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**THE ORIGIN OF ELEVATED WATER LEVELS IN
EMPLACEMENT BOREHOLES, PAHUTE MESA,
NEVADA TEST SITE: A NUMERICAL STUDY**

**G.G. Gardner
T.H. Brikowski**

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by

G.G. Gardner
T.H. Brikowski

Water Resources Center
Desert Research Institute
University and Community College System of Nevada

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ABSTRACT

The origin of elevated water levels in emplacement boreholes at Pahute Mesa, Nevada Test Site, is uncertain. If the water is from naturally perched aquifers, then presumed "above water table" weapons tests may directly impact the groundwater quality. The purpose of this study is to determine the probable source of the elevated water in boreholes by comparing modeled seepage of infiltrated drilling fluids, and the seepage from a simulated naturally perched aquifer with the observed water level history. In the model, large volumes of water are infiltrated, yet return flow of fluids back into the hole stops within three days after the end of drilling and is insufficient to produce observed standing water. Return flow is limited for two reasons: 1) The volume of the saturated rock next to the borehole is small. 2) Pressure head gradients direct unsaturated flow away from the borehole. Simulation of seepage from a naturally perched aquifer readily reproduces the observed water levels.

INTRODUCTION

Elevated water levels above the predicted regional water table in emplacement boreholes are a recurring phenomenon at Pahute Mesa on the Nevada Test Site. The origin of these water levels is uncertain. If the water seeps in from naturally perched aquifers in the fractured volcanic rocks, then presumed "above water table" weapons tests may directly impact the groundwater quality. If, however, the elevated water levels are the result of the return of infiltrated drilling fluids, then such impacts are less likely. The purpose of this study is to determine the probable source of the elevated water levels by comparing the modeled return flow of infiltrated drilling fluids and the modeled seepage from a simulated naturally perched aquifer with the observed water level history in a representative borehole (U-19ba) with elevated water levels. Previous attempts to identify the origin of the elevated water levels using tracer tests gave inconclusive results (Brikowski et al., 1993). Additional opportunities for such tracer tests appear unlikely given the current testing moratorium; therefore conceptual hypothesis testing using numerical modeling has been adopted as an alternative approach to answer this question. An understanding of the origin of these elevated water levels will allow an assessment of the potential groundwater contamination risk posed by near water table underground nuclear tests at Pahute Mesa.

BACKGROUND

Location

Pahute Mesa is located approximately 210 km (130 mi) northwest of Las Vegas, Nevada, in Nye County, in the northwestern part of the Nevada Test Site (NTS). It is an elevated plateau of about 500 sq km (200 sq mi) with elevation ranges from 1670 m (5,500 ft) to more than 2130 m (7,000 ft). The water level history of a representative borehole (U-19ba) will be used for comparison with the modeled results. U-19ba is located at Nevada State Plane coordinates of N 926,950 ft, E 602,900 ft in the central portion of Area 19 of the NTS at an elevation of 2134 m (7001 ft) (Figure 1).

Drilling Procedure and History

The current technique for drilling large diameter (2.44 m or 96 in) emplacement boreholes is a dual circulation method using air and water. It requires two concentric pipes with air and water pumped simultaneously down the space between the two pipes into the bit body. Here the fluids entrain drill cuttings and move back up the inner portion of the dual pipe to the surface where the cuttings are removed and the water reused (NTS, 1969). Up to several hundred meters of water are maintained in the hole to provide downward force on the drill bit. Typical drilling rates at Pahute Mesa are about 1.04 m/hr (3.4 ft/hr) for 15 to 23 hours per day, with the drilling rig secured on weekends. At the end of drilling, the borehole is blown "dry" with 0.6 m (2 ft) to 3.0 m (10 ft) of water remaining in the hole (D. Donithan, pers. comm.).

Drilling of U-19ba began on July 27, 1989 and was completed to a total depth of 663.6 m (2177 ft) on September 11, 1989. The column of water above the drill bit ranged in depth from 0 m to over 200 m during the course of drilling. During drilling, lost circulation material was used intermittently

Figure 1. Location map of sites discussed in this study, Nevada State Plane coordinates.

from 42.7 m (140 ft) to about 165 m (540) to reduce the loss of drilling fluid to the welded tuff (Ratheon Services Nevada, 1991). After the borehole was blown dry (0.6 m of water remained in the hole), water levels rose at an exponentially-decaying rate, stabilizing with about 7 meters of water in the hole (Figure 2). A nuclear test was conducted in U-19ba subsequent to these measurements on April 4, 1991 (DOE, 1993).

The choice of borehole to be modeled was based on two criteria: first, lithologic logs (Drellack, 1990) and a post-drilling water level history (USGS, unpublished data) were available; second, the water levels in the borehole must be anomalously high, that is, the standing water in the hole is above the predicted regional water table, based on the contour map of Blankennagel and Weir (plate 1, 1973) and water levels in nearby wells. For example, five wells (U-19an, U-19ax, U-19ac, UE-19t and U-19t) within 2 km of U-19ba and drilled to about the same depth are all dry (USGS, 1993).

Previous Investigations

The return flow of infiltrated drilling fluids has often been cited as the source of elevated water levels in emplacement boreholes. Winograd (1970) suggested that large volumes of drilling fluids lost into fractured aquifers ("thief zones") above the water table can enter the borehole if the formations above the water table are not cased and cemented off before measurement and an example of a borehole where this was apparently the case was cited.

Figure 2. Water levels in U-19ba after completion. Data before November 1990 are from USGS records, levels after this date are Desert Research Institute data.

