

CRITIQUE by Richard Hayes Phillips, Ph.D. of:  
WASTE ISOLATION PILOT PLANT FINAL REPORT  
Culebra Hydrogeology Conceptual Model Peer Review  
Conducted by Anthony Burgess, Ph.D., P.E., L.G.  
Thomas Doe, Ph.D., L.G., L.E.G., L.H.G.  
Tim Lowenstein, Ph.D.  
John A. Thies, Peer Review Manager  
For the Carlsbad Field Office Technical Assistance Contractor  
In Support of the U.S. Department of Energy September 24, 2008

Introduction

On August 11-14, 2008, scientists for Sandia National Laboratories (Sandia Labs) made numerous presentations to a Peer Review Panel regarding the Waste Isolation Pilot Plant (WIPP), a nuclear waste disposal site near Carlsbad, New Mexico. The purpose was for Sandia Labs to defend its conceptual model for groundwater flow in the Culebra dolomite, arguably the most transmissive member of the Rustler Formation. The WIPP site was certified by the Environmental Protection Agency (EPA) in 1999, based upon the Performance Assessment (PA) contained in the Compliance Certification Application (CCA) submitted by the Department of Energy (DOE) – which, in turn, was based upon this conceptual model.

It is apparent from a CD entitled “Culebra Hydrogeology Conceptual Model, Peer Review, All Documents” that alternative interpretations were not presented to the Peer Review Panel. The CD consists entirely of submissions by Sandia Labs, including: (1) power point presentations which are, in effect, outlines of what was presented verbally, along with numerous graphics, some of them very informative; and (2) written responses by Richard L. Beauheim and others to questions by the Peer Review Panel.

Despite the sometimes one-sided nature of the power point presentations, the Peer Review Panel, to its credit, was not fully convinced of the validity of the Culebra Hydrogeology Conceptual Model. The Panel found that while adequate data existed to develop a model, the current conceptual model has “failed to correlate the detailed hydrogeology of the Culebra with its tested hydrologic character.” Specifically, the Panel was concerned that fundamental and interrelated assumptions were not demonstrated by the evidence, the assumptions being: (1) groundwater flow in the Culebra is not affected by rainwater recharge; (2) dissolution of evaporites (halite and gypsum) in the Rustler is not occurring; (3) the Culebra is effectively at hydraulic steady state; and (4) the Culebra can be modeled in two dimensions as a confined aquifer, with no vertical component to groundwater flow. The ultimate concern is this: (5) if the conceptual model is wrong, the groundwater transmissivity values utilized in Performance Assessment might not be representative of conditions in the field. The bottom line is this: if rainwater recharge *does* reach the Culebra dolomite, then dissolution of overlying evaporites *is* occurring, the Culebra is *not* in hydraulic steady state, the Culebra is *not* a confined aquifer, and the conceptual model *is* wrong, bearing little or no resemblance to reality.

In the following pages, the words in italics are taken, usually verbatim, from the Final Report of the Peer Review Panel. These are followed by the responses of this author.

(1) Rainwater recharge does reach the Culebra dolomite

*“Water level observations in the Culebra show short term fluctuations that have been correlated with precipitation events.” (page 19)* These correlations are illustrated in four hydrographs presented to the Peer Review Panel by Beauheim (*Water-Level Responses to Rainfall*, pages 72-75), the importance of which cannot be overstated. One of these graphs illustrates data from wells within the WIPP site, showing numerous short-term responses to rainfall over a five-year period at test wells WQSP-1, WQSP-2, H-2b2, H-6b, WIPP-13 and WIPP-19. Four of these wells are located within the rainwater recharge area mapped twelve years ago by Phillips (1997, *Rainwater Recharge at the WIPP Site*, Figure 2), submitted to the EPA, and denied at that time by the DOE (see Phillips, 1998, *Rebuttal to DOE Responses to CARD Comments*, p. 4). We now have obtained 22 years of precipitation measurements for the WIPP site, and 32 years for the Carlsbad airport; and we have obtained 19 years of monthly water level measurements from dozens of WIPP monitoring wells. A detailed analysis of the correlation between specific rainfall events and short-term fluctuations in water levels over an eleven-year period, involving nearly every WIPP monitoring well, is in preparation.

