Department of Energy
Office of Civilian Radioactive Waste Management
Office of Repository Development
1551 Hillshire Drive
Las Vegas, NV 89134-6321

QA: N/A
Project No. WM-00011

MAY 28 2004

OVERNIGHT MAIL

ATTN: Document Control Desk
Director, Division of High-Level Waste
Repository Safety
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

TRANSMITTAL OF ADDITIONAL INFORMATION TO ADDRESS KEY TECHNICAL ISSUE (KTI) AGREEMENT UNSATURATED AND SATURATED ZONE FLOW UNDER ISOTHERMAL CONDITIONS (USFIC) 5.02

References: (1) Ltr, Schlueter to Ziegler, dtd 1/15/03 (Agreement USFIC 5.09)
(2) Ltr, Ziegler to Chief, High-Level Waste Branch (NRC), dtd 10/02/03 (Transmittal of *Technical Basis Document No. 11: Saturated Zone Flow and Transport)*

This letter provides additional technical information on two issues identified by the U.S. Nuclear Regulatory Commission (NRC) in Reference 1, related to Agreement USFIC 5.09. In that letter, the NRC indicated that no additional information was needed and that KTI Agreement USFIC 5.09 was considered complete. However, additional information related to the following five subjects was requested to be provided in future KTI deliverables:

1. Groundwater specific discharge.
2. Horizontal hydrologic anisotropy.
3. Flow fields for future climate states.
4. Regional and site-scale fluxes comparison.
5. Model validation of the site-scale saturated zone flow model.

In Reference 1, the NRC requested that the U.S. Department of Energy (DOE) provide the additional information in responses to agreements USFIC 5.01, USFIC 5.02, USFIC 5.12, or in those agreements to which the information was best suited.

Responses to subjects 2, 4, and 5 were provided in Appendices D and E of *Technical Basis Document No. 11: Saturated Zone Flow and Transport* (Reference 2). Responses to subjects 1 and 3 were not explicitly addressed in Reference 2; these responses are provided in Enclosures 1 and 2 of this letter.

NMSS07

The DOE considers the issues on groundwater specific discharge and flow fields for future climate states to be fully addressed in the enclosures. This information, in conjunction with the information in Appendix D of Reference 2, addresses USFIC 5.02. Pending review by the NRC, this KTI agreement should be closed.

There are no new regulatory commitments in the body or the enclosures to this letter. Please direct any questions concerning this letter and its enclosures to Carol L. Hanlon at (702) 794-1324 or e-mail carol_hanlon@ymp.gov, or Drew H. Coleman at (702) 794-5537 or e-mail drew_coleman@ymp.gov.

for Joseph D. Ziegler, Director
Office of License Application and Strategy

OLA&S:CLH-0970

Enclosures:
1. Response to NRC Additional Information Needs on Groundwater Specific Discharge
2. Response to NRC Additional Information Needs on Flow Field for Future Climate States

cc w/encls:
D. D. Chamberlain, NRC, Arlington, TX
G. P. Hatchett, NRC, Rockville, MD
J. D. Parrott, NRC, Las Vegas, NV
D. B. Spitzberg, NRC, Arlington, TX
B. J. Garrick, ACNW, Rockville, MD
H. J. Larson, ACNW, Rockville, MD
W. C. Patrick, CNWRA, San Antonio, TX
Budhi Sagar, CNWRA, San Antonio, TX
J. R. Egan, Egan & Associates, McLean, VA
J. H. Kessler, EPRI, Palo Alto, CA
M. J. Apted, Monitor Scientific, LLC, Denver, CO
Rod McCullum, NEI, Washington, DC
W. D. Barnard, NWTRB, Arlington, VA
R. R. Loux, State of Nevada, Carson City, NV
Pat Guinan, State of Nevada, Carson City, NV
Alan Kalt, Churchill County, Fallon, NV
Irene Navis, Clark County, Las Vegas, NV
George McCorkell, Esmeralda County, Goldfield, NV
Leonard Fiorenzi, Eureka County, Eureka, NV
Michael King, Inyo County, Edmonds, WA
Andrew Remus, Inyo County, Independence, CA
Mickey Yarbro, Lander County, Battle Mountain, NV
Spencer Hafen, Lincoln County, Pioche, NV
Linda Mathias, Mineral County, Hawthorne, NV
L. W. Bradshaw, Nye County, Pahrump, NV
Mike Simon, White Pine County, Ely, NV
R. I. Holden, National Congress of American Indians, Washington, DC

cc w/o encls:
A. C. Campbell, NRC, Rockville, MD
L. L. Campbell, NRC, Rockville, MD
R. M. Latta, NRC, Las Vegas, NV
N. K. Stablein, NRC, Rockville, MD