Limited chemical and tracer studies have been carried out in three holes in Area 19 that have standing water above the predicted water table: U-19az, U-19ba and U-19bh. While constraining possible origins of the standing water, the results of these studies were equivocal. The chemical composition of the water in U-19az was found to differ significantly from that of the original drilling fluid, but whether this was from the addition of natural perched water or dissolution of solids from the formation by the drilling fluids is uncertain. A point-dilution test performed in U-19ba indicated that there was no movement of groundwater between the borehole and the surrounding rocks. The fluids used during the drilling of the bottom 90 m (300 ft) of U-19bh were labeled with a tracer. Unlabeled fluid composed the bulk of the fluid entering the hole after completion, but it was uncertain whether this was from infiltrated drilling fluid before labeling began or from naturally perched water (Brikowski et al., 1993).

HYDROGEOLOGIC SETTING AND CONCEPTUAL MODEL

Geology

Gravity data have revealed a deep structural depression, the Silent Canyon Caldera, underlying much of Pahute Mesa. Geologic studies of Pahute Mesa have described a thick sequence of generally flat-lying Tertiary volcanic rocks that include ash-fall tuffs, welded and nonwelded ash-flow tuffs and rhyolitic lavas. These volcanic-tectonic features have been described by various authors (Blankennagel and Weir, 1973; Orkild et al., 1968; Byers et al., 1989).

At Pahute Mesa, the ash-flow tuffs range from nonwelded to densely welded with fractures common in the welded tuffs. The fractures are more closely spaced in the zones of most intense welding and are absent in the nonwelded parts of the flow (Ross and Smith, 1961). The ash-fall (bedded) tuffs have a much lower fracture frequency than either the welded tuffs or the rhyolitic lava flows. In addition, the fractures in the less competent ash-fall tuffs are often resealed. The ash-fall tuffs can either be vitric (in which the glassy fragments are unaltered) or zeolitized (glassy fragments are altered to zeolites). In the rhyolite, high-angle joints are more common than low-angle joints; jointing in flow breccia is variable (Blankennagel and Weir, 1973).

U-19ba penetrates 663.6 m (2177 ft) of Tertiary volcanic rocks that include ash-flow tuffs, ash-fall tuffs, tuff breccias and rhyolite lavas. A generalized stratigraphic log and a geologic cross section of U-19ba are reproduced in Appendix A. The surface traces of four normal faults are within 180 m to 350 m (591 ft to 1148 ft) of the borehole (Drellack, 1990).

Hydrogeology

Saturated properties

A hydrologic investigation was initiated by the USGS in the 1960s to determine the water yield potential of the volcanic rocks of Pahute Mesa (Blankennagel and Weir, 1973). A combination of injection tests, withdrawal tests and single well pumping tests were used to determine the transmissivities of rhyolitic lavas, welded tuffs and zeolitized bedded tuffs. Winograd and Thordarson (1975) determined transmissivities of welded tuffs and vitric bedded tuffs with pumping

tests; laboratory studies determined matrix conductivities and porosities on vitric and zeolitized tuffs. Straddle packer pump tests have been used to obtain the hydraulic conductivity of welded tuff near Yucca Mountain (Thordarson, 1983). More recent aquifer tests by the USGS (DOE, 1991) at Pahute Mesa have been used to calculate the hydraulic conductivity of welded and nonwelded tuffs and rhyolites. In general, the lowest permeabilities were found for the zeolitized tuffs, the vitric tuffs are more permeable than the zeolitized tuffs. The rhyolites and the welded tuffs have the highest permeability depending on the local fracture density.

An estimate of the potential recharge to the water table beneath Pahute Mesa has been made by Blankennagel and Weir (1973) using a method developed by Eakin (1951). Based on a percentage of the annual precipitation, recharge at Pahute Mesa is estimated between 4 mm/yr and 23 mm/yr.

At Pahute Mesa, the elevation of the water table ranges from about 1280 m to 1480 m above sea level (asl). In the vicinity of U-19ba, the elevation of the water table is approximately 1432 m (4700 ft), based on the water level contour map of Blankennagel and Weir (1973). The elevation of the bottom of U-19ba is 1470.3 m asl or about 40 m above the water table. An alternative water level contour map based on shallow wells only (DOE, 1991) puts the water table about 30 m higher, or about 10 m below U-19ba.

Perched groundwater (saturated zone separated from the regional system) and semi-perched groundwater (groundwater with a greater pressure head than an underlying body of water but not separated by any unsaturated rock) is often encountered within Pahute Mesa especially at higher elevations and within the bedded tuff aquitards (Blankennagel and Weir, 1973; Winograd and Thordarson, 1965). Perched water levels may be tens to hundreds of meters higher than the regional system at Pahute Mesa.

Unsaturated properties

For the purposes of modeling, the saturated properties must be supplemented with the unsaturated characteristic curves: the water retention curve (pressure head vs. saturation) and the relative conductivity vs. pressure head (or saturation) curve. Measurements of the unsaturated properties of units at Pahute Mesa are unavailable. Data on matrix porosities, saturation, water content, pressure head and conductivity are available for tuffs at nearby Yucca Mountain. These are based on laboratory analysis of drill cores for welded tuffs, vitric and zeolitized non-welded tuffs from Yucca Mountain from a variety of sources (Anderson, 1981; Rush et al., 1984; Thordarson, 1983; Weeks and Wilson, 1984; Kume and Hammermeister, 1990; Whitfield and Cope, 1992). Unsaturated characteristic curves have been derived for the tuffaceous units at Yucca Mountain (Klavetter and Peters, 1986; Flint et al., 1993). The water retention curves were obtained by fitting the van Genuchten (1980) parameters to laboratory data for drainage of unfractured drill cores. Wetting curves have not been obtained for any tuffs at Yucca Mountain; therefore, there are no data on hysteresis. Limited measurements of relative conductivity vs. saturation have been made (Flint and Flint, 1990), and therefore the van Genuchten parameters were used to estimate this relation for the tuff units at Yucca Mountain (Klavetter and Peters, 1986). Theoretical characteristic curves have been developed for fracture flow based on physical principles and statistical concepts (Wang and

Narasimhan, 1985). The hydrologic properties used in this model are further described in the Model Inputs Section below, and are summarized in Tables 1 and 2.