The response of Sandia Labs to direct evidence of rainwater recharge is largely argumentative:

*“Solute chemistry of the Culebra is not consistent with dominantly vertical recharge over the WIPP site area.” (page 15)* This is not true. Total dissolved solids in Culebra groundwater, within the WIPP site, vary by a factor of 25, being highest in the northeastern part of the WIPP site, where the Santa Rosa sandstone is present and water is not found in the underlying Dewey Lake Redbeds, and steadily decreasing to the southwest, where the Santa Rosa is absent and water is found in the Dewey Lake Redbeds. (Phillips, 1997, *Rainwater Recharge at the WIPP Site*, Figures 1 and 2). This is compelling evidence that rainwater recharge to the Rustler is occurring at the WIPP site, most effectively where the Santa Rosa sandstone is absent. In at least one location within the WIPP site (test well H-2), Culebra water is potable (drinkable) by EPA standards. (Phillips, 1997, *Rainwater Recharge at the WIPP Site*, Table 3 and Figure 3).

*“Freshwater heads calculated for the Culebra are distinctive from freshwater heads from Magenta at all common locations across the WIPP site, indicating lack of good vertical communication between them.” (page 15)* This is not true. At test well H-6, within the WIPP site, and at test well WIPP-25, nearly three miles to the west in Nash Draw (one of the largest surface karst features in North America), the freshwater heads of the Magenta and Culebra are equal, or very nearly so. Somewhere between the WIPP shafts and H-6 the Culebra and Magenta lose their hydraulic distinction and become a single, unconfined aquifer. The recently obtained data reveal that the Culebra and Magenta hydraulic heads are nearly equal at test wells WIPP-30, DOE-2 and H-18, confirming that the Culebra is unconfined three miles east of Nash Draw. This geographic area would include test wells WIPP-33, WIPP-11, WIPP-13, WIPP-14 and P-14, where hydraulic heads in the Magenta have not been reported. The recently obtained

data also show that at WIPP-25, H-6, WIPP-30 and H-18, water levels in both the Culebra and Magenta rise in response to rainfall, with the greater rises sometimes found in the Magenta.

*“Gypsum-filled fractures and sulfate cements in the Dewey Lake, and local perched groundwater on the gypsum cements, argue strongly against continuing vertical infiltration of meteoric water (rainwater) across the site...” (page 15)* Fractures in the Dewey Lake Redbeds are not everywhere filled or cemented; the very fact that perched groundwater is found only in certain locations indicates that elsewhere, infiltrating rainwater is transmitted downward to the Rustler. The newly obtained data show large spikes in water levels in the Dewey Lake Redbeds, followed by spikes in various members of the underlying Rustler Formation shortly thereafter.

*“... our current understanding of the hydrostratigraphy in the WIPP vicinity indicates that recharge should be minimal in areas of the model domain outside of Nash Draw.” (page 16)* A rapid rise in water levels at test wells within the WIPP site in response to major rainfall events, recurrently, over an eleven-year period, should demonstrate that the “current understanding of the hydrostratigraphy” is wrong.

## (2) Dissolution of overlying evaporites is occurring

*“General geological information on the Rustler Formation is found in Holt and Powers (1988); Powers and Holt (1999, 2000); and Powers et al. (2006). Details of the sedimentology of the Rustler Formation, emphasizing sedimentary features found in drill cores and mine shafts (air intake shaft, waste shaft, exhaust shaft), are reported in Holt and Powers (1988) and Powers and Holt (1999, 2000). Mapped facies boundaries between mudstone and halite from four units in the Rustler Formation are detailed in Powers and Holt (1995) and Powers (2002).” (page 3)* It is apparent from this statement that the Peer Review Panel has relied exclusively on Powers and Holt for geological information on the Rustler Formation. Powers and Holt were the first to set forth the proposition, contrary to the entire body of previously existing geologic reports, that the lack of halite in the Rustler Formation across much of the WIPP site, and the corresponding reduction in thickness, is due to lack of deposition of halite, and not to dissolution of halite. At the RCRA hearings in Santa Fe in March 1999, I asked Dennis Powers, under oath, if he could name “any scientist, not in the employ of the federal government, who agrees” with this interpretation. He could not. It appears that the Peer Review Panel was left unaware of the body of work by independent scientists. Even so, the Panel, to its credit, was unconvinced:

*“One of Holt’s arguments against dissolution of gypsum cements and fracture fillings “was the lack of continuous north-south pathways for evaporite-dissolving fluids. This view assumes that the flow in the Culebra is strictly two-dimensional with no significant vertical component. Although possible, the Panel did not feel there was a convincing body of evidence to validate this ...” (page 9)* The assumption that there is no “vertical component” to groundwater flow in the Rustler requires a lack of rainwater recharge, which in turn requires an impermeable barrier to infiltrating rainwater somewhere in the stratigraphic column. But every member of the Rustler Formation has produced water in some WIPP drill holes, and the Magenta dolomite member is saturated everywhere east of Nash Draw (Phillips 1997, *Cavernous Zones at the WIPP Site*, p. 9).

The overlying Dewey Lake Redbeds have produced water also (Phillips 1997, *Cavernous Zones at the WIPP Site*, p. 3). Even within the WIPP site, the Culebra (at H-2) and the Dewey Lake Redbeds (at WQSP-6a) have produced water that is potable (drinkable) by EPA standards. (Phillips, 1997, *Rainwater Recharge at the WIPP Site*, Figures 1 and 2). This is a clear indication of fresh rainwater mixing with groundwater, which renders completely invalid the conceptual model upon which the Performance Assessment is based, as it assumed zero rainwater recharge.

*“Early workers, for example Snyder (1985), interpreted lateral changes from halite to mudstone in the Rustler Formation ... to have been produced by present-day dissolution of Rustler halite by dilute groundwaters. Furthermore, Snyder (1985) postulated that dissolution of halite below the Culebra Dolomite (from the Los Medaños Member) (a.k.a. Unnamed Lower Member) causes the dolomites to settle and fracture and transmit groundwater more readily.” (page 16)* It was not only Richard Snyder who attributed the westward thinning of the Rustler Formation to dissolution of Rustler halite proceeding downward and eastward across the WIPP site. The same interpretation was supported by twenty-one authors of fifteen scientific reports: Powers et al. (1978), Gibbons and Ferrall (1980), Barrows (1982), Borns et al. (1983), Barrows et al. (1983), Mercer (1983), Lambert (1983), Chaturvedi and Rehfeldt (1984), Bachman (1984), Snyder (1985), Chaturvedi and Channell (1985), Lowenstein (1987), Chapman (1988), Brinster (1991), and Anderson (1994), as cited by Phillips and Snow (1997, *Potential Flow Paths from the WIPP Site to the Accessible Environment*, p. 4).

*“Holt and Powers (1988) and Powers and Holt (1999, 2000) have shown from study of mine shaft exposures and cores that mudstone-halite lateral transitions in the Rustler Formation may be interpreted as lateral facies changes, not massive dissolution of halite.” (page 16)* Again, there is no support among independent scientists for the interpretation of Powers and Holt. The extensive character of dissolution in the Rustler at WIPP is recognized by virtually all scientists who have examined this area.

*“One key assumption in the hydrogeologic conceptual model is that the mudstone-halite transitions in the Rustler Formation are depositional rather than being the product of solution. In other words, the mudstone is a primary depositional unit rather than a residual material from solution activities. ... One uncertainty in this interpretation is the appearance that the mudstone-halite boundary closely parallels the Salado dissolution front.” (pages 16-17)* The “mudstone-halite boundary” refers to the line to the west of which there is no halite in the Rustler Formation. The nearly unanimous consensus is that the absence of halite is due to post-depositional dissolution, and that the “mudstone-halite boundary” is in fact a dissolution front. Four such lines, roughly parallel, non-intersecting, can and have been drawn. They are, from west to east, lines to the west of which there is: (1) dissolution in the upper Salado; (2) no halite in the Rustler; (3) halite below the Culebra; and (4) halite above and below the Culebra but not above the Magenta. (See, for example, Borns et al., *Deformation of Evaporites Near the WIPP Site*, SAND 82-1069, Figure A-12, p. 121, and Figure 1.2.3-1, p. 24, of which Dennis Powers was a co-author). This is completely consistent with dissolution of halite progressing downward and eastward across the WIPP site. Time and again, the drillers in the field have described the lithology as “dissolution residue” (e.g. at ERDA-9, H-3, H-6, H-18, WIPP-13, WIPP-18, WIPP-19, WIPP-21, WIPP-22 and WIPP-33). Most scientists have concluded that there is no uncertainty about it.

