table 6-5 and excluded glaciation in Table 6-3. EPA agreed with DOE's explanation of potential climate change effects relative to the disposal system and modeling exclusion.

EPA evaluated the main climatic conditions assumptions and found that these assumptions are related to the climate index's development. This index accounts for variations of the climate on flow conditions in the Culebra by using a velocity magnification multiplier in the two-dimensional SECOFL2D analysis of the groundwater flow in the Culebra. The parameter values of 1.0 to 2.25 were selected for the potential recharge patterns. EPA found that DOE provided adequate documentation to justify the selection of the assumptions related to the climate index parameter development.

At the WIPP site, availability of water for recharge to the Culebra is the primary concern related to global climate change. Using climatic evidence from the past to project potential future conditions at the WIPP site, DOE concluded that global cooling and a return to ice age conditions is the worst case scenario. Increases in temperatures from the past to the present are associated with reduced precipitation. Future global warming could be expected to continue the trend to less precipitation in the vicinity of WIPP, which EPA believes would benefit the WIPP's compliance. DOE appropriately accounted for this scenario by assuming that future potential recharge would be no lower than current recharge. EPA found that this approach probably overestimates the recharge that may be expected if global warming were to occur, and therefore concludes that DOE reasonably accounted for future global climate change in the CCA.

EPA also examined DOE's descriptions of recharge uncertainty associated with potential climate change effects. DOE applied two patterns for potential recharge in its climate change analysis. The first pattern assumed the wetter peak occurs 500, 2,000, 4,000, 6,000, 8,000, and 10,000 years in the future. Potential recharge is assumed to increase and decrease linearly during the wet period 500 years before and after the peaks, and the wet periods are each separated by 1,000 years of a drier climate like that of the present. The second recharge pattern considered the potential recharge that will increase from its present value to a specified larger value 500 years in the future. That potential recharge will then remain constant throughout the rest of the 10,000-year period. Each recharge pattern and its probability of occurrence were assigned climate index parameters ranging from 1.0 to 2.25. EPA concluded that DOE adequately described the future state uncertainty assumptions associated with potential change to the future climate cycles.

EPA concluded that DOE adequately addressed the impacts of potential climate changes to the disposal system. DOE addressed the potential impacts of increased precipitation and increased recharge on hydrogeologic conditions and geologic conditions, as discussed in Sections 25.B and 25.C above. Uncertainties associated with the potential impacts that varying climate conditions may have on geologic shallow dissolution and, consequently, the hydrogeologic transmissivities of the Culebra, are also discussed in Sections 25.B and 25.C of this CARD.

25.E REFERENCES

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