ENCLOSURE 1

RESPONSE TO U.S. NUCLEAR REGULATORY COMMISSION ADDITIONAL INFORMATION NEEDS ON GROUNDWATER SPECIFIC DISCHARGE

Note Regarding the Status of Supporting Technical Information

This document was prepared using the most current information available at the time of its development. This Technical Basis Document and its appendices providing Key Technical Issue Agreement responses that were prepared using preliminary or draft information reflect the status of the Yucca Mountain Project's scientific and design bases at the time of submittal. In some cases this involved the use of draft Analysis and Model Reports (AMRs) and other draft references whose contents may change with time. Information that evolves through subsequent revisions of the AMRs and other references will be reflected in the License Application (LA) as the approved analyses of record at the time of LA submittal. Consequently, the Project will not routinely update either this Technical Basis Document or its Key Technical Issue Agreement appendices to reflect changes in the supporting references prior to submittal of the LA.

ENCLOSURE 1

RESPONSE TO U.S. NUCLEAR REGULATORY COMMISSION ADDITIONAL INFORMATION NEEDS ON GROUNDWATER SPECIFIC DISCHARGE

U.S. NUCLEAR REGULATORY COMMISSION ISSUE

If the U.S. Department of Energy (DOE) decides to incorporate the Saturated Zone (SZ) Flow and Transport Expert Elicitation in the license application but departs from the original panel's recommendations, DOE will need to provide the technical bases for this change in order to complete Agreement Unsaturated and Saturated Flow under Isothermal Conditions (USFIC) 5.02 (Schlueter 2003).

RESPONSE

The DOE is currently using approximately the same uncertainty range for specific discharge developed by the expert elicitation panel and used for the site recommendation. Additional data from the Alluvial Testing Complex reduce uncertainty in the specific discharge relative to the assessment by the expert elicitation panel. From this information, a discrete cumulative distribution function of uncertainty in specific discharge was constructed, in which 80% of the probability is assigned to the new range and 10% of the probability is assigned equally to the lower and upper tails of the old range. The lower and upper tails of this uncertainty distribution approximately correspond to the greater uncertainty reflected in the saturated zone expert elicitation results.

BASIS FOR THE RESPONSE

Uncertainty exists in the groundwater specific discharge in the saturated zone along the flow path from beneath the repository to the accessible environment. This uncertainty was originally quantified as a distribution of specific discharge in the volcanic aquifer near Yucca Mountain by the saturated zone expert elicitation project (CRWMS M&O 1998). Conclusions regarding the uncertainty in specific discharge by the expert panel were primarily based on single-well and multiwell hydraulic testing of wells in the volcanic units near Yucca Mountain.

Since then, three single-well injection–withdrawal tracer tests that provide estimates of specific discharge in the saturated alluvium have been completed at the Alluvial Testing Complex. The three tests were conducted in exactly the same manner except that the tracers were allowed to drift with the natural groundwater flow for different amounts of time (0.5 hours, 2 days, and 30 days) before being pumped back out of the well. The tests were conducted in the uppermost interval of NC-EWDP-19D1 because the upward vertical hydraulic gradient that persists throughout the saturated zone and the small vertical transverse dispersivity estimates that are being used in the saturated zone transport model are consistent with radionuclides staying close to the water table in the saturated zone flow system. The differences in the responses of the tracers in the three single-well tests were analyzed by different methods to estimate groundwater flow velocities that are consistent with the different responses. Specific discharge was then estimated by multiplying the estimated groundwater velocities by the assumed effective flow porosity in each analysis.

The compliance boundary, at the time of the saturated zone expert elicitation, was 5 km from the repository horizon. Because of this, the expert panel only addressed specific discharge in the fractured volcanics. Furthermore, there were no direct or indirect estimates of specific discharge anywhere in the saturated zone at the time of the elicitation. Thus, the expert elicitation panel recommended a large uncertainty range that spanned about 2.5 orders of magnitude.