Conceptual Model

Formulation of the conceptual model requires the specification of the geometry and boundary conditions of the system and hydrologic properties of the units. In this study, the variably saturated flow system is treated as an axisymmetric (cylindrical coordinates), multi-layered system consisting of five flat-lying hydrostratigraphic units (Figure 3). Each unit is assumed to be internally homogeneous. The upper boundary represents the land surface with a constant recharge rate from precipitation. The lower boundary represents the regional water table and is assumed to be 700 m below the land surface or 40 m below the bottom of the borehole. The left (proximal) boundary represents the borehole wall. The continuous drilling rate is approximated by a step function. The column of water above the drill bit causes infiltration into the formation and it is assumed that this water is replaced so that the column remains a constant 100 m. After the water column passes, the borehole wall then becomes a seepage face allowing water to exit the formation into the borehole. The right (distal) boundary is placed far enough away so as not to effect the infiltration or seepage near the borehole.

The rocks at U-19ba are grouped into three informal hydrogeologic types based on their physical properties as determined for similar lithologies at Yucca Mountain (Klavetter and Peters, 1986; Ortiz et al., 1985):

1. Welded tuffs and rhyolites that are highly fractured and are highly permeable.
2. Nonwelded, vitric bedded tuffs that have few fractures and are moderately permeable.
3. Nonwelded, zeolitized tuffs and tuff breccias that have few fractures and have low permeabilities.

MODEL DESIGN

Approach

The approach of this model study is interpretive: to study the dynamics of a site-specific system (Anderson and Woessner, 1992) using the characteristics at a single location, U-19ba. Three scenarios will be modeled: Cases I and II simulate the infiltration of fluids into the unsaturated zone during drilling, and subsequent return flow of fluids during and after drilling; these cases examine the effects of various hydrologic properties, initial and boundary conditions. Case III simulates the seepage of water from a naturally perched aquifer into the borehole. The results of these models will be compared with the observed water level history of borehole U-19ba with elevated water levels to determine their probable source. A sensitivity analysis is done to assess the impact of parameter uncertainty on the conclusions of this study. A conventional model calibration is not done, i.e., adjusting hydrologic properties so that the model matches the observed field data since there are no data on pressure heads in the unsaturated zone for any Pahute Mesa borehole, nor are there any reliable data on infiltration or return flow rates.

Table 1. Hydrologic Properties for Case I.

Hydrostratigraphic Unit	Saturated Horizontal Conductivity (m/d)	Anisotropy Ratio (horizontal/vertical)	Porosity	Specific Storage (m^{-1})	van Genuchten Parameters			Characteristic Curve
					Sr	α ($10^{-2}/m$)	β	
Welded Tuff	1.0	1.0	0.11	1.0×10^{-6}	0.080	0.567	1.798	ψ vs sat Kr vs sat
					0.0395	128.51	4.23	
Bedded Tuff-vitric	4.0×10^{-2}	10.0	0.37	1.0×10^{-6}	0.041	1.60	3.872	ψ vs sat Kr vs sat
Bedded Tuff-zeolithized	1.0×10^{-4}	12.5	0.31	1.0×10^{-6}	0.110	0.308	1.602	ψ vs sat Kr vs sat
					0.080	0.567	1.798	
Rhyolite	1.0	1.0	0.11	1.0×10^{-6}	0.0395	128.51	4.23	ψ vs sat Kr vs sat
Tuff Breccia	1.0×10^{-4}	12.5	0.31	1.0×10^{-6}	0.110	0.308	1.602	ψ vs sat Kr vs sat

Table 2. Hydrologic Properties for Cases II and III.

Hydrostratigraphic Unit	Saturated Horizontal Conductivity (m/d)	Anisotropy Ratio (horizontal/vertical)	Porosity	Specific Storage (m^{-1})	van Genuchten Parameters			Characteristic Curve
					Sr	α ($10^{-2}/m$)	β	
Welded Tuff	partially	1.0×10^{-3}	1.0	1.0×10^{-5}	0.080	0.567	1.798	ψ vs sat
	moderately	0.1	0.10		0.0395	128.51	4.23	Kr vs sat
	densely	1.0	0.1					
Bedded Tuff-vitric	4.0×10^{-2}	10.0	0.40	1.0×10^{-5}	0.041	1.60	3.872	ψ vs sat Kr vs sat
Bedded Tuff-zeolithized	1.0×10^{-4}	10	0.30	1.0×10^{-5}	0.110	0.308	1.602	ψ vs sat Kr vs sat
					0.080	0.567	1.798	
Rhyolite	1.0	0.1	0.10	1.0×10^{-5}	0.0395	128.51	4.23	ψ vs sat Kr vs sat
Tuff Breccia	1.0×10^{-3}	1.0	0.30	1.0×10^{-5}	0.110	0.308	1.602	ψ vs sat Kr vs sat

Figure 3. Conceptual model for U-19ba drilling simulation.

