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MEMORANDUM FOR: John Greeves, Chief
Engineering Branch
Division of Waste Management

FROM: Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

SUBJECT: DRAFT FINAL REPORT - BASALT WASTE ISOLATION PROJECT: HANFORD SITE DISQUALIFYING CONDITION - PRELIMINARY POSITION FOR REPOSITORY WATER INFLOW UNDER HIGH PRESSURE SEPTEMBER 1984

As you requested, I have had Matthew Gordon of my staff review the hydrologic aspects of the subject report by R.D. Allen of PNL. His comments are summarized below:

1. The document presents three calculations of instantaneous water inflows into a tunnel beneath the Hanford Site. As discussed below, the calculations will likely lead to underestimates in initial water inflow. However, they may overestimate the longer-term inflow rate, as noted by Allen on page 5.7.

2. The document presents a summary of parameter values for hydraulic head, hydraulic conductivity, and storativity of the various aquifers and confining units, which are based on what the NRC staff considers to be optimistic interpretations of data in which the NRC staff has limited confidence. As noted in NUREG-0960, and in a letter from Wright to Olson (May 25, 1984) Attachment 1, the heads and hydraulic property data collected during the BWIP drill and test program reflect, at best, the conditions in the immediate vicinity (i.e., tens of meters) of the borehole. Higher conductivity zones, channels, etc., are not likely to have been detected in these tests. The measurements are further confounded by the effects of fluid temperature, wellbore skin, wellbore storage and irregular testing procedures as noted in the attached letter from Wright to Olson. There are also several cases of incorrect analytical interpretations of hydraulic tests, such as in the Strait and Spane reports listed in the documents' reference section. For example, the report on hydraulic testing of the Cohassett colonnade/entablature at RRL-2 has been reviewed by NRC (memo from Knapp to Miller, January 15, 1985, Attachment 2) and was found to probably underestimate the horizontal hydraulic conductivity of that unit by at least an order of magnitude.

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Other tests were also analyzed incorrectly, e.g., the over-pressure pulse test of the Cohassett flow top. For this test, an incorrect application of the analytical method apparently resulted in an under-estimate of the hydraulic conductivity by a factor of twenty. These reports have never been corrected by BWIP. Due to the uncorrected analytical errors and the uninvestigated uncertainties, the test results should not have been used in the subject report. It would have been more appropriate to use a bounding value of horizontal hydraulic conductivity slightly higher than the highest measured values to date.

3. A two-order-of-magnitude uncertainty in the hydraulic conductivity is claimed to have been assumed in the calculations. This uncertainty does not seem to be reflected in the three cases analyzed. In any case, the uncertainty range described should be substantially larger than two orders of magnitude for the reasons noted in item 2 above. In fact, the actual systematic error in analysis, by itself, probably approached two orders of magnitude without even considering the uncertainties in scale, spatial variability, etc.

4. On page 4.11, estimates from uncited "earlier studies" of vertical hydraulic conductivity are presented. There have been no acceptable direct tests nor indirect interpretations of vertical conductivity to date. Thus, there is currently no basis for evaluating potential inflow into the roof or floor of the tunnel in the presence of a vertical gradient, unless DOE can develop a supportable bounding estimate of vertical conductivity.

5. The ambient horizontal hydraulic gradient is estimated to be in a range of 10^{-4} to 10^{-3}. However. the method used to calculate hydraulic gradients is faulty and non-conservative, as we noted in our comments on the draft BWIP EA (comment no. 6-15). Also, gradients higher than 10^{-3} can be inferred, even based on the faulty method (see comment no. 6-15 from NRC's Draft EA review.)

6. The factor of 3.1 in each of the estimates of hydraulic conductivity on page 3.4 suggests that the values were obtained by converting order-of-magnitude estimates in terms of feet/sec to meters/sec. It may be more appropriate to convert hydraulic conductivity to meters/sec prior to rounding to the nearest order of magnitude.

7. It is indicated in the document that any aquifer would be incapable of supplying the calculated potential flow rates (page 5.6). The potential for local connections between aquifers has not been considered in reaching

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this conclusion. Recent data collected at the Hanford site appears to indicate strong vertical connection between the Rocky Coulee and Cohassett flow tops at DC-20C. While this observation may be an anomaly, it is possible that such vertical connections exist at other locations. Also, there may be other high-conductivity zones such as the fracture zone encountered in the Umtanum interior at RRL-2. These vertical connections and high conductivity zones might provide an increased water supply to allow sustained high water inflows into a tunnel.

8. In cases I, II, and III on pages 5.5 and 5.6, it is not clear how the numbers used for fracture and aquifer properties were derived. The numbers used for fracture properties appear to be fairly conservative compared to data in Long and WCC (1984). The 800 ft. head difference between the aquifer and the open tunnel does not appear unreasonable. However, the condition of a meter distance between the aquifer and the tunnel would not likely be present for the host rock units being considered.

9. In case III, the tunnel is assumed to intersect the Cohassett flow top. Apparently to avoid the infinite head gradient that occurs mathematically at the discontinuity in head, a one meter distance over which the head drop occurs is assumed. A more appropriate model may be one of the type described by McWhorter (1981); a discussion by Walton (1982) of this type of analytical model is attached (Attachment 3).

10. The concept of transient decay of inflow presented on page 5.7 appears to be reasonable; however, the calculated rate of decay and quantity of inflow are impossible to evaluate without more information about the boundary conditions and hydraulic properties assumed. (The McWhorter (1981) analytical solutions attached are appropriate for transient analysis.)

Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

Enclosures:
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Enclosures available in DCC.

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Attachment to [illegible] 9/30/85 To J. Greeves

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Attachment 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 25 1984

~~MAY 22 1984~~

Mr. O. L. Olson
U. S. Department of Energy
Richland Operations Office
BWIP Project Office
P. O. Box 550
Richland, Washington, 99352

Dear Mr. Olson:

During January 9-16, 1984, members of the NRC technical staff and consultants undertook a review of hydrogeologic test data at the BWIP. The visit was part of the ongoing technical prelicensing interaction between the NRC staff and the Basalt Waste Isolation Project. The purpose is to identify, early on, potential licensing issues and information needs and to reach agreement on approaches for their resolution during site characterization.

Enclosure I (Trip Report) describes the review procedures of the NRC group. It also tabulates the materials collected by the review team. Copies of these materials have been placed in NRC's public document room in Washington, D.C. and in the licensing public document room at the Richland Public Library. This letter provides our comments on the hydrologic test data reviewed during and after the site visit.

I wish to call your attention to an important observation: --

> "As stated in NUREG-0960 and in this letter (see Appendix I), NRC concludes that much of the single-well data collected to date is questionable in terms of its numerical accuracy"-- item 1, bottom of page 2. (The reference to NUREG-0960 applies to pages 2 and 4, Appendix K).

The basis for this observation is explained by test type in Appendix I, beginning on page 6. It is pointed out that: 1) hydraulic parameters measured by different test methods over a single test interval vary by as much as several orders of magnitude; 2) our analysis of testing in deep horizons suggests that much of the variation may be explained by the effects of fluid density changes on pressure measurements made near the top of the water column; and 3) much of the problem may be solvable in the future by measuring water pressure down-hole, at or near the test interval depth. The BWIP hydrology effort appears to be moving toward the use of down-hole pressure monitoring and shut-in equipment.

Further, with respect to present test results, we have reservations as to the usefulness of this information in licensing. The information may be of value in certain qualitative applications, e.g., general characterization of the

groundwater regime and development of plans for future testing. However, for more rigorous, quantitative applications, such as estimation of groundwater travel time, we believe that DOE should qualify the test data by suitable analysis and demonstration so that the uncertainty bounds are clearly identified. We are prepared to discuss with you suitable approaches to this problem.