The single-well tracer test results at the Alluvial Testing Complex indicate an uncertainty of less than one order of magnitude in specific discharge in the alluvium (1.2 to 9.4 m/yr) (see Table 1). Furthermore, the range of simulated specific discharges in the area of the Alluvial Testing Complex in the saturated zone transport abstraction model, which is based on calibrations of the saturated zone flow model, falls entirely within the range of the estimates from the single-well tracer tests (1.9 to 3.2 m/yr for different values of horizontal anisotropy in the flow model). Given these two corroborative ranges of specific discharge estimates in the alluvium, it was considered appropriate to reduce the uncertainty in specific discharge relative to the expert elicitation panel's recommendations.

Table 1. Specific Discharges and Seepage Velocities Estimated from the Different Drift Analyses Methods as a Function of Assumed Flow Porosity

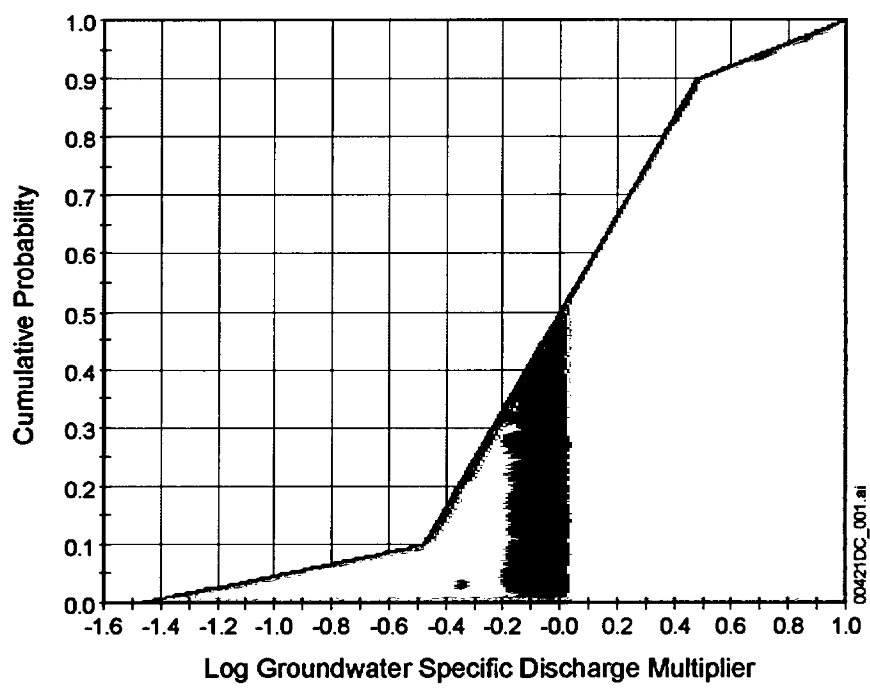
Type of Analysis	Assumed Flow Porosity[a]		
	0.05	0.18	0.3
	Specific Discharge / Seepage Velocity (m/yr)	Specific Discharge / Seepage Velocity (m/yr)	Specific Discharge / Seepage Velocity (m/yr)
Peak Arrival Analysis	1.2 / 24.5	2.4 / 13.1	3.0 / 9.9
Late Arrival Analysis[b]	3.9 / 77.1	7.3 / 40.4	9.4 / 31.3
Mean Arrival Analysis[c]	2.0 / 40.3	3.8 / 20.9	4.9 / 16.4
Mean Arrival Analysis[d]	2.5 / 49.1	4.6 / 25.8	6.0 / 20.2
Linked Analytical Solutions	1.5 / 15 with a flow porosity of 0.10 and a longitudinal dispersivity of 5 m.		

Source: BSC 2003, Table 6.5.7.

NOTE: [a] The three values are approximately the lowest, expected, and highest values of the alluvium flow porosity used in Yucca Mountain performance assessments (BSC 2003).
[b] Time/volume associated with approximately 86.4% recovery in each test (the final recovery in the 0.5-hour rest period test, which had the lowest final recovery of any test).
[c] Mean arrival time calculated by truncating all tracer response curves at approximately 86.4% recovery in each test.
[d] Alternative mean arrival time calculated by extrapolating the tracer response curves in the 0.5-hour rest period test to 91.3% and truncating the response curves in the 2-day rest period test to 91.3% recovery (the final recovery in the 30-day rest period test).

