February 22, 1993

Mr. W. John Arthur, III
Project Director
WIPP Project Integration Office
6501 Americas Parkway, Suite 903
Albuquerque, NM 87110

Attn: Patrick Higgins, WPIO
    Mark Matthews, WPIO
    Ravi Batra, WPSO

Re: Transmittal of the Technical Support Groups' Report of Findings on Culebra Tracer Testing

Dear Mr. Arthur:

The Technical Support Group (TSG) was tasked to provide the WPIO Configuration Control Board with recommendations that could facilitate a decision on funding of the SNL proposed Experimental Plan for Tracer Testing in the Culebra Dolomite at the WIPP Site, dated October 15, 1992. Enclosed are four copies of the Technical Support Group Report on Culebra Tracer Testing.

The report is specific to the questions that were asked of the TSG. However, there are several significant issues that were identified during the course of the TSG's analysis of the proposed test plan that are of concern to the TSG. In the interest of expediting the subject report, the TSG will prepare a separate follow on letter report that addresses the additional concerns. The letter report will be to you by the end of February.
The recommendations from the TSG are:

1. The types of tests outlined in the reviewed test plan are helpful in resolving the hydrogeologic characterization of the Culebra. However, the test plan should be augmented to present a program that addresses a broader set of issues than the preliminary version does. This augmented plan should also address cost and schedule optimization for the program outlined in the revised plan. The "final" test plan is currently scheduled for completion in September 1993. The TSG recommends the technical questions listed below, at a minimum, be addressed in the final plan.

A. How will the tests discriminate among candidate conceptual flow models and serve to validate the appropriate choice or combination of choices for the Culebra?

B. How will the question of "scale-up" of the field flow results to a grid size that matches the grid utilized in performance assessment be approached?

C. What is the basis for location of the test site(s) and, if preliminary drilling is deemed advantageous, where precisely will it be done and why was that site chosen?

D. Is it desirable to incorporate existing pumping test data that may not have been analyzed or that require additional interpretation to better define the flow field? If so, what is required to incorporate those data into current analysis?

E. What drilling procedures will be used to ensure that core and water samples can be obtained that are suitable for laboratory analysis?

F. How are the laboratory retardation results to be scaled-up and correlated with field retardation results? How will the results be further scaled-up to the performance assessment grid size?

G. How will all the results be incorporated into performance assessment and how does the experimental schedule mesh with performance assessment schedule commitments?
H. What is the relative importance of each of the experimental objectives (e.g., rank them); and how do each of these objectives contribute to compliance demonstration?

I. How will the experimental data be used to draw conclusions that are valid for the entire regulatory period (10,000 years)?

J. What is the statistical basis for selecting samples utilized in determining the values for the coefficients (elements) of retardation? How will the mechanisms creating retardation be established? Why is the range of geochemistries investigated adequate to bound the conditions that might occur throughout the regulatory period?

K. What tests and methodology will be utilized to resolve the effect of the numerous wells to the south of the site on the present and long term flow field?

2. The apparent disconnect between performance assessment and the experimental program must be resolved. DOE will be judged on the conceptual model, data supporting that model, and resulting calculations. Two specific suggestions for improvement are:

A. Formal procedures could be developed to ensure that the experimental program supports performance assessment data needs and that the performance assessment model reflects experimental understanding. One implication here is that the experimentalist may develop a much greater interest in participating in finalization of the performance assessment conceptual and mathematical models. A question to be considered is who is responsible for defending the results presented by the performance assessment group?

B. SNL should consider instituting some process that ensures communication between the data generation groups and Performance Assessment. A major objective of the process would be to define the data and model elements necessary to provide sufficient resolution of the regional hydrology to support a preferred baseline case for describing the present hydrological condition.
Please do not hesitate to contact me at (505) 845-6321 or Dave Lechel at (505) 845-6290 with any questions you may have concerning this report.

Sincerely,

[Signature]

John A. Thies
Project Manager

cc:
G. Hanson
D. Lechel
B. Root
D. Sala
B. Farrell

Issue

The WIPP Project Integration Office (WPIO) Change Control Board (CCB) requested the Technical Support Group (TSG) to provide recommendations in support of a decision on partial funding of an $8 million plan for a new set of tracer tests in the Culebra Dolomite Member of the Rustler Formation.

