CONCLUSIONS REGARDING GEOTECHNICAL ACCEPTABILITY OF THE WIPP SITE

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ABSTRACT

Site evaluation studies for the Waste Isolation Pilot Plant are essentially complete. These studies have made extensive use of existing data, geologic mapping, exploration geophysics, and boreholes. Those issues that have been most contentious and that have now been thoroughly investigated are those of salt dissolution, deformation of the Castile salt beds and associated phenomena (i.e., brine reservoirs), definition of the hydrologic regime, and the potential conflict with natural resources. The first two phenomena have been shown not to present a significant threat to WIPP during its required lifetime. The hydrologic regime has been adequately characterized, and it is very favorable with respect to its role in possible breach scenarios. There is a potential for natural resources at the WIPP site, but all promising resources can be exploited without jeopardy to the WIPP. Future breaches by human activity cannot be ruled out but consequences of such activities are relatively benign.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) was authorized by Congress in 1980 as an unlicensed research and development (R&D) facility to demonstrate the safe disposal of radioactive wastes arising from the defense activities and programs of the United States. WIPP is now being constructed in southeast New Mexico, using salt beds about 655 m below the surface of the ground. Construction of the full WIPP facility will not commence until a preliminary underground excavation phase, called Site and Preliminary Design Validation (SPDV), is satisfactorily concluded in the summer of 1983. This SPDV program permits confirmation of subsurface geology, in drifts at planned facility depth that extend for 1555 m in a north-south direction, and in the two vertical shafts that provide access to these drifts. The subsurface studies are nearing completion, and it is therefore appropriate to draw conclusions regarding the geotechnical acceptability of the WIPP site.

BACKGROUND

The geotechnical aspects of the WIPP site and its environs have been investigated, with varying intensity, since 1974. Through 1978, most of these studies were oriented toward a general characterization of WIPP site geology and hydrology.[1] Since then, the geotechnical studies have focused on particular issues that the earlier studies addressed but did not resolve, and that either the WIPP project or the various State and Federal technical review groups felt were significant to an assessment of site acceptability. These latter studies focused on four broad issues thought to be crucial to a full evaluation of the WIPP site: (1) dissolution phenomena; (2) deformation of the evaporites; (3) definition of the hydrologic regime; and (4) potential conflict with natural resources. This paper concentrates on these issues and also briefly mentions other important siting criteria that have not been as contentious.

Data to support the site evaluation come from a wide variety of sources. Extensive geologic mapping and correlation of borehole data provide a solid geological base for interpretation of geophysical surveys. Seventy-eight boreholes (including the two shafts) totaling 34,640 m of hole and 8,960 m of core, have been drilled for evaluation of the WIPP site. About 40 of these holes have been used to obtain hydrologic data. In addition, more than 350 petroleum exploration wells and many potash exploration holes provide data in the 2333-km^2 area centered on the WIPP site. Some 2415 kilometers of existing seismic reflection data from the files of petroleum service companies have been supplemented by 210 kilometers of WIPP seismic reflection surveys configured to investigate the upper 1,220 m of the geologic section. High-resolution seismic reflection data (in the amount of 3.2 kilometers) were acquired to examine areas of suspected structure in the "disturbed zone" north of the center of the site. Electrical resistivity survey methods have been demonstrated to be useful and have been extensively deployed over the entire WIPP site to detect any dissolution phenomena at the top of the evaporites. Characteristic resistivity anomalies have been demonstrated to be associated with breccia pipes in the northern Delaware Basin. Other geophysical tools applied, such as gravity and aeromagnetic surveys, were useful in investigating and searching for particular features. High-precision gravity did not show anomalies associated with the deformation of Castile anhydrites but did indicate shallow anomalies arising from density variations in the near-surface red beds of the Dewey Lake Formation. The aeromagnetic surveys ruled out the presence of intrusive dikes near the site. Laboratory geochemistry and petrologic studies have played an essential role in understanding the nature and origin of dissolution and deformation features in the WIPP region.

The data to establish an understanding of the hydrology in the area were acquired from more than 40 WIPP boreholes; an extensive compilation of data from aquifers below the evaporites was obtained from industry holes.[2] Special techniques, including tracer tests, were used to establish the parameters required for hydrologic modeling.

EVALUATION OF GEOTECHNICAL ISSUES

Before selecting and characterizing the WIPP site, several siting criteria and their associated factors were established.[1] These factors have all been evaluated through the use of data obtained from the previously described programs. The WIPP site met all but a few of the siting factors with very little contention from the various technical review groups. Information pertinent to a few of the siting factors was equivocal, however, and these aspects have since been addressed by additional studies. All these investigations to date show that the siting criteria and factors are satisfied by the WIPP site, with the possible exception of a conflict with natural resources.