The numerical modeling was performed using the finite element computer code VAM2DH (Huyakorn et al., 1988), chosen for its ability to model axisymmetric geometry (cylindrical coordinates), variably saturated flow and the seepage face boundary condition. The governing equation is described in Appendix B. The code has been verified by comparison to analytic solutions for saturated flow problems and has been compared with other numerical codes and laboratory experiments for unsaturated flow problems. VAM2DH's numerical simulation of a constant head

well permeameter is consistent with available semi-analytic solutions (Appendix C) and another numerical model study (Stephens and Neuman, 1982a,b).

Assumptions

Certain assumptions must be made when modeling because of incomplete data and the need for simplification to make the problem tractable. This study assumes that fracture and matrix flow are combined as a single composite continuum system and the rock is modeled as equivalent porous media. The following simplifications are made:

1. Darcy's law for variably saturated porous media is used to describe all flow.
2. Hysteresis is not modeled.
3. Only isothermal, single-phase fluid flow is considered.
4. The continuous drilling rate is simulated with a step function.
5. Infiltration out the bottom of the hole is not modeled; the area for infiltration out the bottom of the hole is two orders of magnitude less than that of the borehole wall.
6. The effect of drilling mud and lost circulation material on infiltration and return flow is not modeled. Limited amounts of both were only used in drilling the upper 100 m of the borehole
7. Recharge from precipitation is uniform spatially and temporally.
8. Discrete faults are not modeled in the flow system.

Model Inputs

The material properties used in Case I are summarized in Table 1, and Table 2 summarizes Cases II and III. Fracture flow is modeled in an implicit fashion with theoretical curves of relative conductivity vs. pressure head (or saturation) developed by Wang and Narasimhan (1985). In addition, relatively high saturated conductivities calculated from pump tests are utilized which reflect fracture rather than matrix characteristics. It is further assumed that the flow between fracture and matrix occurs rapidly, thus the pressure head in the fractures and the matrix are equal (Klavetter and Peters, 1986); therefore, matrix water retention curves are used for the welded tuff and rhyolite units in this study.

For Case I, the conductivity for the welded tuff and the rhyolite is assumed to be homogeneous and isotropic (Figure 4). For Cases II and III, the welded tuff is divided into zones of conductivity based on the degree of welding (Drellack, 1990) and therefore approximate fracture density (Figure 5) (USGS, unpublished data). For Cases II and III, the densely welded tuff and the rhyolite are assumed to be anisotropic to simulate the effect of vertical jointing.

The saturated conductivities of the vitric and zeolitized bedded tuffs used in this model are from drill core data and therefore do not include fracture effects (Montazer and Wilson, 1984;

Figure 4. Element grid, boundary conditions and hydrostratigraphic zones – Case I.

Figure 5. Element grid, boundary conditions and hydrostratigraphic zones – Cases II and II.
Conductivity is a function of the degree of welding within the units.

Klavetter and Peters, 1986) although pumping test data give similar values for these lithologies (Winograd and Thordarson, 1975; Blankennagel and Weir, 1973). These units are assumed to be anisotropic due to bedding, although it is equally possible that zeolitization destroys any anisotropy (Montazer and Wilson, 1984). The unsaturated characteristic curves are given by Klavetter and Peters (1986).

The zeolitized tuff breccia (the bottom 20 m of the borehole, Figure 3) is assigned the same hydrologic properties as the zeolitized tuff for Case I. The conductivity is increased by an order of magnitude for Cases II and III; this adjustment was required to prevent this unit from becoming fully saturated with the increased recharge for those simulations.

Under transient conditions water may be taken into or released from storage; therefore, the specific storage coefficient and the porosity must be specified (Freeze and Cherry, 1979; Huyakorn et al., 1988). Values measured for similar lithologies are used in the model (Klavetter and Peters, 1986; Rush et al., 1984; Barr, 1985).

Grid Design

The axisymmetric grid is 700 m in the vertical (z) direction and 1000 m in the radial (r) direction (Figures 4 and 5). The minimum z coordinate ($z=0.0$ m) corresponds to the water table and the maximum z coordinate ($z=700$ m) corresponds to the land surface. The minimum radial coordinate ($r=1.2$ m) is the borehole wall and the maximum r coordinate ($r=1000$ m) was found by trial and error to minimize any boundary effect. Nodal spacing in the vertical direction is a constant 10 m; nodal spacing in the radial direction is 5 m at the borehole wall and increases with a scale factor of 1.2. Although the element aspect ratio approaches 20:1 (distally to the borehole), there are no observed numerical instabilities, since the hydraulic gradients in the radial direction are small.

MODEL PROCEDURE

The drilling simulations (Cases I and II) are modeled in three sequential stages: pre-drilling, drilling and post-drilling. The naturally perched aquifer simulation (Case III) omits the drilling stage.

Pre-drilling Stage

The purpose of this simulation is to generate initial conditions consistent with a water table at depth and recharge at the surface. The pre-drilling simulation for all three cases is similar, differing only in the recharge rate due to precipitation and in assumed hydrologic properties. No-flow conditions are specified for the vertical sides of the model, saturated conditions are specified along the bottom, and a constant recharge specified along the top. Since the purpose of modeled Cases I and II is to determine if drilling fluids alone can account for the observed water level, recharge rates are chosen that do not produce perching. The simulated naturally perched aquifer uses a value of 12.0 mm/yr, the mean value estimated for Pahute Mesa (Blankennagel and Weir, 1973). The resulting pressure head distribution is obtained with a steady-state solution using the Newton-Raphson iterative procedure.

Drilling Stage

The purpose of these simulations is to model the infiltration of drilling fluids and the subsequent return of the fluids to the borehole during drilling. The model is started with the nodal values from the pre-drilling simulation as initial conditions. The distal boundary nodes are held at constant pressure head corresponding to the values from the pre-drilling simulation to allow the system to return to the pre-drilling conditions after the water column has passed.