*“Based on the geological data, there is high confidence in the location of the margins of the principal zones (Salado dissolution zone, central zone and halite bounded zone). The margin between the Salado dissolution zone and the central zone is the most critical, since if it were to extend farther east than currently mapped, the zone of high-T (transmissivity) would extend closer to the WIPP area. The extension of the Salado dissolution zone into the WIPP area is considered unlikely, based on the drillhole data along the western LWB (Land Withdrawal Boundary). Furthermore, since ... transport pathways from the WIPP repository are approximately north-south, eastward extension of the Salado dissolution zone would have only a minor impact on transport pathways and travel times.”* (page 20) This entire paragraph begins with an unwarranted assumption based upon falsified evidence presented to the Peer Review Panel by Sandia Labs. As early as 1982, Sandia Labs was well aware that dissolution in the upper Salado extends into the WIPP site. A map stamped “OFFICIAL USE ONLY” but later published by Sandia Labs in Borns et al. (1983, Figure A-12), showed the Salado dissolution front extending into the WIPP site at test well H-6, and at potash test holes P-6, P-12 and P-13, all located within the WIPP site or alongside its western boundary. In addition, there is Salado dissolution at WIPP-33 and P-14, about one-half mile and one mile, respectively, west of the Land Withdrawal Boundary. To the contrary, the maps presented to the Peer Review Panel show a finger of Salado dissolution extending to test wells SNL-9 and SNL-10 (in the vicinity of P-14), and another finger extending to test well SNL-3 more than two miles north of the WIPP site, but otherwise show no Salado dissolution outside of Nash Draw. This is simply false. It is likewise unwarranted to assume that all transport pathways are “approximately north-south.” One of the multi-well pump tests (none of which were incorporated into the Rustler model for Performance Assessment), centered at WIPP-13, within the WIPP site, showed a rapid response at WIPP-25 to the west, in Nash Draw, four miles distant. (Phillips, 1998, *Rebuttal to DOE Responses to CARD Comments*, p. 2). The WIPP-33 sinkhole, with its proven cavernous porosity, is located directly between WIPP-13 and WIPP-25. This is an east-west groundwater transport pathway, involving the Magenta and higher units (see below), and its very existence renders invalid the conceptual model upon which the Performance Assessment was based.

The Peer Review Panel did acknowledge evidence of karst presented by Hill (2006), including *“insoluble residues and collapse breccias in the Rustler Formation, lack of surface runoff at the WIPP Site, and Well WIPP-33 sinkholes and caves.”* (page 17) The WIPP-33 drill hole has never been converted to a test well. At WIPP-33, located 0.5 miles west of the WIPP site, a nested sequence of five open, water-filled caverns in Dewey Lake siltstone, Forty-Niner gypsum, and Magenta dolomite was found beneath a sinkhole 600 to 700 feet in diameter. By design, the Sandia Labs data set lacks any measurements of cavernous porosity. Moreover, Hill’s paper is entirely derivative, containing no original research. The list of references indicates that the Panel did not review the extensive body of evidence of karst at the WIPP by Larry Barrows and others.

### (3) The Culebra is not in hydraulic steady state

*“... the original conceptual model hypothesized that ... the Culebra was effectively at hydraulic steady state. Subsequent monitoring has shown that water levels in the Culebra are steadily rising.”* (page 1) And again: *“The monitoring well network in both the Magenta and Culebra*

*has shown a gradual rise in groundwater levels over the last two decades.” (page 4) This has been known since before the WIPP was certified. Beauheim, in Silva (EEG-62, August 1996, pages 39-62), presented 36 hydrographs, nearly all of which depicted this long-term rise in water levels. Nonetheless, the Culebra was modeled as being in a steady state, and the WIPP was certified on this basis. Now we have monthly water level measurements from 38 WIPP monitoring wells covering most or all of the period from 1989 to 2007. All 38 wells showed a steady rise in water levels during the period of record, and only 8 of 38 appear to have equilibrated. Note that the spikes in water levels that correlate with rainwater recharge events are superimposed upon and are distinguishable from this long-term rise in water levels.*