The siting criteria and factors that guided the site selection and characterization for WIPP have been restated in the Site Validation Program[3] in a format more consistent with that used in the commercial waste-management program. The 21 site qualification criteria listed cover existing geologic conditions (topography, depth, thickness of host rock, lateral extent, lithology, stratigraphy, structure, groundwater, surface water, subsidence, physical-chemical compatibility, natural resources); geologic processes that could affect future integrity (dissolution, tectonic stability), and nongeologic aspects (man-made penetrations, transportation, accessibility, land acquisition, population density, ecological effects, sociological impacts). These issues have all been addressed in various documents; the nongeologic issues were considered in the Environmental Impact Statement,[4] the geologic and hydrologic issues in the Geological Characterization Report,[1] and in subsequent topical reports.[5-11] Those factors given more extensive consideration were groundwater and natural resources and the "geologic processes" of dissolution and tectonic stability. These geologic factors involve prediction of future behavior.

The rest of this paper discusses those four geotechnical elements that received additional study or consideration because of their contentious aspects. In this regard, it is important to realize that an attempt to understand complex geological processes may not result in absolute proof of one or another hypothesis. A hypothesis may be ruled out if observed data clearly refute it, but more often one adopts a hypothesis because it best explains the observations and presents fewer conflicts with the evidence. Likewise, it is often impossible to prove a negative aspect of an issue. For example, it is not possible, in a practical sense, to prove that a large area does not contain a breccia pipe or a brine reservoir. The best that can be done is to establish a preferred hypothesis for the origin of these features, and then to show that the area in question does not possess the requisite characteristics to satisfy the hypothesis. Conversely, hypotheses may be ruled out that would admit such features if the hypothesis requires conditions that can be shown not to exist. Professional judgment is sometimes the only way of reaching a conclusion on geotechnical issues. For this reason, the State and Federal technical review groups are important in providing an independent, unbiased judgment of the various hypotheses that are offered to explain the observations.

DISSOLUTION

Dissolution of salt at certain locations in the Delaware Basin is known to occur at the top of the evaporite sequence and is also believed to occur within or at the base of the evaporites in other areas. Both regional or "blanket" dissolution, and local dissolution resulting in small-scale features such as breccia pipes or sinks, must be considered. Regional dissolution at the top of the evaporite sequence is present in the area of the WIPP site. The maximum average rates of horizontal and vertical progression of this dissolution front, as determined by the USGS[12] from observations in Nash Draw, west of the WIPP site, are ~10 to ~13 km per million years and ~152 m per million years, respectively. These rates pose no threat to the WIPP site from the dissolution mechanism. Rates at which dissolution within or at the base of evaporites occurs cannot be established by observation. Some investigators[13] have suggested it may be quite rapid, proposing that vast quantities of salt have been removed from the Delaware Basin in the last few million years. Recently completed studies[7,9] have shown that this rapid removal is not possible for the northern part of the Delaware Basin based on the measured hydrologic and geochemical characteristics of deep aquifers. The USGS[5] and Sandia[7] geologists also believe that much of the "missing" salt was never there to begin with, but is absent because of nondeposition or removal before lithification. Absence of the substantial dissolution residue zones, which would result if hundreds of meters of salt were dissolved, supports this view. There is no evidence of regional deep dissolution near enough to the WIPP site to pose a concern to its integrity.

Local dissolution features, such as breccia pipes, have also been considered as a possible threat to the WIPP by virtue of short-circuiting the salt barrier and providing a direct connection to aquifer systems. The USGS study[6] of these and similar features shows they are not a threat; they occur only over the Capitan Reef and not in the interior of the basin where the WIPP is located. Further observations on those breccia pipes that have been studied over the Capitan Reef show that they do not enlarge in diameter through the salt beds, but have instead become quite impermeable to flow of water. Thus their effect on the salt beds is limited outside their initial dimensions.

In view of these observations, natural dissolution of salt will not pose a threat to the integrity of the salt beds surrounding WIPP in the next 10,000 years and, indeed, would not be expected to be a concern over the next few million years.

DEFORMATION

Deformation of the halite and anhydrite beds is known to occur in areas of the northern Delaware Basin. Existing deformation could be detrimental if its magnitude is sufficient at the excavation depth to preclude practical mining operations. Deformation is also important because it seems to be a necessary condition for the formation of brine reservoirs in the Castile anhydrite.

The deformation studies[8] and the petrofabric analyses[14] show that existing deformation in the evaporites has been episodic and is not largely a result of geologically recent movement. Existing and postulated future deformation does not present unacceptable conditions for the WIPP.