We appreciate the opportunity to review the test data and hope our comments will be useful to BWIP's ongoing hydrologic characterization efforts. If you have any questions, please contact Matthew Gordon (FTS 427-4133) or Neil Coleman (FTS 427-4677), who are responsible for this review.

Robert J. Wright
Senior Technical Advisor
Repository Projects Branch
Division of Waste Management

Enclosure:
Comments on BWIP Hydrologic Test
Data.

COMMENTS ON BWIP HYDROLOGIC TEST DATA

I. Background

During January 9-16, 1984, the NRC hydrogeology review team for BWIP visited the BWIP site in Richland, Washington. The purpose of the visit was to selectively review the hydrologic data and data collection procedures. In addition to reviewing representative data and procedures, certain members of the NRC team attended portions of the geochemistry workshop being held concurrently in Richland, viewed selected rock cores, and participated in a regional geologic reconnaissance field trip.

This NRC data review was the second of its type at BWIP, the first having been held in July of 1982. A description of the conduct of the January data review and other materials examined is provided in Attachment 1. The materials that were collected by the NRC review team have been placed in the NRC Public Document Room and in the Licensing Public Document Room located in the Richland Public Library.

This letter documents the observations of NRC staff and contractors during the visit. These comments incorporate suggestions by Matthew Gordon (NRC), Neil Coleman (NRC), Adrian Brown (subc. Golder Assoc.), Jerry Rowe (Golder Assoc.), Gerry Winter (Williams and Assoc.), Dale Ralston (Williams and Assoc.), and Roy Williams (Williams and Assoc.)

II. General Comments

As a result of the July 1982 review, NRC raised the following concerns about BWIP's Hydrologic Site Characterization Program. These were also embodied in Chapter 3 and Appendices D through J of the Draft Site Characterization Analysis of BWIP (NUREG-0960):

1. Slug tests conducted by BWIP are considered to be adversely affected by wellbore conditions (e.g. wellbore friction, wellbore storage, skin effects);

2. Point measurements in single, small-diameter boreholes are considered to be of questionable value in characterizing large volumes of rock;

3. Measurements of vertical permeability, long-term head, and effective porosity are needed;

4. The occurrence of non-standard test responses, such as the "overshoot" phenomenon, has not been adequately evaluated by BWIP.

Since publication of NUREG-0960, BWIP in consultation with NRC has been developing an approach to future hydrologic testing which attempts to resolve those concerns. This strategy is expected to include provisions for evaluation of drilling fluid effects on hydrologic testing, development of a baseline hydraulic head monitoring system, and the performance of large-scale pump/injection tests to characterize larger rock masses and possibly identify features and structures affecting ground water flow (i.e., barrier/recharge boundaries) (USNRC STP 1.1, 1984).

The major comments made about the data reviewed during the July 1982 visit (listed above) still hold for most of the data examined and collected during the January 1984 visit. In addition, observations made during the latter visit lead to the additional comments discussed in the following section and in Appendix I.

III. Conclusions and Recommendations

1. As stated in NUREG-0960 and in this letter (see Appendix I), NRC concludes that much of the single-well data collected to date is questionable in

terms of its numerical accuracy. Nevertheless, the data collected has been used by BWIP in the past as the basis for preliminary performance assessments and candidate horizon selection (cf., BWIP Site Characterization Report (1982), Repository Horizon Identification Report (ST-28, 1983)). NRC considers use of the existing data in this manner to be inappropriate. Repository performance assessments and program decisions based on the present data base should be carefully qualified by BWIP with regard to reliability. We consider that an appropriate use of the existing data base lies in qualitative planning for future tests. Appendix I provides specific observations on the matter of the reliability of the test data in terms of its adequacy for use in hydrologic and radionuclide transport analyses of the site.

2. The NRC staff notes the following significant improvements in BWIP hydrologic test procedures:

   o reverse circulation air drilling rather than drilling with mud in construction of the boreholes;

   o trend toward the use of down-hole pressure monitoring and shut-in equipment;

   o adoption of large-scale multi-well pump tests (as suggested in NRC STP 1.1).

3. For relatively deep hydrologic testing, such as that performed in the Grande Ronde formation at the Hanford site, NRC suggests that DOE consider the placement of pressure measurement devices at or near the test interval level. Although, as discussed in Appendix I, NRC recognizes that there are potential difficulties with the utilization of downhole transducers, we consider that the use of downhole pressure transducers would eliminate or reduce the severity of numerous problems encountered during testing

thus far, such as the effects of dissolved gases, temperature variations, wellbore friction, and wellbore compressibility on inferred pressures at depth.

4. NRC considers that a detailed field and office manual for hydrologic test design, procedures, analyses, and documentation should be produced by BWIP. The Basalt Operating Procedures Manual (RHO-BWI-MA-4) is currently deficient in these four aspects of hydrologic data reliability assurance and control. The improved procedures manual should contain sufficient information for BWIP hydrologists to avoid irregularities in these four aspects of geohydrologic site characterization. The document should include procedures and criteria for, as examples: establishment of static head or head trend prior to test; intra-test head trend (pulse tests); sufficient recovery (recovery, slug and pulse tests); preparation of s vs. Q plots (constant head injection step tests); tests for tubing and packer leaks; equipment calibration procedures; etc., as required for each test method. Without detailed, documented test procedures, future data are likely to be subject to questions which may preclude their use in licensing assessments.

5. NRC recommends that future BWIP interval reports include the following information, in addition to the hydrologic and geologic information provided as standard material in the previously published interval reports:

   - Topographic/cartographic data for all borehole tops, including latitude, longitude, and elevation for all reference points;

   - Elevations of tops of major stratigraphic units penetrated by borehole;

- Borehole deviation information based on gyroscopic survey data for paired or clustered boreholes used in multi-well tests;

- Information pertaining to calibration of pressure transducers and other measuring devices;

- All hydrologic test data collected for the given interval whether or not it is used in the report, including data from incompleted tests. Also, inferred storativity values should be presented.

6. It is expected that the large-scale testing strategy currently being implemented by BWIP, as discussed at the BWIP/NRC July 1983 hydrology workshop, will soon provide important data about horizontal hydraulic conductivity and the extent of vertical communication between hydrostratigraphic units. It is important that DOE and NRC engage in early technical interactions to resolve NRC concerns about the test procedures to be used.

5/25/84

Neil Coleman
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5/25/84

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APPENDIX I: COMMENTS ON SPECIFIC TESTS

A. Constant Discharge Drawdown and Recovery Tests

Seven out of the eleven recently published BWIP interval reports describing hydrologic testing illustrate the reliance of BWIP investigators on analyses of aquifer recovery following pumping for determination of "best estimates" of transmissivity and horizontal hydraulic conductivity. Analyses of field data for both pumping drawdown and subsequent recovery are based on the method of Theis (1935) and modifications by later workers. BWIP has used the results of the drawdown data mainly in a qualitative fashion because of the difficulty in maintaining constant discharge while pumping from the deep basalts. Also, for early time data, the drawdown is primarily affected by wellbore storage. Though methods exist to account for wellbore storage (e.g. Earlougher (1977), p. 11), BWIP has apparently not analyzed the data to evaluate these effects.

In several recovery tests reviewed, very limited recovery was permitted prior to termination of the test. NRC suggests that the recovery period required to yield representative and useful data should be specified by BWIP in a detailed procedures manual, possibly as some multiple of the pumping period preceding recovery.

Many of the existing single-hole measurements of hydraulic parameters based on the recovery method are of questionable reliability because of problems associated with near-surface placement of head monitoring devices. This refers to head measurements which use reference points at or near the water surface in an open piezometer. Analyses of tests based on these uphole measurements apparently incorporated no corrections for fluid density variations within the vertical borehole. These effects can be very significant, as described in the following discussion.