This reduction in uncertainty in specific discharge is reflected by a narrowing of the cumulative probability distribution in the saturated zone flow and transport model abstraction (BSC 2003) over the middle 80% of the probabilities in the distribution. Specifically, the middle 80% of the distribution is assigned an uncertainty range that amounts to approximately 1/3 to 3 times the best estimate of specific discharge, which is consistent with the range of specific discharge estimates from the single-well tracer tests at the Alluvial Testing Complex. However, to account for potential convergence or divergence of flow pathways in the saturated zone (which would affect specific discharge at any given location) and also uncertainty associated with the representativeness of the Alluvial Testing Complex location, the upper 10% and lower 10% of the cumulative distribution for specific discharge are extended beyond the uncertainty range indicated by the Alluvial Testing Complex single-well tests. The lower 10% of the distribution is extended from 1/3 to 1/30 of the best estimate of specific discharge, and the upper 10% of the distribution is extended from 3 to 10 times the best estimate (Figure 1). Both of these extensions are assumed to be log-linear. The overall uncertainty range of nearly 2.5 orders of magnitude in Figure 1 approximately corresponds to the uncertainty range originally recommended by the expert elicitation panel for the fractured volcanics. A single distribution for specific discharge is used for both the volcanics and the alluvium because the specific discharge is expected to be of roughly the same magnitude in both parts of the flow system. Also, overall radionuclide transport times will be dominated by transport times in the alluvium because of the greater flow porosity in the alluvium relative to the volcanics.

Uncertainty in the groundwater specific discharge is incorporated into saturated zone flow and transport model abstraction (BSC 2003) using the continuously distributed groundwater specific discharge factor parameter. This parameter is a multiplication factor that is applied to the permeability and specified boundary flux values in saturated zone flow and transport model abstraction (BSC 2003) to effectively scale the simulated specific discharge in the model. Note that a separate steady-state groundwater flow field is simulated for each realization of the system using the value of groundwater specific discharge factor. The groundwater specific discharge factor sampling is performed on the log-transformed values of the specific discharge multiplication factor (BSC 2003). The cumulative distribution function of uncertainty in the groundwater specific discharge multiplier is shown in Figure 1.



Source: BSC 2003.

Figure 1. Cumulative Distribution Function of Uncertainty in Groundwater Specific Discharge Multiplier

REFERENCES

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CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1998. *Saturated Zone Flow and Transport Expert Elicitation Project.* Deliverable SL5X4AM3. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980825.0008.

Schlueter, J.R. 2003. "Agreement Unsaturated Zone and Saturated Zone Flow under Isothermal Conditions (USFIC) 5.09." Letter from J.R. Schlueter (NRC) to J.D. Ziegler (DOE), January 15, 2003, 0121035744. ACC: MOL.20030401.0059.

ENCLOSURE 2

RESPONSE TO U.S. NUCLEAR REGULATORY COMMISSION ADDITIONAL INFORMATION NEEDS ON FLOW FIELD FOR FUTURE CLIMATE STATES

Note Regarding the Status of Supporting Technical Information

This document was prepared using the most current information available at the time of its development. This Technical Basis Document and its appendices providing Key Technical Issue Agreement responses that were prepared using preliminary or draft information reflect the status of the Yucca Mountain Project's scientific and design bases at the time of submittal. In some cases this involved the use of draft Analysis and Model Reports (AMRs) and other draft references whose contents may change with time. Information that evolves through subsequent revisions of the AMRs and other references will be reflected in the License Application (LA) as the approved analyses of record at the time of LA submittal. Consequently, the Project will not routinely update either this Technical Basis Document or its Key Technical Issue Agreement appendices to reflect changes in the supporting references prior to submittal of the LA.