There is a positive correlation of brine reservoirs (when they occur) with Castile deformation and with the upper Castile anhydrites. The fluid may accumulate in fractured anhydrite from disseminated original fluids in the evaporites, or it may come from an external source. In any event, hydrologic

tests and analyses of samples show that these brine reservoirs are hydrologically isolated from aquifers and from each other; they are saturated and incapable of dissolving more salt; they are stagnant; and they have been in their present environment for at least several hundred thousand years.[10] Consequently, it is unlikely that these features now occur, or that they will occur in the future beneath the WIPP site. Even if a brine pocket did occur beneath the WIPP, it would not be a threat from natural processes but could conceivably become involved in a release scenario if both WIPP and the brine reservoir were penetrated by drilling. Calculations of this scenario show consequences as relatively benign.[15]

HYDROLOGIC REGIME

Since any realistic breach scenario for WIPP involves transport of isotopes by groundwater, an adequate definition of the hydrologic regime is critical to development of credible modeling and safety analysis. Early evaluations assumed (in the absence of definitive data and for the sake of bounding the consequences) that the release path would always be through the Rustler aquifers overlying the WIPP. Regional hydrology studies[2] now indicate this is not the case. If aquifers above and below the salt were connected by a drill hole, the actual potentiometric heads are such that flow would tend downward into the Delaware Mountain Group (DMG) aquifers. This places less emphasis on the characteristics of the overlying Rustler aquifers. The hydrology of both the shallow and deep aquifer systems is extremely favorable with respect to transport of isotopes. The flow velocity in the DMG is very low,[9] and transit times to the Capitan Reef (the nearest aquifer used by man), are much greater than 10,000 years. Available data indicate this transit time is about 500,000 years. Because of the discontinuous sand lenses in the DMG, it is questionable whether any significant transport of water actually takes place in the DMG.

The Rustler aquifers could be involved in the release scenario for a breach involving a brine reservoir. Water flowing over the WIPP site in the Rustler aquifers would discharge into the Pecos River, about 23 km away, in 1,000 to 10,000 years. Sorption and retardation of transuranic radioisotopes would be pronounced in these carbonate aquifers. Recent tests have confirmed that the flow in the Rustler dolomite aquifers is governed by filled fractures. Near the WIPP these fractures are very tight, or they are few, so that the effective hydraulic conductivity is very low.[2,11] The significance of this fact is that the first few kilometers of path account for most of the flow time involved in reaching the Pecos River. Greater flow velocities and quantities are possible in areas nearer the end of the travel path where aquifers have been severely fractured when dissolution of underlying salt has caused collapse.

One other aspect of the WIPP site hydrology that has been examined is that of karst hydrology. The concern is whether solution channels in the Dewey Lake Red Beds or the Rustler Formation could provide more rapid access of radionuclides to the biosphere. Gravity studies have indicated sinuous anomalies north of the WIPP that imply shallow (152 m) low-density zones. These could be due to a number of causes, and one investigator[15] has suggested karst channels as an explanation. More likely, these are primary channels later filled by deposition of sediments. In the opinion of USGS and WIPP hydrologists, typical karst is unlikely at the WIPP site for several reasons. There is no free water table at the WIPP site, a normal prerequisite for active karst geohydrology. Further, all the drilling and hydrologic testing in this region have provided no indications of karst channels except in and near Nash Draw, where shallow dissolution features are known to exist. The distinct difference in heads in the Rustler aquifers and the fact that they are confined systems also argues against significant karst development in the Rustler. No topographic or geophysical data exist to suggest karst development over the WIPP facility. Finally, even if karst channels of some dimension did exist near WIPP, the only mechanism for raising water to their elevation is by means of the brine-reservoir-breach scenario. Since the consequences to man would be less than those that have been assumed, namely flow to the surface, the presence of such channels would not present a safety threat to man.

NATURAL RESOURCES

Potentially economic potash exists above the WIPP depth on the north edge of the WIPP site, and there is significant potential for natural gas beneath the WIPP site at depths of 3,000 to 4,600 m. A recent study[16] has shown that both potash mining and hydrocarbon drilling can be permitted within 1.6 km of WIPP, and DOE has recently adopted a policy to recognize this fact. This allows most of the potash and all of the natural gas (through deviated drilling) to be developed as economics dictate. A more persistent concern is that future generations may be attracted to do deep drilling here just because sedimentary basins have long been a focus for such activities. One can argue about active and passive controls, but the fact remains that human penetration scenarios cannot be ruled out. They are, in fact, far more likely to occur than are failures caused by natural processes. It is necessary, therefore, to examine the consequences of inadvertent human intrusion. These safety analyses were conducted, and the consequences were shown to be relatively benign.[4]

In conclusion, the WIPP site geology and hydrology are very favorable for the long-term isolation of radioactive waste. Breaches of the salt barrier by natural processes are not credible, and breaches because of human intrusion (which can never be ruled out) have no significant consequences.

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