BWIP investigators have reported the occurrence of a response called "overshooting" which interferes with aquifer recovery tests. The effect, which is more accurately referred to as over-recovery, occurs after pumping of a deep aquifer is terminated. The depressed potentiometric surface returns to the static head level and rises above it creating what appears to be an artificially high head. Subsequent to reaching this maximum elevation the head level slowly subsides to the pre-test static condition.

BWIP hydrogeologists consider this to be a significant problem and have taken measures to address it. The over-recovery effect is referred to on pages 18,23

and 24 of SD-BWI-TI-105, and also on page 19 of SD-BWI-TI-089. The presence of liberated gas in the borehole was "believed responsible for producing an apparent "overshooting" of the pre-test water level when using surface-based measurements (page 18 of the quoted report)."

NRC staff and contractors have studied the over-recovery problem and have identified two contributors to the anomalous uphole head measurements: (1) variations in water temperature and (2) liberated gas. Both of these effects are described below in detail.

1. Temperature variations in the riser pipe.

For groundwaters of the Hanford Site, there exists a 20-30 °C temperature difference between the surface water table (20°C) and the formation waters of the Grande Ronde (40-50°C). Assuming an average steady-state temperature at equilibrium of about 30°C, we have calculated the isobaric effects that would arise from temperature-caused density variations in a water column with a vertical length of about 880 meters. (This depth is appropriate for calculations relevant to the Grande Ronde Formation.) Under these conditions a vertical water column of the specified approximate length at a temperature of 45°C would be about 5.7 meters higher than a corresponding water column at an average equilibrium temperature of 32.5°C. This considerable difference by itself is more than sufficient to account for the over-recovery noted after extensive pumping of geothermally-heated formation waters from the Grande Ronde. The gradual return of the potentiometric head to the pre-test static level is interpreted to be a response to gradual cooling. We note that this calculated head difference from temperature effects is of the same order of magnitude as head changes induced directly by aquifer tests in the higher permeability zones. Thus the problem is of considerable concern.

Additionally, temperature-induced density variations are likely to influence results of constant head injection tests. These involve injection of lower temperature fluids into formations which, at Hanford, are of a higher temperature. As a general statement which is applicable to relatively deep aquifers, whenever injected or withdrawn fluids significantly change the ambient temperature profile in or around the riser pipe, then the corresponding density changes will modify the test results.

2. Gas liberation and migration in the riser pipe.

Liberation of gas from the test interval via the riser pipe has been documented in several Hanford site boreholes. Gas noted in wells of the DC-16 cluster was shown to consist primarily of methane from a deep source. Formation gases, when present, are liberated during the depressurization of a confined system during pumping withdrawals. The gases are evolved to the riser pipe and rise to the surface with the effect of reducing the average density of the wellbore fluid during the pumping and recovery periods. Thus, head elevations measured at the surface will give anomalously high values of inferred pressure at depth.

Conclusions about over-recovery

As described above, the effects of gas entrainment and temperature variations within the borehole can cause measurements of the potentiometric surface elevation to be unreliable guides in calculating the in-situ pressures in deep test horizons. It would probably prove difficult to systematically correct previously collected potentiometric surface head data without knowing the varying combined effects of both gas evolution and temperature variation. Thus, the NRC staff feels that many of the existing single-hole measurements of hydraulic parameters based on near-surface reference points are of questionable reliability.

As suggested by BWIP hydrogeologists, the direct solution to these induced density effects is to obtain hydraulic pressure measurements at depth within the test interval using transducers. We endorse this approach, with an understanding of problems previously encountered with deeply placed pressure transducers, such as instrumental drift and accuracy limitations. These problems should be addressed as soon as practicable. Specific examples of instrumental drift problems are described in interval reports SD-BWI-TI-089, -095, and -105. Also, we recognize the accuracy limitations of the transducers which have been used with and housed within the TAMMS straddle packer system. The accuracy of these 3000 psi pressure transducers is reported to be ± 5,8 ft (1.8 m). As described on p. 8 of RHO-BW-SA-189, because of the relatively large error band, pressure readings are calibrated using steel tape and electric water-level measurements. This procedure would be accurate only if thermal steady-state conditions persist throughout the borehole fluid column (i.e., while measuring static head prior to hydrologic testing). Clearly, technological improvements are needed in both equipment and methodology for pressure head measurements in deep formations. Such improvements would provide major contributions toward improving the quality and reliability of collected hydrologic data.

B. Instantaneous Slug Injection/Withdrawal

None of the published interval reports which describe slug tests analysed with Cooper et. al's (1967) method or with Van der Kamp's (1976) method (SD-BWI-TI-102, -105, and -095) report the values of storage coefficient (S) that were assumed in or derived from the test analyses. While it is recognized that values of S derived from these tests are unreliable, the values derived or assumed should always be reported so that the reader may verify that the conditions required by the test analyses have been met.

In the published data reviewed during the site visit, results of Cooper et. al. analyses were highly variable in quality. In some cases, excellent fits were obtained between the data and the type curves. However, in many cases, only early time or late time data could be fit and in some cases no reasonable fit could be obtained. In some cases, wide variations in transmissivity estimates were obtained from different slug tests performed in the same interval. Slug tests are susceptible to wellbore storage effects, which cause deviations from the ideal response upon which the type curves are based. Observed data variations should be explained by BWIP before the results can be considered reliable.

We have in a previous letter (R. Wright (NRC) to O. Olson (DOE), 11/4/83) raised serious questions regarding the applicability of the Van der Kamp (1976) method of slug test analysis for BWIP test conditions. Data reviewed in the published interval reports tends to shed additional light on this subject. For several tests performed in hole RRL-2 (e.g., Composite Middle Sentinel Bluffs Flow Bottom, Test #1), both uphole and downhole head data are available during a slug test exhibiting an oscillatory response. The uphole data display oscillations of several feet above and below static levels. The downhole data have oscillation amplitudes considered by BWIP to be too low to analyze using Van der Kamp (although data were not presented in the interval reports). This suggests that the amplitude of oscillations at surface may be controlled primarily by wellbore characteristics. Accordingly, there is as yet no solid evidence that the Van der Kamp analysis of tests conducted at the BWIP site yield information representative of formation properties.

C. Underpressure/Overpressure Pulse Tests

The overpressure pulse test was originally described by Bredehoeft et. al. (1980). This test method is designed for use in formations of very low transmissivity, where pump and slug tests are impractical due to time considerations. The test procedure described by Bredehoeft et. al. involves monitoring the pre-test trend of head or determining the static head in the interval, filling the riser pipe to the surface, observing the decay of the water level in the riser pipe to establish an intra-test head trend, instantaneously pressurizing and shutting in the system, and monitoring the response to the pressurization. The pressurized response may then be analyzed by the Bredehoeft et. al. method. The intra-test head trend must be subtracted from this pressurized response for the Bredehoeft et. al. solution to be applicable.

Bredehoeft et. al. indicate that the method yields unreliable estimates of S as S becomes very small (as for the conventional slug test); and that for α (as

defined in Bredehoeft et. al.) greater than 0.1, the method will only yield values of the product of S and transmissivity (T).

The overpressurized pulse test should be performed at pressures below that which would hydrofracture the formation, as discussed in RHO-BWI-MA-4, Appendix G. NRC suggests that interval reports include verification that the pressures enforced during a given pulse test were within the limits necessary to avoid hydrofracturing. Hydrofracturing could result in higher estimates of transmissivity than would be representative of the undisturbed formation.