The downward movement of the water column during drilling is simulated in discrete one-day steps to match the typical 20 m/day drill rate. A 100-m array of constant head nodes representing the column is moved down 20 m at the end of each simulated day. The simulation is restarted at the beginning of each drilling day using the final results of the previous day as the initial conditions. For drilling depths less than 100 m, the column height is set equal to the drilling depth. Once the water column passes, the borehole wall becomes a seepage face where the boundary condition may be switched from atmospheric pressure to no-flow to satisfy the constraints of: negative flux values (seepage only from the formation into the borehole), negative pressure head values above the seepage face and zero pressure heads on the seepage face (Huyakorn et al., 1988). A transient solution using the Picard iteration procedure required small initial time steps (.864 sec) and a step multiplier of 1.2 for 54 time steps per simulated day.

For Case I, the 100-m column of water moves down the borehole boundary in constant increments of 20 m per day. For Case II, the column of water is allowed to stand for an additional 20 days in contact with the highly saturated units (the bedded tuffs and the tuff breccia) to evaluate the effect of a slower drilling rate and standdowns in drilling, a common occurrence in the field (Figure 6). At 20 m per restart, 33 restarts are required for the column of water to reach the bottom of the hole at 660 m below the surface or 40 m above the water table. For Case I, the total simulated drilling time is 33 days and for Case II, 53 days.

Post-drilling Stage

The purpose of this simulation is to model the seepage of fluids back into the borehole after the hole is pumped dry at the end of drilling. Since nearly all borehole water is removed at the end of drilling, it is this post-drilling seepage that must supply all the observed standing water in the completed borehole.

The constant pressure head nodes representing the column of water are now replaced with the seepage face boundary condition and the model is restarted with the nodal values from the previous simulation. In effect, the 100-m column of water is removed instantaneously and the borehole wall becomes a seepage face. The transient simulation of the system continues until conditions approach the pre-drilling state.

MODEL RESULTS

Case I

This simulation is an initial view of the system using the best estimates of the hydrologic properties to determine if these estimates are consistent with the conceptual model and to indicate

Figure 6. Borehole depth vs. time. Actual drilling history shown for U-19ba and for simulated Cases I and II.

where parameter adjustment is necessary. The results of the pre-drilling stage with 0.5 mm/yr of recharge gives low pressure heads near the ground surface. While this recharge rate is less than that estimated for Pahute Mesa, experimentation showed that a larger value would result in saturation of the tuff breccia unit given the assumed hydrologic properties (Table 2). The pressure heads range from 0.0 m (saturation 1.00) at the water table to approximately -500 m (saturation 0.45) at the land surface (Figure 7). The pressure heads at the land surface are likely too small based on comparison with data from Yucca Mountain (Montazer et al., 1985; Kume and Hammermeister, 1991), although the modeled saturation values are similar with a general increase in saturation with depth (Weeks and Wilson, 1984). The small pressure heads at the land surface result from the assumption of a thick homogenous unit with a vertical saturated hydraulic conductivity greater than the vertical flux (in this case, the welded tuff and the rhyolite), which will gravity drain and therefore will be at unit vertical hydraulic gradient in steady state. For every meter in the vertical direction, the pressure head must change by one meter.

At the end of the simulated fifth day of drilling, a small saturated bulb forms around the water column extending no more than 10 m in the radial direction from the borehole wall. Approximately 5 percent of the infiltrated water is in the saturated bulb and the remainder in the unsaturated envelope (Figures 8 and 9). The saturated bulb spreads laterally and is, in effect, perched when the column of water reaches the contact between the high conductivity welded tuff and the low conductivity bedded tuff (Figure 10) and again at the contact between the rhyolite and the tuff breccia. The volume of return flow increases when these perched zones are exposed after the water column passes (Figure 11). When the water column is in contact with the higher pressure heads near the bottom of the hole (Figure 12), the infiltration rate is reduced by a factor of about three (Figure 13) and the saturated bulb extends about 40 m radially from the borehole wall.

Fluid flow is outward from the hole while the water column is present and then briefly inward toward the borehole while the seepage face is active. Seepage ends quickly when saturation at the borehole wall drops below 1.00 after which the borehole wall becomes a no-flow boundary. Elevated pressure heads and saturations (Figures 10, 12, 14), with respect to the initial conditions, cause the flow to once again be outward from the borehole (Figure 15).

In this simulation, water is released too rapidly back into the borehole to be consistent with the observed water level history for U-19ba and for Pahute Mesa in general. In the field, water levels are observed to rise in the borehole for about eight months after the end of drilling (Figure 2) while the modeled return flows of infiltrated drilling fluids stop after less than one day (Figure 11). In actuality, seepage stops after several hours, but this interval is too small to show at the scale of Figure 11.

These results also indicate that the volume of water released from storage through the seepage face after the simulated well is blown dry is likely to be too small to account for the observed water levels even if the duration of the return flows could be extended. Even if no leakage is allowed out of the borehole, it would take about 30 cubic m to fill to the observed depth of 7 m, yet the volume of water returned to the borehole after the end of simulated drilling is only about 10 cubic m (Figure 11).

Figure 7. Initial pressure heads (meters) vs. distance above the water table for the three modeled cases. Saturation in the bedded tuffs occurs when the recharge rate exceeds the saturated conductivity of the zeolitized bedded tuffs.

Figure 8. Pressure head (meters) contour diagram for day five of the drilling simulation - Case I. The thick line shows the extent of the saturated bulb.