*Sandia Labs has proposed only four “potential causes of the long term rise in water levels.” (1) leakage from potash tailings ponds; (2) leakage from poorly cased or improperly plugged boreholes; (3) leakage of brine injected at depth for secondary oil recovery or salt water disposal; and (4) vertical leakage from the shallow water table in Nash Draw.” (page 4) None of the above can be the cause of the long-term rise in water levels in the Culebra and Magenta, because all would require water to flow upgradient, which it cannot do. The cause is obvious when the long-term rises at specific wells in specific locations are analyzed and compared. The water table is still recovering from the cone of depression caused by the sinking of the WIPP shafts beginning in July 1981. The water levels have risen by 69.34 feet at ERDA-9 and by 75.10 feet at WIPP-21, the two test wells nearest to the center of the WIPP site. Water levels in the wells outside the periphery of the WIPP site have risen by less than 10 feet, with the exception of H-17. Contour lines can be drawn depicting what appears to be a mound, but is in fact the partial recovery of the water table from the human-induced cone of depression. This means that the difference between the hydraulic heads of Nash Draw and the center of the WIPP site is 60 to 65 feet greater than before, and because only two test wells within the WIPP site (H-6 and WIPP-12) appear to have equilibrated, the hydraulic gradient will continue to increase as the water levels continue to rise, thereby facilitating groundwater flow toward Nash Draw.*

(4) The Culebra is not a confined aquifer

*“... the Culebra Dolomite Member of the Rustler Formation ... has been found to be the most significant potential groundwater transport pathway for radionuclides released from the WIPP repository by inadvertent human intrusion.” (page 1) And again: “The Culebra Dolomite of the late Permian Rustler Formation is the most transmissive saturated unit above the WIPP repository.” (page 2) The Culebra may or may not be the most transmissive groundwater pathway. Both the Magenta dolomite (at test well H-3) and the Dewey Lake Redbeds (at test well WQSP-6a), within the WIPP site, very close to the waste disposal area, have yielded transmissivities four times greater than the Culebra dolomite. At WIPP-33, open, water-filled caverns were found in the Magenta, Forty-Niner, and Dewey Lake; none were in the Culebra. The truth is that the Culebra dolomite was the only groundwater pathway considered in the Compliance Certification Application (CCA). This was said to be an analysis of the worst case scenario, other groundwater pathways being deemed less transmissive. But it also served the purpose of enabling Sandia Labs to model the Culebra as a single confined unit, without having to take into consideration rainwater recharge or any vertical component to groundwater flow.*

*The Conceptual Models Peer Panel found that the conceptual model “failed to correlate the detailed hydrogeology of the Culebra with its tested hydrologic character.” (page 1)* This statement only begins to address the failure. The Rustler Formation cannot be adequately modeled as confined flow within a 25-foot interval of dolomite. The Rustler Formation is a complex aquifer involving five distinct and interconnected members, composed of both dolomite and anhydrite/gypsum, with open fractures and solution channels providing preferential pathways for groundwater transport. The perched water sometimes found in the overlying Dewey Lake Redbeds and Santa Rosa sandstone are also part of this same groundwater system. A two-dimensional model of groundwater flow confined to a 25-foot-thick marker bed is not at all representative of actual conditions in the field.