BWIP also extends the Bredehoeft method to an "underpressurized" test wherein the pre-test head or head trend is established, a slug of water is removed, response is monitored, the well is shut in, and the response after shut-in is monitored and analyzed with Bredehoeft et. al.'s solution. This test differs from a conventional slug withdrawal test in that the well is shut in subsequent to slug withdrawal, and pressure recovery in the shut-in interval is monitored rather than water level recovery in the well. This is essentially the same as a drill stem test.

The Bredehoeft et. al. solution is valid only if the pulse can be considered instantaneous (i.e., time to initiate pulse is small compared to time required for recovery). In some tests, recovery after constant head injection tests was analyzed using the Bredehoeft et. al. solution (e.g., RRL-2, Middle Sentinel Bluffs Colonnade/Entablature). Although the constant head tests were of short duration, the length of the injection period was, in some cases, comparable to the length of time that data was collected during recovery. In these cases, the assumption of an "instantaneous pulse" may have been violated.

In several pulse tests, only limited recovery was attained prior to termination of the test (e.g., RRL-6, Umtanum Colonnade/Entablature, 12/82). NRC considers that test results would be more reliable if recovery were permitted to proceed to at least 75% decay of the initial head change.

The Bredehoeft et. al. solution does not account for skin or wellbore storage effects although methods are available which do consider these effects (e.g., Ramey et. al, 1975). BWIP should consider using these alternative methods to evaluate the significance of these skin and storage effects to the test results.

The Bredehoeft et. al. method requires that the intra-test head trend (open-tube water level recovery following initial water column

addition/removal) be subtracted from the hydraulic head recovery following shut-in of the well. In some of the cases reviewed during the visit, BWIP subtracted the pre-test trend (prior to water column addition) rather than the intra-test trend. This is not consistent with the analytical method used.

Tests analyzed by BWIP when $\alpha > 0.1$ (e.g., RRL-14, Cohassett Colonnade, 2/83), which yield only the product of S and T, are considered by NRC to be of limited utility for estimation of transmissivity since S is very poorly known in most cases.

D. <u>Constant Head Injection Test</u>

A review of constant head injection test procedures is presented by Zeigler (1976) in a review of methods for determining rock mass permeability. The technique is also known as a water pressure or packer test, and in Europe it is commonly referred to as a Lugeon test. As shown on page 18 of RHO-BW-SA-189, this method is applied to test zones where transmissivity values are expected to be low, in the range of 10^{-14} to 10^{-9} m^2/sec. Thus, like instantaneous pulse tests, the method is applied in basalt flow interiors to obtain estimates of transmissivity. The procedure involves the injection of water under constant pressure conditions into a test zone of low hydraulic conductivity. The riser pipe is filled with water to ground surface and the test interval is then quickly pressurized by opening a shut-in tool. As the fluid is injected an equal pressure is maintained by topping-off the riser pipe to maintain constant head conditions. Subsequent analysis of the rate of injection provides information about the hydrologic characteristics of the test interval. An important test assumption is that steady-state inflow conditions are achieved.

Irregularities were noted in applications of this method as published in the interval reports. Possible conditions of non-steady-state inflow are mentioned by BWIP on page 18 of SD-BWI-TI-107. In the hydrologic testing of basalt interiors, the problem persists of how to obtain reliable estimates of pre-test static head conditions. RHO investigators have commonly used measurements of static conditions in flow tops overlying dense interiors as being approximately representative of test intervals within these denser zones (SD-BWI-TI-107, p. 12; SD-BWI-TI-109, p. 13). The rationale for this projection is based on the postulated long periods of time (months to years) which would be required for the re-establishment of equilibrium conditions in depressurized basalt interiors.

The NRC staff recognizes that procedures necessary to obtain in-situ static pressure measurements in the dense interiors for the purpose of single-hole tests would be prohibitive, given available time and equipment constraints. However, we can recommend a possible solution which can help refine projected pressure estimates and yet avoid extensive temporal measurements. The procedure would involve collecting static pressure data in more highly transmissive units both overlying and underlying a dense interior. These results would either be averagable or in close agreement. We believe that this procedural modification would serve to somewhat reduce the uncertainties encountered in projecting pre-test static conditions prior to performing constant head injection and instantaneous pulse tests. NRC also suggests the use of a downhole shut-in tool to isolate the test interval when determining static pressure in units of low transmissivity. Downhole shut-in permits a more rapid return to undisturbed conditions in the tested formation around the borehole than would an open piezometer or uphole shut-in tool.

The constant head injection tests are commonly performed in steps of hydraulic buildup. BWIP generally analyzed these step tests individually and then compared the results.. NRC considers that a plot of hydraulic buildup (s) vs. steady-state injection rate (Q) should be routinely prepared for evaluation of step injection test results. These plots should yield a straight line with intercept at s=0. In one case (RRL-2, Umtanum Entablature) where BWIP neglected to prepare a plot of s vs. Q, a plot would have yielded a straight line, but with an intercept at 248 feet, which is physically unrealistic. This non-standard response could have been identified if the s vs. Q plots were drawn routinely by BWIP.

E. Tracer Test

A review of the tracer testing conducted at boreholes DC-4/5 and subsequent analytical results was recently completed and is contained in a letter to O. L. Olson, dated April 6, 1984. No further comments will be provided in this letter regarding the tracer test methodology.

F. Vertical Hydraulic Conductivity Test

BWIP has documented the results of an experimental vertical hydraulic conductivity test in boreholes DC-4/5 (SD-BWI-TI-136, September, 1983). This test was based on the "ratio method", as described by Neuman and Witherspoon (1972). BWIP concluded that the test yielded no discernable formation

response. Citing formation conditions and equipment constraints, BWIP suggested that the method may be of limited applicability at the Hanford site.

NRC considers that BWIP's conclusions regarding the applicability of the ratio method at the Hanford site are not fully supported at this time. Recognizing the general complexity of this test procedure and the practical limitations of the available test equipment, NRC has identified the following points of concern:

- The design and equipment configuration of the DC-4/5 test was not appropriate for performing a ratio test as described by Neuman and Witherspoon. Specifically, the existence of open boreholes above the packer arrangements, the placement of the packers, and the length of the monitoring intervals was inconsistent with the configuration described by Neuman and Witherspoon (1972). The open boreholes alter the flow conditions between boreholes so that horizontal flow conditions may not have been maintained. The placement of packers apparently resulted in a short-circuit of the test response in the aquitard. The open borehole below the middle packer in DC-4 was in direct hydraulic communication with the aquifer. Thus the hydraulic response only had to propagate three to four feet (packer seal length) before a pressure change would have been noted in the aquitard. BWIP assumed a vertical distance from the aquifer to the monitor zone of 26 feet. Also, the length of the monitoring zone was too large to be considered a point measurement.

- Static conditions did not prevail at start of testing.

- Initial testing of packer compliance was questionable, in that an uncased borehole section was used.

- Alternative interpretations of the test results are possible which would infer the existence of a significant formation response with a relatively higher calculated vertical conductivity.

Based on these concerns, NRC considers that the performance of multiple well tests for vertical hydraulic conductivity should not be ruled out by BWIP on the basis of the DC-4/5 test results. Because of the importance of vertical conductivity in evaluating groundwater flow, we suggest that BWIP consider further attempts at measuring vertical hydraulic conductivity with multiple well tests at both small scales such as the DC-4/5 test, and at large scales as

described in NRC's BWIP Hydrogeologic Testing Strategy Site Technical Position (1.1) (1983).