Figure 9. Pressure head (meters) contour diagram for day five of the drilling simulation (expanded scale) – Case I. The thick line shows the extent of the saturated bulb.

Figure 10. Pressure head (meters) contour diagram for day 18 of the drilling simulation - Case I. The thick line shows the extent of the saturated bulb, perching occurs when the low conductivity bedded tuff is encountered.

Figure 11. Borehole return flow vs. time - Case I.

Figure 12. Pressure head (meters) contour diagram for day 33 of the drilling simulation: the last day of drilling - Case I. The thick line shows the extent of the saturated bulb.

Figure 13. Borehole infiltration vs. time – Case I.

Figure 14. Pressure head (meters) vs. time for a location on the borehole wall 600 m below the land surface: in the rhyolite – Case I. Return flow occurs for less than one day during day 34. Steps in the saturated pressure head reflect the movement of the simulated water column.

Figure 15. Velocity vector plot for the seepage face one minute after the removal of the simulated water column, day 34 - Case I. Note that the flow is away from the borehole above the seepage face. Length of vectors is indicative of velocity, the density of the vectors is only dependent upon grid spacing.

The total cumulative borehole infiltration of about 120,000 cubic meters (30 million gallons) (Figure 13) is larger than expected. The actual amount of water lost to the formation is not known but has been estimated to be over one million gallons (Donithan, Brikowski, pers. comm., 1993). The large modeled infiltrations are the result of: 1) the welded tuff and rhyolite are assumed to have homogeneous high conductivities as opposed to discrete zones of fractures (Blankennagel and Weir, 1973); 2) the background pressure heads are likely too low, and 3) the water column is assumed to be a constant 100 m when in fact the column height is often much less than that (Raytheon Services Nevada, 1991).

Case II

The goal of this simulation is to extend the duration of return flow of infiltrated fluids in an attempt to match the observed water level rise for U-19ba. This is accomplished by saturating the maximum possible volume of low conductivity rocks by arbitrarily keeping the water column in contact with those units until the saturated bulb no longer increases with time. In addition, Case I demonstrated that the size of the saturated bulb is proportional to background pressure heads; therefore, areal recharge is increased for Case II so that the low conductivity units (bedded tuff and tuff breccia) are at high pressure heads and nearly saturated.

The results of the pre-drilling stage with 5.0 mm/yr of recharge give a range of pressure heads from 0.0 m (sat 1.00) to about -400 m (sat 0.60). The latter value is also likely too low near the surface for the same reasons as in Case I. The recharge value was chosen since it is almost the saturated vertical hydraulic conductivity for the zeolitized bedded tuff and therefore maximizes pressure heads while avoiding perching. This results in a reversal of vertical head gradients (Figure 7), high pressure heads (-10.0m to -0.5m) and near saturation (0.999) in the bedded tuff units.

The water column is kept in contact with the highly saturated bedded tuffs for 17 days and tuff breccia for six days as opposed to eight days and one day, respectively, for Case I (Figure 6). In this time, the infiltration rate and the saturated bulb reach steady state; that is, the size of the saturated bulb no longer increases with time. The saturated bulb extends about 60 m from the borehole and a saturated lens continues for another 60 m along the contact between the vitric and zeolitized portions of the bedded tuffs (Figure 16). The volume of saturated rock next to the borehole is larger by a factor of about five compared to Case I at the same location.

The duration of modeled return flows was extended over Case I and continues for three days after the end of drilling. The volume of water released is again about 10 cubic meters (Figure 17). The total infiltration is less than half that of Case I since the welded tuff is no longer a homogeneous, high conductivity unit. The total infiltration volume is about 50,000 cubic meters (14 million gallons) (Figure 18) with much of the flux going into the rhyolite; this unit has an assumed uniformly high conductivity.

Case III

Since Cases I and II indicate the return flow of infiltrated drilling fluids would have a limited impact on the observed water level rise, the purpose of this simulation is to model the seepage of

Figure 16. Pressure head (meters) contour diagram for day 32 of the drilling simulation: during the simulated drilling standdown – Case II. The thick line shows the extent of the saturated zone, a saturated lens forms at the contact (not shown) between the vitric and zeolitized portions of the bedded tuff.

Figure 17. Borehole return flow vs. time - Case II.

Figure 18. Borehole infiltration vs. time - Case II.

water into the borehole from a naturally perched aquifer. The initial conditions simulation using a recharge of 12.0 mm/yr, the mean estimated value for Pahute Mesa (Blankennagel and Weir, 1973), results in a saturated zone in the bedded tuffs (Figure 6) about 140 m thick. The thickness of this modeled perched zone is somewhat arbitrary (and therefore the volume of seepage is also arbitrary) since it depends on the contrast between the vertical flux and the vertical conductivity of the lowest conductivity units. It would have been equally plausible, given the uncertainty in the data, to adjust the input parameters so that the tuff breccia was fully saturated, i.e., as a semi-perched aquifer. In that case, the depth of the standing water in the modeled borehole would simply be the thickness of the saturated zone.

The seepage from this perched aquifer into the borehole (Figure 19) exhibits, qualitatively at least, the same kind of behavior necessary to duplicate the observed water level rise for U-19ba (Figure 2). That is, an exponentially decaying flow rate that continues for several months and reaches an apparent constant value. It would be possible to match the decay rates of the modeled seepage and observed water level rise by arbitrarily reducing the areal recharge and/or by decreasing the saturated conductivity of the perched unit. The gradient-driven flow is toward the hole (Figure 20) and continues for all time steps of the simulation.