Importance

Human intrusion scenarios, which presume future inadvertent drilling activity intercepts an underlying pressurized brine reservoir and/or the repository, have focused on the Culebra Member of the Rustler Formation as the final barrier in the potential pathway to the 40 CFR 191 Subpart B subsurface compliance boundary. A determination of the effectiveness of the Culebra as a geologic barrier to radionuclide transport is therefore important in demonstrating compliance with this regulation. A sound technical position must be prepared if the U. S. Environmental Protection Agency (EPA) is to accept a U. S. Department of Energy (DOE) position that the Culebra is a natural geologic barrier to the release of radionuclides. The data to be collected from the proposed Culebra Tracer Tests will provide additional information that will be useful in demonstrating the effectiveness of the Culebra barrier. The unresolved issue is whether the proposed additional tests will lead to a successful defense of the radionuclide transport retardation affects included in the performance assessment (PA) model. The objectives of the test program should align with the reduction in uncertainty necessary for validation of the conceptual model, mathematical model and sensitive parameter ranges utilized to predict radionuclide transport.

Scope of Evaluation

The questions to be answered are as follows:

(1) Are additional experiments for fluid flow and transport characterization of the Culebra necessary? If additional testing is necessary, (2) will the planned Culebra Tracer Tests, as described in the proposed test plan, provide a final additional set of data that can be used to establish that the Culebra retards radionuclide transport to the degree necessary to demonstrate the Culebra is an effective geologic barrier? This report is specific to resolving these questions.

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Conclusions

In response to the two questions stated above, the TSG concludes that additional characterization of the Culebra is necessary but that the preliminary "Experimental Plan for Tracer Testing in the Culebra Dolomite at the WIPP Site", dated October 15, 1992, will not provide a final (comprehensive) set of data. The experimental plan needs substantive modification and refinement. Revisions to this plan (and/or a governing experimental plan of which this specific test plan is a subset) should support an objective of developing a comprehensive set of data that will fulfill all the data requirements for model selection and validation. An important consideration is that the National Academy of Sciences (NAS) has cautioned, in the September and December 1992 meetings, that the proposed Culebra Tracer Tests may not substantially contribute to the overall reduction of an already high uncertainty level. The task confronting the WIPP Project is to define an integrated experimental program that will reduce the uncertainty to acceptable levels or, at least, quickly identify critical performance assessment parameters whose uncertainties will not be reduced to acceptable levels by the planned experiments. Specific TSG conclusions with brief supporting rationale follow:

1. **Retardation in the Culebra:** Experimentally derived fluid flow velocities indicate fairly rapid movement of fluid to the compliance boundary relative to the regulatory period. Therefore, the Culebra cannot be assumed to be a major barrier to radionuclide transport if retardation is not demonstrated to the satisfaction of the regulatory agencies. An experimental determination of chemical (primarily) and physical retardation is vital to establishing robust evidence that the Culebra is an effective geologic barrier. This must be done in the laboratory with corroboration in the field.

   **Summary Rationale:** Experimental determination of distribution coefficients ($K_d$'s) is required to establish a conservative range of values for each element of retardation. In fact, DOE has agreed with the State of New Mexico in the Consultation and Cooperation Agreement that, "in the absence of experimentally justifiable values, $K_d$ will equal zero, e.g., no credit for retardation will be taken in the performance assessment calculations". Current field experimental data support estimated fluid flow velocities in the range of 1 meter per day to 1 meter per year. In meetings with the TSG, Sandia National Laboratory (SNL) scientists agreed that the estimated flow velocities, when integrated over the general flow path from the storage panel area to the vertical compliance boundary, translate to fluid arrival times at the subsurface compliance boundary that generally range from 100 to 1,000 years. This is an indication that flow time alone cannot be relied upon to ensure compliance. However, additional phenomena act to reduce the concentrations of radionuclides reaching the boundary. These concentrations will be diluted (at least initially) by chemical and pressure gradient diffusion into the relatively static fluid volume (currently assumed to be about 100 times larger than the dynamic fluid volume) contained in the nonconductive pores of the rock matrix. This dilution, or physical retardation, delays the time it takes to accumulate a total release that may exceed the 40 CFR 191 Subpart B standard, although the delay in some scenarios
may be substantial. Compliance may be assumed if very long-term or permanent chemical retention of the radionuclides in the rock matrix can be shown. Chemical bonding with the host rock and/or filler materials (generally clay) would ensure long-term retention. However, the degree to which this chemical retention occurs has not been established experimentally, which remains as a potential breach of the previous agreement with the State until these experiments are completed.