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ATTACHMENT I

TRIP REPORT
HYDROGEOLOGY DATA COLLECTION VISIT
HANFORD RESERVATION, WASHINGTON
JANUARY 9-16, 1984

The purpose of the NRC visit to the Hanford site was to obtain and review recent, unpublished hydrologic test results relevant to NRC's evaluation of BWIP's site hydrologic characterization efforts. The visit represents a follow-up to the previous NRC data review visit which formed part of the July 1982 Hydrology Workshop at the Hanford site. The data collection and review during the January visit consisted mainly of independent evaluations by NRC of raw data and data analysis files. The visit was augmented by an examination of core, drill rigs, packers, and a downhole pressure and temperature probe, and a guided reconnaissance field trip highlighting interesting hydrogeologic features on-and off-site. It was distinctly not the purpose of this visit for NRC to hold any substantive discussions with DOE/BWIP regarding NRC's official position regarding the conduct and merit of any facet of BWIP's current hydrologic characterization programs.

The NRC hydrogeology team present for the visit were:

Malcolm Knapp (WMGT, NRC)
Matthew Gordon (WMGT, NRC)
Neil Coleman (WMGT, NRC)
Roy Williams (Williams and Associates)
Dale Ralston (Williams and Associates)
Gerry Winter (Williams and Associates)
Jerry Rowe (Golder Associates)
Adrian Brown (Golder Associates)

Linda Lehman (Yakima Indian Nation) was also present for the first day of the visit.

The data collection activities took place at the Exploratory Shaft/RRL-2 site within the reference repository location. On Monday morning, January 9th, BWIP provided NRC with introductory review materials briefly describing the hydrologic characterization activities at the site since the last hydrology meeting (July, 1983). Bill Price, Steve Strait, and Greg McClellan provided a very brief (about 5 minutes each) update on the following topics, intended to aid us in our review of the hydrologic test data:

1) Changes in hydrologic test plan since 7/83 meeting (Strait)

   * In DC-19C, DC-20C, and DC-22C, six zones will be monitored rather than seven. A separate "O" hole at each of the

three clusters will be drilled to monitor the Mabton interbed.

* DC-18 will be drilled 1600' to the Mabton by FY86.

* The need for DC-23 (formerly called 5783) will be evaluated in April, 1984.

* Westbay piezometer/packer system will not be used. To the extent possible bridge plugs will be used instead of Baske system.

* Emphasis in 1984 will be establishment of baseline.

2) Core losses (McClellan):

* Triple core-barrel was used, which failed to work properly when stop ring and core spring dislodged. Used double tube assembly afterwards.

* Mechanical problems with double tube. Did not meet the vendor's specifications, causing core loss.

* Other core losses caused by unconsolidated sand washing away.

3) Discing (McClellan)

* Info in BWIP Data Package 035.

After the fifteen-minute orientation, the group commenced reviewing hydrologic test data. All data supporting planned or early draft "interval reports" for intervals (BWIP documents describing test results in series SD-BWI-TI within the Wanapum and Grande Ronde) were examined and reviewed. Data supporting recently published interval reports were not reviewed, as it was decided that the published reports could be efficiently reviewed offsite, and most of the data contained in the published reports had been reviewed during the previous workshop. The test data results and evaluations performed by the team were recorded on borehole review forms [now available in docket room]. Our comments on BWIP's data collection efforts are presently being prepared for transmittal to DOE.

On January 10th, Coleman, Gordon, Brown, Rowe and Williams attended the morning session of the NRC/BWIP Geochemistry workshop, being held concurrently in Richland. At this session, a preliminary hydrochemical interpretation of the Hanford site hydrology was offered by Tom Early (BWIP). Our comments on this discussion will be documented in a memorandum to the Geochemistry section (WMGT).

On January 11th, during the a.m. hours, we examined all rock cores recovered from the Cohassett Basalt Flow, Borehole RRL-2. These cores are located in the 200 East Area Complex.

On January 12th, during the a.m. hours, we observed piezometer installation procedures at borehole DC-19C, cluster site DC-19. The work-over rig and crew were installing the first of six piezometers which will comprise this nested well. In the afternoon, we toured the exploratory shaft (ES) drilling rig complex. Drilling of the ES had previously terminated at a depth of 100 ft. Also, on the afternoon of January 12th, we received a presentation about the design and application of inflatable packers used to isolate hydrologic test intervals.

On January 13th, the NRC hydrogeology team held our own group discussion of hydrogeologic test procedures and preliminary evaluation of methodology. The purpose of the discussion was to ensure that all of our important observations would be recorded for future use. Later in the afternoon, we received a presentation and demonstration of the Seling Triple Sub-Surface Probe (TSSP) (multiport pressure and temperature probe) in the office complex near RRL-2.

On January 16th, an introductory geologic reconnaissance field trip of the Hanford Reservation and Sentinel Gap was led by Steve Reidel, a BWIP Geologist. The attendees for this field trip were:

N. Coleman (NRC)
M. Gordon (NRC)
P. Davis (Sandia Lab.)

Topics of discussion and presentation included:

- structural and stratigraphic features of Rattlesnake Mtn.
- geologic data collection field methods
- regional borehole exploration
- tectonic and flow top breccias
- pillowed basalt sequences
- basalt flow emplacement
- interflow geology
- historical facts about the Hanford region

This introductory reconnaissance trip was extremely informative, and future on-site training of this kind is highly recommended for NRC's BWIP and NTS site specialists.

The information that was collected during this visit is represented by the following materials, all of which are available from the Document Control Center (Nancy Still's office):

1. Borehole Review Forms (evaluations of unpublished hydrologic test data)

2. Review of BWIP's data analysis software

3. Water level data from RRL-14, RRL-2, DB-14, DC-1, and McGee

4. Notes on six test procedures

5. Published documents provided with introductory materials, listed on Attachment A.

Also obtained were the following items which can be viewed by interested parties upon request of M. Gordon or N. Coleman:

1. Borehole location map

2. Hourly barometric records from calendar year 1983

The following information has been requested and will be provided to NRC by BWIP:

Item requested	Status
1. Photocopies of hydrographs for all monitored zones in:	To be sent to RWright by early February
RRL-2	"
RRL-14	"
DB-14	"
DC-16B	"
DC-22B	"
DC-20B	"
McGee	"
DC-19C	No data available until piezometers are developed
DC-19D	"
DC-20A	"
DC-14	No data available for years of interest
2. Copy of hydrologic data summary	To be sent by end of Jan.
3. Compilation of weekly drilling reports	"
4. Water quality data	"
5. Listing of data analysis programs and user's guides	Undergoing QA check; will not be provided at this time.

6.	Thickness data, geophysical and geologic logs for cluster holes	To be sent by end of Jan.
7.	As-built locations, depth projections and borehole geometry for clusters	A downhole trace plot for each cluster will be provided by end of Jan.

Summary and Future Plans

The trip was highly productive in terms of hydrologic test data acquisition and qualification. In addition to the hydrologic test data, a substantial quantity of other hydrologically relevant material and information was collected which should prove useful to NRC's review of BWIP's hydrologic characterization program.

The information collected is now being reviewed by the members of the NRC hydrogeology review team for the BWIP site. We expect to compile our observations and comments on the data in a letter to be sent to DOE by March, 1984.

Subsequent use of the data is presently under discussion. Among the most likely possibilities are:

1. Development of NRC position on quality of past testing activities, to be discussed at upcoming May 1984 BWIP/NRC hydrogeology workshop;

2. Development of NRC recommendations on conduct of future testing activities to be discussed at upcoming May 1984 hydrology workshop; and

3. Development of revised conceptual model for use in Environmental Assessment review (and to better our understanding of system).

Other projects (e.g., sensitivity studies, hydrochemical analysis) may be performed as agreed to between the members of the NRC Hanford site hydrogeology review team, the NRC BWIP Project Section Leader, and NRC management.