ENCLOSURE 2

RESPONSE TO U.S. NUCLEAR REGULATORY COMMISSION ADDITIONAL INFORMATION NEEDS ON FLOW FIELD FOR FUTURE CLIMATE STATES

U.S. NUCLEAR REGULATORY COMMISSION ISSUE

Uncertainty in present-day flow fields is considered only with regard to horizontal hydrologic anisotropy in the U.S. Department of Energy (DOE) site-scale saturated zone flow model. No uncertainty or variability in climate-change time or magnitude are considered. When a climate change does occur, no uncertainty or variability in flow paths or water-table elevation are considered. This is especially important, considering that present-day flow fields represent only 6% of the compliance period. Greater recharge can be expected during the following climate states with an expected rise of the water table. Future conditions of the groundwater flow system at Yucca Mountain are unknown, but estimates from past changes in climate and observation of paleosprings deposits have indicated 80 to 120 m higher water-table elevations. Contaminants traveling near the surface of the saturated zone during future climate states would be in different hydrostratigraphic units at different locations. Transport modeling results could be affected. In addition, present-day flow paths may diverge for the monsoon and glacial-transition climates, and transport times altered. DOE has discussed at various public meetings plans to change the current method for determining flow fields for future climates. These changes need to be documented, or the justification for not making any changes needs to be shown, in order to complete Agreement Unsaturated and Saturated Flow under Isothermal Conditions (USFIC) 5.02.

RESPONSE

Results of climate change simulations (D'Agnese et al. 1999) indicated that during past climate conditions for the Death Valley Regional Flow System (DVRFS), recharge increased in most areas to produce a similarly shaped but higher regional potentiometric surface. Under future climate conditions, the simulations indicated that configuration of the potentiometric surface changed only slightly from the current one to indicate depressions at discharging playas. The flow fields for future and present-day climate conditions do not appear to be appreciably different at the DVRFS scale.

The regional and local increases in recharge will tend to increase the groundwater flux through the saturated zone system and lead to a rise in the water table beneath Yucca Mountain. The effects of climate change on radionuclide transport simulations in the saturated zone are incorporated into the total system performance assessment (TSPA) analyses by scaling the simulated saturated zone breakthrough curves by a factor representative of the alternative climate state (BSC 2001, Section 6.2.5).

Regional groundwater system modeling under climatic conditions, reconstructed to have existed during the glacial maximum at about 21,000 years ago, results in estimated water-table levels beneath Yucca Mountain that are 60 to 150 m higher than present (D'Agnese et al. 1999). Given the uncertainties in such simulations, these estimates are consistent with the field evidence.

Although there is mineralogic evidence for a water-table rise beneath Yucca Mountain of as much as 100 m, the age of such a rise is poorly constrained and may represent conditions from as long as 10 million years ago (BSC 2004, Section 8.4.5). Other reported large rises at paleodischarge sites assumed greater depth to water than is now known to exist and, in some cases, involved deposits of unknown age. The most reliably dated paleospring deposits (where depth to water is known) suggest groundwater table rises of only 10 to 30 m in the last 15,000 years (BSC 2004, Section 8.4.5).

Even though site-scale and regional models use a more conservative simulation technique that increases flux during the future glacial climate period, the most recent field evidence now suggests that the water-table rise within the regulated area will be small and would not cause the water table to encounter new hydrostratigraphic units with different flow and transport properties during the regulatory period.

BASIS FOR THE RESPONSE

Water-Table Rise–Wetter glacial climatic conditions are expected to occur in the future at the Yucca Mountain site within the 10,000-year period of regulatory concern (CRWMS M&O 2000). These changes in the climate relative to present conditions would affect groundwater flow in the saturated zone by significantly increasing the amount of recharge to the regional groundwater flow system. These regional and local recharge increases will tend to increase the groundwater flux through the saturated zone system and lead to a rise in the water table beneath Yucca Mountain.

The TSPA analyses incorporate effects of climate change on radionuclide transport simulations in the saturated zone by scaling the simulated saturated zone breakthrough curves by a factor representative of the alternative climate state (BSC 2001). The scaling factor used in this approach is the ratio of average saturated zone groundwater flux under the future climatic conditions to the flux under present conditions. This approach approximates the impacts of future wetter climatic conditions in which the saturated zone groundwater flux will be greater. However, this approach implicitly assumes the same flow path for radionuclide transport through the saturated zone under wetter climatic conditions of the future.