2. **Flow in the Culebra:** Additional characterization of the Culebra will enhance the basis for establishing a representative hydrologic model. Selection of a model type that adequately represents all the observations is an important element of compliance demonstration. Care should be exercised to not bias the approach for differentiating between flow model types, especially in light of the strongly held view that dual porosity is the correct model type.

Summary Rationale: In addition to the retardation, uncertainties still exist with other fundamental issues. These issues include identification of the physical characteristics of the pathways (e.g., layers, channels, fractures, connection of fractures with matrix porosity). For example, there is general agreement within SNL that the Culebra is a layered member, but layering has not been directly incorporated into the model. In another example, INTRAVAL has suggested a conceptual flow model based entirely on channeling also will produce an acceptable fit to the current data; but current modeling utilizes a dual porosity concept instead. The implication is that if only channel flow is occurring the retardation will be considerably reduced. The inability to convincingly answer such questions indicates an incomplete understanding of the flow regime. A well characterized flow regime is necessary to the establishment of acceptable retardation values.

3. **Integration of the Performance Assessment and Experimental Programs:** As an addendum to these technical conclusions, the TSG notes a lack of integration of the experimental program and the performance assessment group. This is a concern in that it affects the Project’s chances of reaching a sound scientific basis for compliance. Finding ways of fostering closer integration, or at least more effective cooperation, would greatly enhance the quality and defensibility of the resulting performance assessment; and therefore is an integral part of rectifying the technical issues addressed in this report.

**Recommendations**

The TSG review of the "preliminary" Culebra Tracer Test Plan and meetings with SNL staff culminated in the following recommendations. These recommendations will aid in promoting both a comprehensive experimental test program and a broad-based compliance strategy.

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The types of tests outlined in the reviewed experimental plan are helpful in resolving the hydrogeologic characterization of the Culebra. However, the plan should be augmented to present a program that addresses a broader set of issues than the preliminary version. This augmented plan should also address cost and schedule optimization for the program outlined in the revised plan. This "final" test plan is currently scheduled for completion in September 1993. The TSG recommends the technical questions listed below, at a minimum, be addressed in the final plan.

A. How will the tests discriminate among candidate conceptual flow models and serve to validate the appropriate choice or combination of choices for the Culebra?

B. How will the question of "scale-up" of the field flow results to a grid size that matches the grid utilized in performance assessment be approached?

C. What is the basis for location of the test site(s) and, if preliminary drilling is deemed advantageous, where precisely will it be done and why was that site chosen?

D. Is it desirable to incorporate existing pumping test data that may not have been analyzed or that require additional interpretation to better define the flow field? If so, what is required to incorporate those data into current analysis?

E. What drilling procedures will be used to ensure that core and water samples can be obtained that are suitable for laboratory analysis?

F. How are the laboratory retardation results to be scaled-up and correlated with field retardation results? How will the results be further scaled-up to the performance assessment grid size?

G. How will all the results be incorporated into performance assessment; and how does the experimental schedule mesh with performance assessment schedule commitments?

H. What is the relative importance of each of the experimental objectives (e.g., rank them); and how do each of these objectives contribute to compliance demonstration?

I. How will the experimental data be used to draw conclusions that are valid for the entire regulatory period (10,000 years)?

J. What is the statistical basis for selecting samples utilized in determining the values for the coefficients (elements) of retardation? How will the mechanisms...
creating retardation be established? Why the range of geochemistries investigated is adequate to bound the conditions that might occur throughout the regulatory period?

K. What tests and methodology will be utilized to resolve the effect of the numerous wells to the south of the site on the present and long term flow field?

The term "comprehensive" could be substituted for the term "final" used in this report to describe the desired status for the data to be generated from the proposed test program. The important message is that reactionary experimental testing often leads to additional unplanned testing programs. DOE can not afford to be dependent on a test plan that does not address all of the issues or potential issues related to validating a representative flow model. Within the bounds of current knowledge, this test plan must encompass collection of all the data that will be required for validation. In this sense "final" means there is a high level of certainty that unplanned tests will not be required after the proposed tests are concluded.

2. The apparent disconnect between performance assessment and the experimental program must be resolved. DOE will be judged on the conceptual model, data supporting that model, and resulting calculations. Two specific recommendations for improvement are:

A. Formal procedures should be developed to ensure that the experimental program supports performance assessment data needs and that the performance assessment model reflects experimental understanding. One implication here is that the experimentalist may develop a much greater interest in participating in finalization of the performance assessment conceptual and mathematical models. A question to be considered is who is responsible for defending the results presented by the performance assessment group?