SENSITIVITY ANALYSIS

The purpose of this analysis is to study the effects of variability in saturated conductivity, characteristic curves and background pressures on the duration of return flows of infiltrated fluids. This analysis shows that with the most favorable conditions the modeled return flows stop after no more than three days (Appendix D). This was accomplished with a combination of high-background pressure heads (-1.0 m) and high saturations (0.999), low conductivity (0.001 m/day) and by allowing the water column to remain in contact with the rocks until the saturated bulb reached its maximum size. Therefore, the conclusion that returned drilling fluids are not sufficient to reproduce the observed water level rise is not significantly affected by data uncertainty.

DISCUSSION

Modeled Cases I and II both show that the return flow of infiltrated drilling fluids could not produce the observed water level rise in U19-ba. This rise requires an inflow that decays exponentially for about eight months, yet in Cases I and II, the modeled return flow stops within three days after the end of drilling. Even if the duration of the return flows could be extended, the volume of returned fluids (10 cubic meters) is too small to fill the borehole to the observed depth of 7 m. The duration of inflow into the borehole appears to be the distinguishing feature between drilling fluids and natural water as the source of elevated water levels. The volume of influx is a less sensitive criterion since it could reasonably vary several orders of magnitude depending on the assumed hydrologic properties.

Return flow of infiltrated fluids is limited in duration and volume because 1) the volume of fully saturated rock next to the borehole is relatively small and remains small regardless of the

Figure 19. Seepage vs. time for the simulated perched aquifer – Case III.

Figure 20. Velocity vector plot for the simulated perched aquifer - Case III. Length of vectors is indicative of velocity, the density of the vectors is only dependent upon grid spacing.

volume of water infiltrated. Of that saturated bulb, only a small volume is released from storage, limited by the storage coefficient and the porosity. The water is released quickly since the rocks are fully saturated and therefore hydraulic conductivities are at their maximum; and 2) as water is released from storage, the rocks next to the borehole become unsaturated but remain at higher pressure heads and saturations than the rocks distal to the hole, which are essentially at initial pressures; therefore, pressure gradients drive the flow radially away from the hole toward the drier portions of the system.

The modeled naturally perched aquifer provides the correct form of a seepage history: an exponentially decaying rate that reaches an apparent steady-state value. Flow continues for an extended period since the simulated naturally perched aquifer has neither of the limitations of the drilling simulations: the volume of saturated rock is substantial and the hydraulic gradients continue to drive the flow toward the borehole. The inflow to mined chambers below the water table at Pahute Mesa shows the same kind of influx vs. time behavior (Blankennagel and Weir, 1973).

Limitations

There are several limitations in the approach taken in this study, none of which appears to alter the conclusions. The suitability of the van Genuchten parameters for unsaturated flow in indurated tuffs has been questioned (Klavetter and Peters, 1986; Rulon et al., 1986). These parameters were developed for flow in unconsolidated soils (van Genuchten, 1980) but have been used for preliminary studies at Yucca Mountain. This approach appears to be appropriate since the water retention curves for core samples of tuff can be fitted accurately with the analytic representation of van Genuchten (DOE, 1988). These relations will remain the best available until in-situ measurements of water retention and relative conductivity as a function of saturation are made.

In this model, it was assumed that the drying curve represents both the wetting and drying condition. If hysteresis were considered, the return flows of infiltrated fluids would be further reduced. Since the saturation associated with a given pressure head is less during wetting than with drying (Jury et al., 1991), the relative conductivity will also be less at a given pressure head. Therefore, if hysteresis were considered, the volume of water infiltrated would likely be less than was modeled.

Modeling fracture flow using an equivalent porous medium may not be appropriate at the scale of this study. This assumes that matrix and fracture properties can be represented as spatial averages over rock mass volumes large enough to include a representative statistical sample of hydraulically connected fractures (Bear, 1979; Freeze and Cherry, 1979). This approach may be valid for representing a regional flow system but may be inappropriate for local conditions (Long and Billaux, 1987; Cacas et al., 1990). Klavetter and Peters (1986) have concluded that the continuum approach appears applicable to the unsaturated, fractured tuffs at Yucca Mountain. The alternative of modeling discrete fractures is not practical since flow in approximately 10^{10} fractures would need to be considered. Even if it were feasible to model the system using discrete fractures, it is likely that the porosity (approximately 10^{-5} , Klavetter and Peters, 1986) of such a system is too small to store the releasable volume of water necessary to replicate the observed water level rise.

Future Work

Structural pathways for flow such as faults or preferentially oriented fracture networks could realistically control the return flow of infiltrated fluids and could be modeled with current computer codes. The intersection of structural conduits or barriers and dipping beds might also prove to have an effect on the return flows to emplacement boreholes. In the absence of structural control, the formation would require unlikely hydrologic properties for infiltrated fluids to replicate the observed water level rise. The rocks would have to infiltrate and store large volumes of water quickly and then slowly return this water back into the hole. This would require that the saturated conductivity during infiltration be substantially greater than during return flows. These issues could be explored using a discrete model or a dual porosity model, although it seems unlikely that the observed water level rise could be duplicated using plausible material properties.

Finally, if underground testing resumes, all drilling fluid should be labeled to unequivocally resolve this issue.