To evaluate the potential effects of climate change, the saturated zone site-scale flow model was adapted to include the effects of estimated water-table rise and to compare the results of particle-tracking simulations using this adapted model to the simple flux scaling approach used in TSPA analyses. This modeling assumes, based on qualitative arguments, that the flux scaling approach to simulation of climate change is conservative with regard to radionuclide transport in the saturated zone, compared to the more realistic situation in which water-table rise is included in the modeling. This discussion provides a justification for that assumption (BSC 2003a, Section 6.4.5).

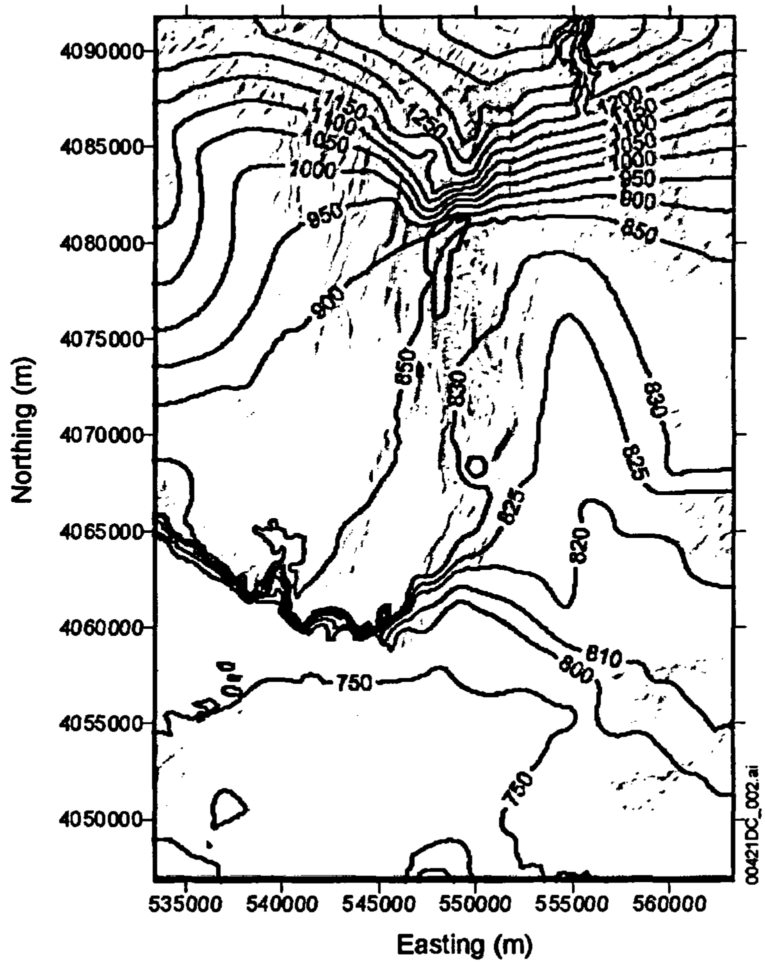
Estimating Water-Table Rise from Climate Change–Rise in the water table during wetter climatic conditions at Yucca Mountain is a complex function of increased recharge to the saturated zone and fluctuations in the amount and spatial distribution of discharge from the regional saturated zone system. Simulations of groundwater flow under wetter glacial climatic conditions with the saturated zone regional-scale flow model (D'Agnese et al. 1999) indicate that groundwater flow paths from beneath Yucca Mountain do not change appreciably. These simulations also show that groundwater discharge from the saturated zone for the wetter glacial climate would not occur along the flow path from Yucca Mountain any closer than the controlled area boundary about 18 km south of the repository (BSC 2003a, Section 6.4.5). The estimated elevation of the water table under wetter glacial climatic conditions within the domain of the saturated zone site-scale flow model is calculated using the software code WTCONVYD V.1.00 (SNL 2002). This software code uses an algorithm that incorporates qualitative information on the paleo-flow system, an estimate of increased groundwater flux under glacial conditions, and physical limits to the position of the water table. The software code calculates the estimated rise in the water table using this algorithm, along with data on the present water-table surface and the elevations of the topographic surface (BSC 2003a, Section 6.4.5).