ATTACHMENT A

WM DOCKET CONTROL CENTER

'84 JAN 23 P4:34

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

WM Record File	WM Project 10
102.2	Docket No.
	PDR ✓
	LPDR ✓

Distribution: RWright

(Return to WM, 623-SS)

Dr. Robert J. Wright
Senior Technical Advisor
High-Level Waste Technical
Development Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Wright:

BWIP HYDROLOGIC DATA

The following documents were provided to you and your consultants during the hydrologic data review sessions held at Richland the week of January 9, 1984:

- Basalt Operating Procedure, RHO-BWI-MA-4 (selected sections)
- Deep Borehole Stratigraphic Correlation Charts and Structure Cross Sections, SD-BWI-DP-035
- Results and Evaluation of Experimental Vertical Hydraulic Conductivity Testing at Boreholes DC-4 and DC-5, SD-BWI-TI-136
- Preliminary Results of Hydrologic Testing the Umtanum Basalt Fracture Zone at Borehole RRL-2 (3,781 - 3,867 ft.), SD-BWI-TI-089
- Preliminary Results of Hydrologic Testing the Middle Sentinel Bluffs Vesicular Zone at Borehole RRL-2 (3,057 - 3,172 ft.), SD-BWI-TI-090
- Preliminary Results of Hydrologic Testing the Composite Middle Sentinel Bluffs Basalt Flow Bottom at Borehole RRL-2 (3,247 - 3,344 ft.), SD-BWI-TI-095.
- Preliminary Results of Hydrologic Testing the Middle Sentinel Bluffs Flow at Borehole RRL-2 (2,981 - 3,020 ft.), SD-BWI-TI-102
- Preliminary Results of Hydrologic Testing the Composite Umtanum Basalt Flow Top at Borehole RRL-2 (3,568 - 3,781 ft.), SD-BWI-TI-105

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2pp.

- Preliminary Results of Hydrologic Testing the Umtanum Basalt Entablature at Borehole RRL-2 (3,762 - 3,805 ft.), SD-BWI-TI-107
- Preliminary Results of Hydraulic Testing the Middle Sentinel Bluffs Basalt Colonade/Entablature (3,175 - 3,244 ft.) at Borehole RRL-2, SD-BWI-TI-109
- Hydrologic Test Results for the Rattlesnake Ridge Interbed and Pomona Basalt Flow Top at Borehole DB-15, SD-BWI-TI-130
- Hydrologic Test Results for the Selah Interbed at Borehole DB-15, SD-BWI-TI-131
- Hydrologic Test Results of the Cold Creek Interbed and Asotin Basalt Flow Top at Borehole DB-15, SD-BWI-TI-142
- Results of Hydrologic Testing of the Cold Creek Interbed and Umatilla Basalt Flow Top at Borehole DC-15, SD-BWI-TI-150
- Drilling, Piezometer Design, and Testing Specifications for the DC-19, DC-20, and DC-22 Borehole Clusters and RRL-2B, SD-BWI-TC-016

The additional hydrologic data requested by your consultants will be forwarded in February 1984. If you have any questions covering this material, please contact A. G. Lassila of my staff, telephone FTS 444-6158.

Very truly yours,

O. L. Olson

O. L. Olson, Project Manager
Basalt Waste Isolation Project Office

BWI:AGL

cc: M. W. Frei, DOE-HQ

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JAN 15 1985 . Attachment 2

3101.2/MG/84/12/19

MEMORANDUM FOR: Hubert J. Miller, Chief
Repository Projects Branch
Division of Waste Management

FROM: Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

DISTRIBUTION:
WM 3101.2 s/f
NMSS r/f
WMGT r/f
~~MGordon~~ & r/f
MFliegel
MKnapp
NColeman
JOBunting
MJBell
REBrowning

SUBJECT: ROCKWELL HANFORD OPERATIONS DOCUMENT SD-BWI-TI-109, "... HYDRAULIC TESTING OF MIDDLE SENTINEL BLUFFS..."

Enclosed please find a review of the subject document for your information. The subject document describes a hydraulic test of the current preferred candidate repository horizon. The enclosed review identifies the following problems with the data collection and analysis described in the subject document:

1) BWIP has ignored the fact that the responses to the four steps of the described constant head injection test are inconsistent with theoretical responses. This inconsistency calls the constant head injection test results into question.

2) BWIP chose an average, rather than a conservative value for their "best estimate" of constant head injection test results.

3) The described overpressure pulse test appears to have been analyzed in two ways: one contrary to existing literature on the subject (yielding a low value of transmissivity) and the second consistent with existing literature on the subject (yielding a transmissivity value an order of magnitude higher). The results of the second (correct, based on existing literature) analysis were thrown out, apparently because the yielded transmissivity was higher than expected.

4) No storativity values were reported.

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11pp.

C	:WMGT	kd :WMGT	:WMGT	:	:	:	:
ME	:MGordon	:MFliegel	:MKnapp	:	:	:	:
TE	:84/12/19	:84/12/	:84/12/				

JAN 15 1985

3101.2/MG/84/12/19

5) The BWIP best estimate of horizontal hydraulic conductivity assumes that the entire test interval contributes uniformly to the transmissivity. This is a non-conservative assumption that requires further justification.

You may wish to consider transmittal of this document to BWIP and other interested parties.

Original Signed By

Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

Enclosure:
As stated

C	WMGT HG kd	WMGT MF	WMGT MK				
ME	MGordon	MFliegel	MKnapp				
TE	84/12/19	84/12/20	84/12/15				

JAN 15 1985

3101.2/MG/84/12/07/0

WASTE MANAGEMENT DOCUMENT REVIEW

DOCUMENT: Preliminary Results of Hydraulic Testing of the Middle Sentinel Bluffs Basalt Colonnade/Entablature (3175-3244) feet at Borehole RRL-2, Rockwell Hanford Operations (RHO), SD-BWI-TI-109, released January 1983.

FILE CODE: 3101.2, 3101.5, 3109.2, 3109.3

DATE REVIEW COMPLETED: December 20, 1984

REVIEWER: Matthew J. Gordon

SUMMARY OF DOCUMENT: [Quoted from document abstract]

"This report presents preliminary results and description of hydrologic test activities for a section of Middle Sentinel Bluffs [now called Cohassett] basalt colonnade/entablature at borehole RRL-2 over the depth interval 3175 to 3244 feet. Hydrologic tests conducted include a four-step constant head injection test and one over-pressure pulse test. Preliminary results from hydrologic tests performed indicate transmissivity values ranging between 3.2 x 10-6 and 5.5 x 10-5 ft^2/day with [BWIP's] assigned best estimate of 4.4 x 10-6 ft^2/day. [BWIP's] best estimate of equivalent hydraulic conductivity, based on a thickness for the effective test interval of 69 feet, is 6.4 x 10-8 feet/day."

SIGNIFICANCE OF INFORMATION TO NRC PROGRAM:

The zone tested is the currently preferred candidate horizon for a HLW facility at BWIP, and RRL-2 is the closest hole to the planned location of shaft drilling for underground facility construction. The hydraulic properties measured in this zone are critical parameters for repository performance assessment.

In this review, several problems with the data collection and analysis techniques are identified which have a significant negative impact on the reliability of the test results and conclusions as reported by BWIP.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

Comments on four-step constant head injection test

The constant head injection test, described by Zeigler (1976), yields test zone transmissivity through a calculation which relates the measured steady state inflow of water required to maintain a constant imposed head in the borehole to the imposed head as a function of transmissivity. BWIP performed this test in four steps, i.e., they imposed four different constant heads and measured the corresponding constant flow rates needed to maintain these heads.