(5) Groundwater transmissivity values are much too low

Simply stated, transmissivity is the rate at which water is transmitted through an aquifer. *Sandia Labs claims to have utilized transmissivity values for the Culebra that are: (1) “consistent with observed groundwater heads,” (2) “consistent with groundwater responses in the Culebra to pumping tests,” and (3) “consistent with water chemistry.” (page 3)* These statements are misleading, because of the use of partial data sets by Sandia Labs. (1) Hydraulic heads show that the ultimate discharge point for groundwater from the WIPP site is at Laguna Grande de la Sal, in Nash Draw, one of the largest surface karst features in North America. WIPP-29, located very near Laguna Grande, has by far the lowest hydraulic head of any WIPP test well. Had this well been included in Performance Assessment, any modeled groundwater flow path would have, necessarily, entered into this karst terrain. Only by excluding WIPP-29 from its data set of hydraulic heads was Sandia Labs able to manipulate its model to simulate a groundwater flow path southward from the WIPP site, away from Nash Draw (Phillips and Snow, 1997, *Potential Flow Paths from the WIPP Site to the Accessible Environment*, Table 2; Phillips and Snow, 1998, *A Conceptual Model for Contaminant Transport in Karst Aquifers at the WIPP Site*, p. 13, and Table 4, p. A-5). (2) The transmissivity values selected for Performance Assessment are consistent only with pumping tests that yielded results acceptable to Sandia Labs. Only those derived from single-well pumping tests, or from triangular arrays of test wells tens of meters apart, were used in Performance Assessment (Beauheim, 2008, *Responses to Questions from the Peer Review Panel*, p. 10). Only by excluding measured transmissivities from multi-well pump tests, derived from rapid responses in test wells thousands of meters apart, was Sandia Labs able to manipulate its model to produce the desired groundwater travel time. (3) Geochemistry of Rustler groundwater is, in fact, consistent with westward flow from the WIPP site toward Nash Draw. Dissolved sodium and chloride decreases steadily from east to west across the WIPP site, being higher to the east, where halite remains in the Rustler, and lower to the west, where there is no halite in the Rustler. Culebra groundwater at the WIPP site is everywhere fresh enough to dissolve more halite, and contains dissolved sodium and chloride even where there is no halite in the Rustler – that is, west of the Rustler dissolution front. This requires a westward component to groundwater flow, and is consistent with the interpretation that Culebra groundwater becomes mixed with increasing amounts of fresh water as it approaches Nash Draw. (Phillips and Snow, 1997, *Potential Flow Paths from the WIPP Site to the Accessible Environment*, pp. 4-8, Table 1, Figure 1, and Figure 2, inclusive).

*“The specific genesis of some features, such as the high-T (transmissivity) feature that extends into the southern part of the WIPP and terminates at a low-T (transmissivity) area, cannot be determined. However, well test data provide strong evidence of the feature, and limited cores through the Culebra show that transmissivity values are strongly influenced by the presence or absence of CaSO<sub>4</sub> (gypsum) cements and fracture fillings.” (page 8)* Of course this is true. The Culebra and Magenta dolomites are fractured rocks and, as the Peer Review Panel noted, these fractures “serve as preferential pathways for groundwater flow.” Open fractures, from which gypsum cements and fracture fillings are absent, will be more transmissive to groundwater than fractures where cements and fillings are present. As the Peer Review Panel correctly observed, *“the potential for similar features elsewhere in the model domain outside the area of intensive well-to-well testing cannot be dismissed.”* Moreover, this high-transmissivity pathway does not “terminate at a low transmissivity area.” It veers southwestward into Nash Draw where the transmissivities are higher and the hydraulic heads are lower. (Phillips and Snow, 1997, *Potential Flow Paths from the WIPP Site to the Accessible Environment*, p. 11).

*Sandia National Laboratories proposes “to incorporate additional information that has been obtained and developed since the CCA in order to demonstrate that the conceptual understanding of the Culebra is adequate...” (page 1)* Specifically, Sandia Labs intends to justify its stochastic method – that is, interpolating between data points to assign transmissivity values at locations untested in the field. One wonders why Sandia Labs has not yet incorporated into its model the transmissivity data from multi-well pump tests (Beauheim, 2008, *Responses to Questions from the Peer Review Panel*, p. 10). Moreover, to incorporate additional data “in order to demonstrate” any preconceived notion is the reverse of the scientific method. One should develop a conceptual model wholly consistent with the body of evidence, not vice versa.