Estimates for Yucca Mountain water-table elevation for wetter glacial climatic conditions indicate that the water table could have been on the order of 100 m higher. Consequently, the water table is calculated as 100 m higher than present conditions in the area beneath Yucca Mountain. In addition, the elevation of the water table under glacial conditions is assumed to be 100 m higher than at present for all areas within the model domain except where this would result in a water-table rise above ground surface (BSC 2003a, Section 6.4.5). In these areas, the software code increases the elevation of the water table by a uniform value of 10 m for locations within the model domain south of the repository site, where the water table is already near land surface under current conditions (BSC 2003a, Section 6.4.5).

Simulations of groundwater flow under wetter glacial climatic conditions with the saturated zone regional-scale flow model (D'Agnese et al. 1999) indicate that the groundwater flux in the area of Yucca Mountain would be about four times greater than at present (BSC 2001, Section 6.2.5). The software code WTCONVYD V.1.00 (SNL 2002) calculates the higher water-table elevations for glacial conditions so that the approximate hydraulic gradient would be greater by a factor of 4 for locations in the model domain where the present water table is intermediate between the 100 m rise areas and those areas to the south where only 10 m of rise was added. This range of water-table elevations covers that portion of the saturated zone flow system along the flow path from beneath the repository to the controlled area boundary about 18 km south of the repository. The approximation used in this approach assumes that the average permeability along the flow path would not differ significantly between present conditions and the glacial climatic conditions and that a four-fold increase in the gradient would result in an approximately four-fold increase in the groundwater flux.

WTCONVYD V.1.00 (SNL 2002) also limits the estimated rise in the water table under glacial climatic conditions to within 1 m of the topographic surface, which constitutes a physical limit to the rise in the water table within the domain of the saturated zone site-scale flow model. Rise of the water table to within 1 m of the surface would induce significant groundwater discharge by evapotranspiration and the formation of local springs (BSC 2003a, Section 6.4.5).

The estimated elevations of the water table under wetter glacial climatic conditions, as calculated by WTCONVYD V.1.00 (SNL 2002), are shown in Figure 1. The contours for the water-table surface are generally similar to the present water table, with the exception of the area in Fortymile Canyon in the northern part of the model domain and in some areas in the south-central and southwestern parts of the model domain (BSC 2003a, Section 6.4.5).

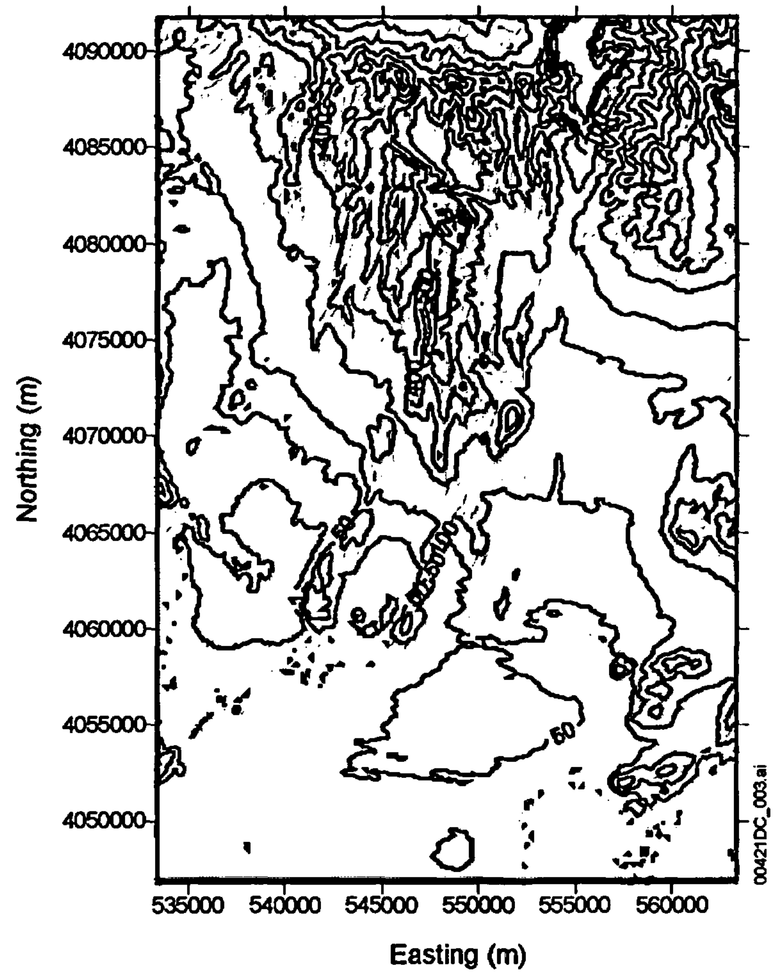


Source: BSC 2003b (repository outline).