BWIP does not indicate the temperature of injected fluid; this could make their estimates of imposed heads erroneous, as NRC has pointed out in reference to other tests at BWIP (c.f., Wright to Olson, May 25, 1984). Regardless of this point, however, the results presented by BWIP in Table 2 of the subject report (attached) indicate substantial irregularities in these tests. Figure 1 shows the calculated transmissivities as a function of the steady-state flow rates for each step. These should theoretically plot along a straight horizontal line. Figure 2 shows the steady flow rate as a function of the imposed head. This should plot as a straight line of positive slope with flow (Q)=0 intercept at imposed head (H)=0. However, this is not the case for the BWIP tests. For example, the BWIP tests indicate that the lowest head imposition required the highest flow rate to maintain, which is contrary to the theoretical response. The only portion of the plot which even has positive slope is section B; however, this section has a Q-intercept (H=0) at -1.56e-5 gpm, rather than zero.

BWIP uses the arithmetic mean transmissivity value calculated by these four tests to get a best estimate for the constant head injection tests. It is not clear why they did not use the highest (most conservative) value as their best estimate as they have done occasionally in other interval reports. The high value (1.1e-5 ft^2/d) is twice the assigned best estimate (5.5e-6 ft^2/d) for these tests.

<u>Comments on overpressure pulse test</u>

After the constant head injection tests, an "overpressure pulse test" was performed. As BWIP notes, "the recovery pressures monitored are in response to a constant head injection test and, therefore, would appear to violate the test specification for a "sudden" pressurization and shut-in as described by Bredehoeft and Papodopulos (1980)." BWIP claims that the difference is expected to have a minor effect on pressure response for zones of transmissivity less than 10-4 ft^2/d. They provide no analysis or reference to support this assumption; however, based on the relatively long duration of the recovery to shut-in pressurization compared to the duration of the constant head injection test, this assumption appears reasonable.

The BWIP pulse test is analyzed in two ways in the document. BWIP describes the first case as one where the initial pre-test (prior to filling the open borehole with water) head in the unit is assumed to be known. They incorrectly identify this "method" as the Bredehoeft and Papodopulos (1980) analytical method. The second analytical case is described as one where the initial head is unknown. They identify this "method" as the Neuzil (1982) analytical method. Actually, neither the Bredehoeft and Papodopulos (1980) nor the Neuzil (1982) methods require knowledge of pre-test head.

For case one, BWIP assumes that the pressure pulse is equal to the sum of the pressure imposed by filling the open-hole test system and the pressure imposed by the overpressure pulse; and for the second case they assume that the pulse is equal only to the overpressure pulse. The Bredehoeft and Papodopolus (1980) as well as the Neuzil (1982) methods assume the pressurized response to be due predominately to the overpressure pulse, since near-equilibrium conditions are considered to apply after filling the open borehole, and directly prior to pressurization and shut-in. This requires some explanation, as it has apparently been the source of some confusion for both BWIP staff hydrologists and this reviewer. The response to the overpressure pulse in the shut-in well considered by Bredehoeft and Papodopulos (1980) and Neuzil (1982) is accounted for predominately by the decompression (expansion) of the water in the shut-in portion of the well. The initial open-hole falling slug in the well does not significantly contribute to the over-compressed initial state of the water immediately following imposition of the pulse. Rather, it is the physical "squeezing" of the water by the overpressurization that accounts for virtually all of the compression of the water. Once the well is shut in, there is no falling slug-type response to the original (uncompressed) slug permitted. The decay in the shut-in pressure following the pulse is due only to decompression of the water in the shut-in interval, rather than release of water from well storage. Bredehoeft and Papodopulos (1980) and Neuzil (1982) consider that the slow decline of the water-filled open-hole system can simply be extrapolated linearly past the shutting-in of the well. (This assumption is discussed below.)

Based on the above comparison of BWIP's testing and anlytical procedures with the assumed conditions and procedures of Bredehoeft and Papadopulos (1980) and Neuzil (1982), BWIP's case one is inconsistent with the referenced analytical procedure, and the second case is the correct analytical method in this respect. The two BWIP analysis methods yield different transmissivities: Method ("case") one yields 3.2e-6 ft^2/d, while method ("case") two yields 5.5e-5 ft^2/d. BWIP explains that the "difference [in results] is not completely understood; however, it may be attributable to not fully compensating for the effects of filling the test system in the analysis procedure for case two." For case two, the pressure response caused by filling

the open test system with water (determined to be -4.46e-4 psi/minute) was subtracted from the pulse response, as it should be according to Bredehoeft and Papodopulos (1980). The only question BWIP should be asking in analyzing the test with method ("case") two is whether the -4.6e-4 psi/minute trend represents near-equilibrium conditions. In any case, the case one analysis is incorrect, based on Bredehoeft and Papodopulos (1980) and Neuzil (1982).

BWIP states that "due to [the "uncertainty" in case two], results of analyzing the overpressure pulse test for case two are not included in the best estimate calculation of transmissivity." I consider that the case one analysis should have been rejected, rather than the case two analysis, because an incorrect analytical procedure was followed, according to the existing literature referenced by BWIP.

It should also be mentioned that no storativity values are reported for either case one or case two. Calculated storativity values should be reported along with all calculated transmissivity values for tests which yield these values. NRC recognizes that these storativity values are unreliable; however, they are part of the test analysis which may help to establish the validity of the result and should be included in the test analysis documentation. For example, if the storativity necessary to match a type curve is "unreasonable" (e.g., greater than about 1e-3 for a tight unit), then certainly this calls the associated transmissivity value into question.

The above comments regarding the overpressure pulse test in the Cohassett colonnade/entablature in RRL-2 also apply to the testing in RRL-2 of the Umtanum entablature, as described in Strait and Spane (1982), RHO document SD-BWI-TI-107. A separate, future in-depth review of that document is currently planned.

Comments on choice of "best estimates" for transmissivity and hydraulic conductivity

Since the constant head injection test results are erratic and inconsistent with theory, and since the case one analysis of the overpressure pulse test was performed incorrectly while the case two analysis was rejected even though it was performed correctly, according to methods described in the existing literature, I consider the best estimate of transmissivity from these tests would be the case two pulse test result, 5.5e-5 ft^2/d, rather than the BWIP best estimate of 4.4e-6 ft^2/d.

BWIP assumes that the entire 69 foot test interval contributes uniformly to the transmissivity (T). By dividing their "best estimate" T by the entire thickness, they arrive at a "best estimate" of horizontal hydraulic

conductivity (K) of 6.4e-8 ft/day. Due to uncertainty in the contributing zone thickness, K should be reported as a range rather than a single value. If the contributing zone were much thinner than the assumed 69 foot thickness, a correspondingly higher K would be effective for that zone. It is these high-K zones which may provide the major conduits for groundwater flow.

ACTION TAKEN: None.

ACTION RECOMMENDED: None.

Original Signed By

Matthew Gordon
Hydrology Section
Geotechnical Branch
Division of Waste Management

References:

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Table 2. Summary of Hydraulic Property Values Determined at Various Injection Steps During the Constant Head Injection Test for the Middle Sentinel Bluffs Basalt Colonnade/Entablature at Borehole RRL-2.