B. SNL should consider forming a hydrogeology intergroup team or instituting some other process that ensures communication between groups. A major objective of this interactive team would be to define the data and model elements necessary to provide sufficient resolution of the regional hydrology to support a preferred baseline case for describing the present hydrological condition.

Background Observations and Analysis

During this review process, the importance of the national and international scientific interchange sponsored by SNL has become apparent. This interchange has resulted in the identification of issues that need to be addressed by the experimental and performance assessment programs. The SNL initiative to institute the proposed Culebra testing seems to be partially in response to this influential scientific community.

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In a joint meeting with SNL performance assessment and experimental program staff, agreement was reached that estimated water flow rates within the WIPP site are bounded by a range of \(1\) meter per day to \(1\) meter per year. This estimated range is based on fracture flow. It is generally agreed that the flow over the storage panels will be in a south-easterly direction until it intersects a much higher transmissivity zone with flow to the site boundary in a southerly direction. In a later meeting with the experimental program group, there was agreement that the integration of these variations in flow rates from the storage panels to the site boundary will not exceed an aggregate flow time of \(1,000\) years and could be as low as \(100\) years. This conclusion is in apparent disagreement with travel times published in the working draft 1992 Performance Assessment Report (9,000 to 14,000 years).

Features of the present flow system in the Culebra suggest a possible relationship with the oil and gas wells located south of the WIPP site. These features include (1) an anomalous flow direction (south) which is not the direction of the slope of the topography as is the usual case, (2) closed potentiometric depressions to the south that suggest vertical loss of water, and (3) low hydraulic head in the Culebra with respect to the Magenta above the Rustler-Salado Residuum below. The features could be explained by depletion of hydraulic head in the Culebra in the vicinity of the oil and gas wells resulting from vertical leakage between the Culebra and pressure-depleted petroleum production horizons. Consequently, the flow system may change after oil and gas production cease.

The SNL performance assessment report for 1991 discusses recharge and discharge in Volume 1, pages 5-32 to 5-34. This discussion states that "There is no direct evidence for the location of either recharge to or discharge from the Culebra Dolomite" and that "small amounts of inflow may also occur as leakage from overlying units throughout the region." Quantifying this vertical leakage is important because it may have a substantial effect on dilution of any contaminant that enters the Culebra. Note that Figures 5-13 and 5-14 show a hydraulic head difference between the Magenta and Culebra of 45 feet (959-914 at the southeast corner of the WIPP site). These units are separated by the Tamarisk, which has an average thickness of 118 feet at the WIPP (p. 5-16). Thus the vertical hydraulic gradient is about 0.38 ft/ft. If the vertical hydraulic conductivity of the Tamarisk were \(10^{-12}\) m/s (which seems possible), crude Darcy calculations show that most of the flow in the Culebra would be coming from vertical seepage. Furthermore, the head in the Rustler-Salado Residuum is also considerably higher than the head in the Culebra, suggesting the possibility of upward flow as well. These considerations do not prove that vertical recharge to the Culebra is significant, but suggest that it might be and that it is worthy of investigation. Also note that the low head in the Culebra relative to units above and below is consistent with depletion of head in the Culebra by leakage around oil and gas well casings to the south. If the oil and gas wells are affecting head in the Culebra, vertical leakage may change in the future if the effect of the wells changes.

INTRAVAL has suggested that a channel flow model be considered as an alternative to the dual porosity model now used to describe the Culebra. This channel model could possibly result in much less matrix contribution to retardation than is currently assumed. Either the existence of

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channel flow needs to be shown to be minimal (on the scale of the performance assessment model) or it needs to be shown that the channel flow and matrix retardation are both occurring and not mutually exclusive. It is unlikely that the system operates as a single porosity system because it is already known from examination of the cores that the matrix is porous and has interconnecting fractures. It is reasonable to attempt to demonstrate by field testing that the system is dual porosity and to quantify the effect of clay fracture linings in answer to the INTRAVALE suggestion. Otherwise, the regulatory agencies may require testing at a late stage of the permitting process.