*“The peer review process consisted of an in-depth analysis and evaluation of: 1. Validity of assumptions; 2. Alternate interpretations; 3. Uncertainty of results and consequences if wrong; 4. Appropriateness and limitations of methodology and procedures; 5. Adequacy of application; 6. Accuracy of calculations; 7. Validity of conclusions; and 8. Adequacy of requirements and criteria, in accordance with approved technical and quality assurance requirements and the applicable peer review plan(s).” (page 2)* Not included in this list is: Validity of data. The highest measured transmissivities generally came from multi-well pump tests, none of which were incorporated into the CCA. These values are real. They were measured in the field. Sixteen of them are one or two orders of magnitude (10 or 100 times) higher than the values selected for Performance Assessment (Phillips, 1998, *Rebuttal to DOE Response to CARD Comments*, Table 1, page 9; updated in Phillips and Snow, 1998, *A Conceptual Model for Contaminant Transport in Karst Aquifers at the WIPP Site*, Table 3, p. A-3). When the most unfavorable data are excluded, the remaining data set is not valid.

*“An error by orders of magnitude in the (transmissivity) fields would be necessary to significantly affect the Culebra contribution to the overall radionuclide release. The Panel sees no basis for such an error.” (page 21)* This can only be because the Panel did not see the relevant data. As shown in Phillips and Snow (1998, *A Conceptual Model for Contaminant Transport in Karst Aquifers at the WIPP Site*, Table 3) there are sixteen WIPP test wells at which the transmissivities utilized in Performance Assessment are one to two orders of magnitude (10 to 100 times) lower than the highest Culebra transmissivities measured in the field.

## Implications

The conceptual groundwater model of Sandia Labs, and therefore its Performance Assessment, is fatally flawed. The model wrongly assumes zero rainwater recharge, when in fact the water levels in both the Culebra and Magenta rise in response to major rainstorms. The model wrongly treats the Culebra as a confined aquifer with horizontal flow only, bounded above and below by impermeable rocks, when in fact the Culebra is recharged by rainwater infiltrating through overlying units, which requires a three-dimensional model with a vertical component to groundwater flow. The model wrongly assumes that no dissolution has occurred, or is occurring, in the Rustler Formation, when in fact the Culebra is recharged by fresh water which must therefore be passing through feeder channels in the overlying soluble rocks and enlarging them by dissolution as it does so. The model wrongly assumes the Culebra to be in hydraulic steady state, when in fact the water table at the center of the WIPP site has risen by 75 feet and still has not fully recovered from the sinking of the WIPP shafts. The model wrongly excludes hydraulic head data from the vicinity of Laguna Grande de la Sal, thus steering the assumed groundwater flow path in a southerly direction, away from the surface karst terrain of Nash Draw. The model wrongly excludes transmissivity measurements derived from multi-well pump tests, and thus underestimates groundwater velocity and overestimates groundwater travel times by one to two orders of magnitude. The model bears little or no resemblance to reality. The model must be withdrawn, and the WIPP certification rescinded.

The revelation that Culebra water levels in test wells at the WIPP site fluctuate with rainfall is critical, because it leads to the inescapable conclusion that the WIPP site is undergoing the same dissolution processes as the rest of the Pecos River Valley. There is no longer any other credible explanation. The Culebra dolomite is overlain by soluble rocks – anhydrite, gypsum, and, in places, halite. If fresh rainwater is reaching the Culebra through these overlying units, it must be flowing downward through open channels and enlarging them by dissolution as it does so. Alternative explanations require groundwater to flow upgradient, which it cannot do. Rainwater cannot be entering Culebra outcrops directly and flowing thence to the WIPP site, because the only nearby surface exposures of the Culebra are near Laguna Grande de la Sal in Nash Draw, which is downgradient from WIPP; modeling would have shown this if test well WIPP-29 had not been excluded from the data set of hydraulic heads utilized in Performance Assessment. Nor can the WIPP recharge area be at Clayton Basin (Final SEIS-II, 1997, p. 4-21), or at Bear Grass Draw (CCA, 1997, Appendix HYDRO, p. 51), as previously postulated by DOE, because these locations are 10 and 25 miles north of the WIPP site, and recharge that far away cannot account for such a rapid response to rainfall in test wells at the WIPP site. Nor can flooding of potash mines in the Salado, or secondary oil recovery in the Bell Canyon and lower formations, account for the rapid response, because these formations are lower than the Rustler in the stratigraphic column, and because this explanation requires human activity to correlate with rainfall.

In short, the WIPP conceptual model is a failure. It fails to correlate with the tested hydrology of the Rustler aquifer. Because the WIPP was certified on the basis of this false model, the certification must therefore be rescinded.