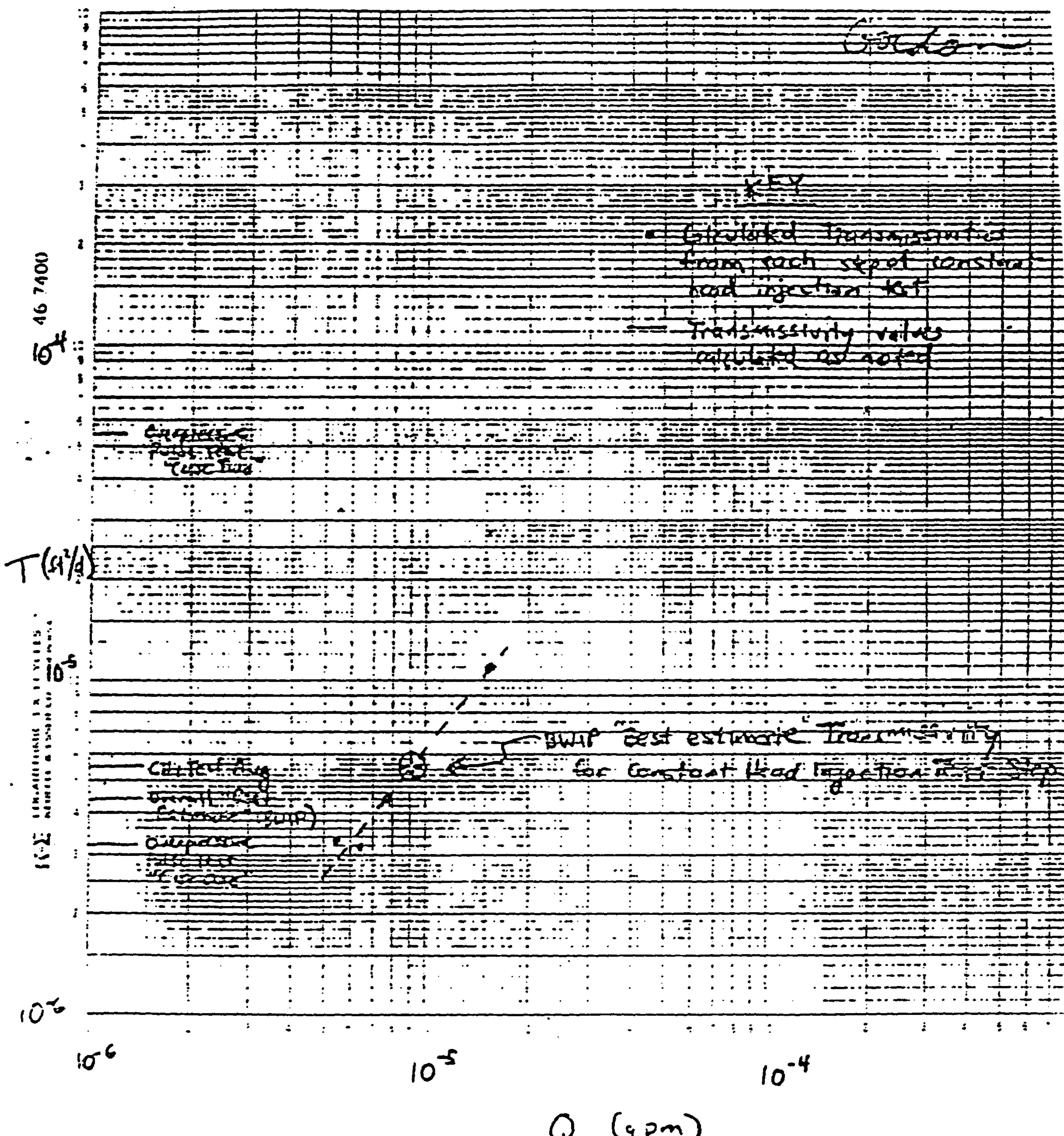
INJECTION STEP	STEP DURATION (min.)	Hg -(ft)	Ho (ft)	$\bar{Q}$ (gpm)	r_w (ft)	R (ft)	Transmissivity (ft^2/day)
#1	62	240.2	38.1	1.53×10^{-5}	0.124	69	1.1×10^{-5}
#2	104	240.2	72.1	5.55×10^{-6}	0.124	69	3.4×10^{-6}
#3	117	240.2	109.3	7.90×10^{-6}	0.124	69	4.4×10^{-6}
#4	52	240.2	146.1	6.42×10^{-6}	0.124	69	3.2×10^{-6}
						Average	5.5×10^{-6}
						Best Estimate	5.5×10^{-6}

$H_g + H_o$ = total imposed head

Figure 1. Flowrate vs. transmissivity for each step.

TI-109 Cohassett Interior.

4 Step Injection Test



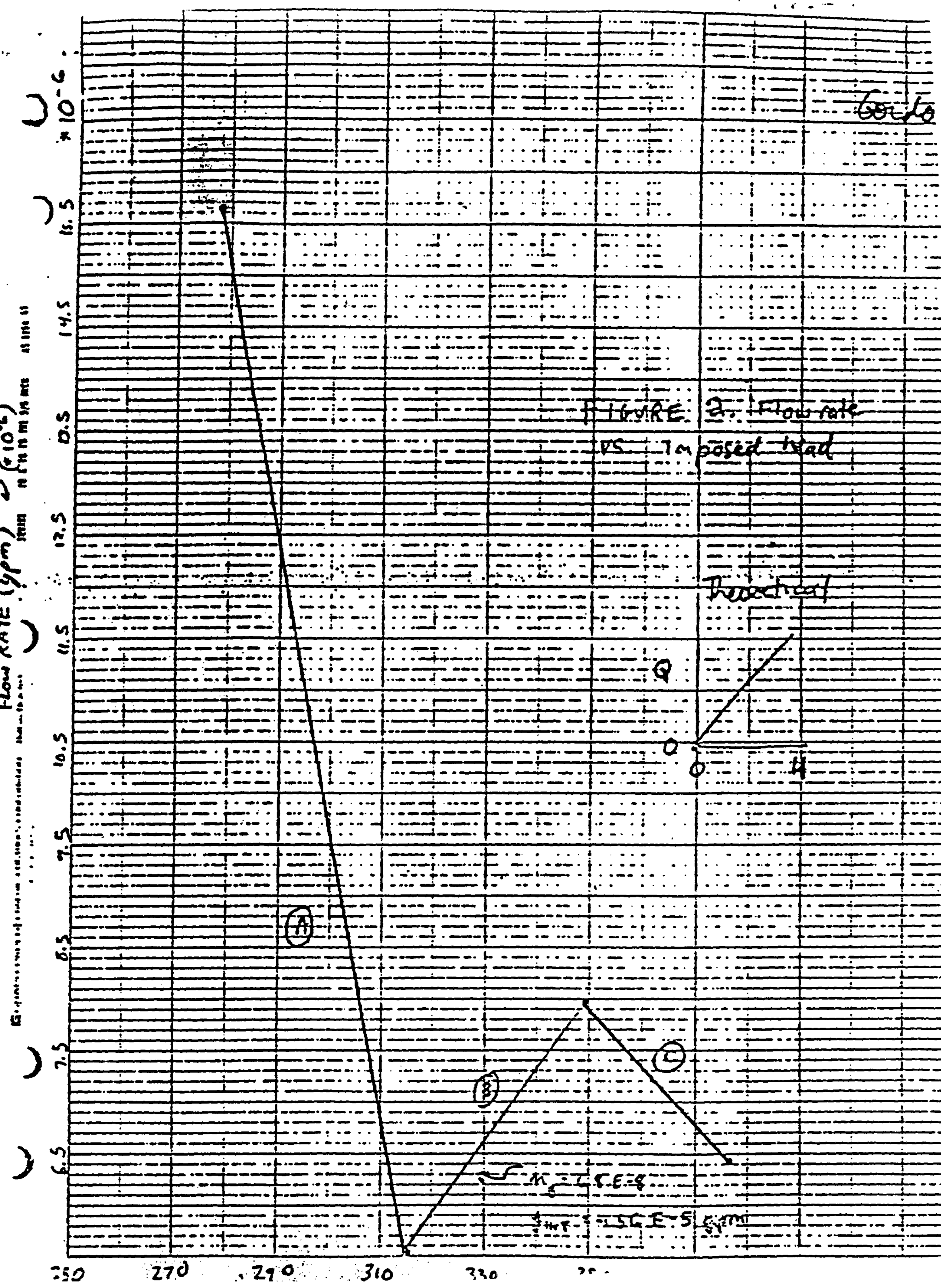


FIGURE 2. Flow rate vs Imposed head