There are large zones within the regional hydrologic model that have not been well characterized with data, but only modeled by Kriging techniques. An example is the zone south of the repository along the most direct geometric path to the vertical compliance boundary. The Environmental Evaluation Group (EEG) has suggested that a well be placed in this zone. The NAS WIPP panel made the same observation in the December 1992, meeting in Albuquerque. The TSG adds emphasis by reaching the same conclusion. A final set of data should include tests (even if simple) to obtain hydrologic parameters in one or more of the regions that have not been investigated.

There is a prevailing view within SNL that the probabilistic analysis currently used in performance assessment to define the range of possible transport paths and transport times adequately bound the hydrogeologic regime over the range of time required (10,000 years). That may not be true because of scale dependencies not yet accounted for and differences in hydrologic and chemical behavior not yet explained.

Several clauses in the "1988 Modification to the Working Agreement of the Consultation and Cooperation Between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant" have special relevance to the hydrological mapping of the Culebra and to the determination of transport retardation factors. Quotes from one clause are "Development of a generalized three-dimensional regional flow model extending from the ground surface to the Bell Canyon Formation. Care will be taken that, over the long term, geologic and modeling expertise and interpretations developed as part of WIPP site-characterization activities are included in such modeling." Quotes from a second clause are "DOE recognizes that radionuclide retardation within the Culebra remains to be proven experimentally and remains committed to demonstrate experimentally the actual range of $K_d$’s to be expected for transport within the Culebra. It is unlikely that transport will involve a single set of $K_d$ values, and performance assessment likely must consider a range of values for each element. DOE will select, after consultation with the State, a range of values to be conservative, but reasonable, based on the lowest reasonable values experimentally obtained. In the absence of experimentally justifiable values, $K_d$ will equal zero, i.e., no credit for retardation will be taken in the performance assessment calculations."

One of the major objectives of the Culebra Tracer Tests is to collect enough retardation data to satisfy the Consultation and Cooperation Agreement with the State of New Mexico. This

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agreement stipulates, as stated above, that the flow model's radionuclide distribution coefficients must be set to zero until a defensible value has been established experimentally. The planned tests (including the laboratory phase) can provide a valuable set of data. However, additional data from other zones will probably be required.

Despite the uncertainty in the overall model, SNL experimental staff state that physical and chemical retardation of the radionuclides will occur and will provide a very large reduction to total release. This opinion contrasts with some NAS WIPP panel members' comments in the quarterly meetings with WIPP that DOE will not be able to take credit for chemical retardation ("You will have to set the $K_d$ coefficients to zero").

Assuming chemical retardation is important, the hydrogeology over the storage panels should be known with a greater degree of certainty than the higher transmissivity zones to the east. If retardation is demonstrated, most of the retardation should occur in the region above the repository since this is the first region to be exposed. Also the low transmissivity of this region means the brine resides in this region much longer than in the faster flow zones to the east. The TSG designated this region as the "local zone" in our internal discussions because of the relative importance this zone attains if retardation is necessary to demonstrate compliance. Current plans do not include additional characterization of this zone.

The objectives of the Tracer Tests, as described by the SNL staff planning them, are to provide evidence for a matrix retardation component and to further characterize the flow regime in the highest known conductivity path to the boundary. These objectives are important and will contribute to a final resolution. The printed objective of proving or disproving channel flow, although directly related to these real objectives and interesting from a scientific view, is not the basic objective. The basic objective should be to establish a modeling approach that provides a representative description of the Culebra flow.

An important aspect of the proposed field testing is to provide high quality core and fluid samples for laboratory testing. This aspect has not been fully stated and incorporated into the experimental plan.

A recurring question is whether or not credit for physical or chemical retardation of radionuclide transport within the Culebra is even necessary to compliance arguments because compliance might be proven without reliance on the retardation provided by the Culebra. Dr. Wendell Weart pointed out to the TSG that viewing the Culebra, as an additional potential geologic barrier, serves an important role of increasing the confidence in demonstration of regulatory compliance. Even if the additional barrier is not needed or an exact value cannot be put on the effect of the barrier, this is a compelling argument. Dr. Weart's point is valid even if radionuclide retardation within the Culebra aquifer is not needed to demonstrate compliance.

Future changes in the hydrogeology that are a result of climate changes, etc. do not appear to be sufficiently developed in current performance assessment analysis. A major focus has been

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to predict transport pathways and transport times based on best-fit transmissivity zones that satisfy the observed hydrological response in existing wells. This means that possible future conditions have to be applied to a maze of best fit transmissivity zones since the baseline definition consists of multiple best fit cases.