NOTE: Repository outline is shown with bold blue line. For illustration purposes only.
Legend: —1,000— Potentiometric contour. Contour interval, in meters, is variable. Datum is mean sea level. Coordinates are Universal Transverse Mercator.

Figure 1. Estimated Water-Table Elevations for Future Glacial Climatic Conditions

Figure 2 shows the estimated depth to the water table under wetter glacial climatic conditions, as calculated by WTCONVYD V.1.00 (SNL 2002). The areas in which the estimated water table is within 5 m of the topographic surface are shown with the yellow shading. The larger yellow area of shallow estimated groundwater in the southwestern part of the domain contains the three areas of paleospring deposits located along Highway 95 and at the southern end of Crater Flat. This shows a certain degree of consistency between the estimated higher water table and the geologic features associated with Pleistocene spring discharge. The specific paleospring locations are probably controlled by structural controlling features below the resolution of the analysis of the estimated water-table elevation under glacial climatic conditions. The other site of shallow estimated groundwater shown in Figure 2 is Fortymile Canyon. Although paleospring deposits are not observed in Fortymile Canyon, it is not unreasonable to postulate that such deposits would not be preserved in such an active geomorphic location as the bottom of this canyon. In any event, the large block sizes of the numerical model would average out heterogeneities of this scale (BSC 2003a, Section 6.4.5).



Source: BSC 2003b.

NOTE: Repository outline is shown with bold blue line. Areas with estimated depth to the water table of less than 5 m are shown with yellow shading. For illustration purposes only.
Legend: —50— Depth to water table from topographic surface. Contour interval, in meters, is variable.
Coordinates are Universal Transverse Mercator.

Figure 2. Estimated Depth to the Water Table for Future Glacial Climatic Conditions

In summary, a reasonable estimate of the water-table elevation under wetter glacial climatic conditions is developed for the saturated zone site-scale flow model domain. The estimated rise in the water table is consistent with the estimated increase in groundwater flux along the inferred flow path from beneath the repository. In addition, the pattern of the estimated rise in the water table is generally consistent with the locations of paleospring deposits within the domain (BSC 2003a, Section 6.4.5).

Hydrogeologic Units Encountered by Water-Table Rise in the Saturated Zone Site-Scale Flow Model–The saturated zone site-scale flow model is adapted to the higher estimated water table for glacial climatic conditions by creating a new grid with an upper surface corresponding to the higher water table. The lateral and bottom boundary locations remain the same in this adaptation of the model.

There are potential differences in the hydrogeologic units present in the shallow saturated zone beneath the repository and along the inferred flow path to the south and east of the repository. The upper volcanic confining unit is much more widely distributed at the water table beneath the repository under estimated future glacial climatic conditions than it is under present conditions, particularly under the northern and eastern parts of the repository. To the south and east of the repository, the alluvium unit (absent under the present conditions) is present at the water table over a broad area under estimated future conditions (BSC 2003a, Section 6.4.5).

Summary of Water-Table Rise Scenarios–Although there is mineralogical evidence for a water-table rise beneath Yucca Mountain of as much as 100 m, the age of such a rise is poorly constrained and may represent conditions from as long as 10 million years ago. More recently dated paleospring deposits (where depth to water is known) suggest groundwater table rises of only 10 to 30 m in the last 15,000 years (illustrated on Figure 2 by the yellow shading to the south and west of the repository block). However, this more constrained water-table rise was measured some distance from Yucca Mountain. These two evaluations are not inconsistent but represent a potentially realistic case in areas where datable deposits occur distant from the site, and a possible extreme case closer to the repository block is utilized in modeling. By using the larger water-table rise, the model enters lower conductivity hydrogeologic units but with a higher flux related to the increased recharge. In this way, the model bounds the uncertainty.

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