SUMMARY AND CONCLUSION

Elevated water levels in emplacement boreholes have important environmental implications since they may indicate that there is groundwater interaction at sites of presumed above-water table nuclear tests. The purpose of this study was to identify the probable origin of the elevated water levels by comparing the numerically modeled return flows of infiltrated drilling fluids and seepage from a modeled perched aquifer with the post-drilling observed water level history of an emplacement borehole, U-19ba. Using the best estimates for the hydrologic properties of the units at U-19ba, the model results indicate the following:

1. Large volumes of water are likely to infiltrate into the formation during the drilling of emplacement boreholes.
2. The return flow of the infiltrated drilling fluids back into the borehole is limited in duration and volume because the volume of saturated rock next to the borehole is small and hydraulic gradients drive the unsaturated flow away from the borehole.
3. The modeled duration and volume of return flow into the borehole cannot replicate the observed water level history in an actual borehole.
4. The seepage from a simulated naturally perched aquifer does not have the above limitations and can readily replicate the observed water levels. Therefore, as modeled, the probable source for elevated water in emplacement boreholes is natural and not drilling induced. This conclusion remains the same over a large range of assumed hydrologic properties.

If the formation as a whole behaves as a porous medium in response to the infiltration-return flow process, then it is highly unlikely that the observed elevated water levels in Pahute Mesa emplacement boreholes are the result of returned drilling fluid. Since the origin of these elevated

water levels is most likely naturally perched aquifers, the potential for groundwater contamination from nuclear tests is much greater than previously recognized.

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APPENDIX A

STRATIGRAPHIC LOG AND GEOLOGIC CROSS SECTION FOR U-19BA

Table 3. Stratigraphic Log for Drill Hole U-19ba (Drellack, 1990).

Depth		Lithology	Unit	Symbol	Thickness	
Meters	Feet				Meters	Feet
0 - 60.0	0 - 197	Partially to Densely Welded Ash-Flow: Devitrified	Mafic-poor Ammonia Tanks Tuff	Tmap	60.0	197
60.0 - 74.7	197 - 245	Bedded Tuff: Vitric	Ammonia Tanks Tuff (bedded zone)	Tma(b)	14.6	48
74.7 - 365.8	245 - 1200	Nonwelded to Densely Welded Ash-Flow Tuff: Vitric to devitrified	Rainier Mesa Tuff	Tmr	291.1	955
365.8 - 489.2	1200 - 1605	Nonwelded and/or Bedded Tuff: Vitric, zeolitized and silicified	Mafic-poor Calico Hills Formation	Tacp	123.4	405
489.2 - 502.9	1605 - 1650	Bedded Tuff: Zeolitized	Tuff of Pool (?)	Tcpp	15.2	50
502.9 - 518.2	1650 - 1700	Bedded Tuff: Vitric at top, grading to zeolitized near base	Rhyolite of Sled (?)	Tcps	15.2	50
518.2 - 664.5 TD	1700 - 2180 TD	Lava: Vitric to devitrified; Partly zeolitized flow breccia below 640.1 m (2100 ft)	Rhyolite of Kearsarge	Tcpk	146.3	480

Figure 21. West-east geologic cross section for U-19ba.

APPENDIX B

GOVERNING EQUATION

VAM2DH uses pressure head as the dependent variable. The governing equation for describing transient, variably saturated, groundwater flow where the fluid is assumed to be slightly compressible is (Huyakorn et al., 1988):

$$\frac{\partial}{\partial x_i} [K_{ij} k_{rw} (\frac{\partial \psi}{\partial x_j} + e_j)] = (S_w S_s + \phi \frac{dS_w}{d\psi}) \frac{\partial \psi}{\partial t} - q$$

where:

ψ	pressure head
K_{ij}	saturated hydraulic conductivity tensor
k_{rw}	relative permeability with respect to the water phase
x_{ij}	($i=1,2$) spatial coordinates
t	time
e_j	unit vector assumed vertically upward
S_w	water phase saturation
ϕ	effective porosity
q	volumetric flow rate via sources/sinks per unit volume of the porous medium
S_s	specific storage

Variably saturated flow is a highly non-linear problem because hydraulic conductivity (K_{ij} , k_{wr}) depends on the moisture content which in turn depends on the pressure head. To solve the variably saturated flow problem it is necessary to specify the relationships of relative conductivity versus water phase saturation, and pressure head versus saturation. For this study, the code performs a linear interpolation using tabulated data (calculated with the van Genuchten (1980) functional relation) of relative permeability versus saturation and pressure head versus saturation. Galerkin finite element formulation is used to approximate the flow equation. The pressure head function ψ is approximated by a trial function which contains a basis function and the nodal value for ψ at time t . The basis function is piecewise continuous over each element and is in the form of a linear weighted average. When saturation is less than one, this non-linear equation is solved by either Picard or Newton-Raphson iterative techniques. The solution to the seepage face boundary condition is non-linear because the seepage face positions are unknown in advance and must be located by trial and error. The solution procedure starts with an initial position of the seepage face and proceeds to predict the position at the next time level. The aim is to satisfy the conditions of zero pressure head (atmospheric) on the seepage face and negative flux values (out of the system) at the seepage face

nodes. The seepage face boundary nodes may be switched from prescribed zero pressure head values to prescribed zero flux values to meet the necessary constraints. A more complete description of the solution techniques of the code are found in Huyakorn and others (1988).

APPENDIX C

CONSTANT HEAD PERMEAMETER MODELING: ANALYTICAL AND NUMERICAL

$$Q = K_s \alpha^2 (H^2 - 1)^{1/2} \frac{4.117H(1 - H^{-2})}{\ln[H + (H^2 - 1)^{1/2}]} + \frac{4.028 + 2.517H^{-1}}{1/2\alpha \ln[H + (H^2 - 1)^{1/2}]}$$

The purpose of this section is to compare a VAM2DH simulation of steady-state infiltration from the borehole modeled in this study with two semi-analytic solutions and with a previous numerical study. The solution of Philip (1985) for steady state infiltration from a constant-head uncased borehole permeameter in homogeneous unsaturated soil is:

The solution of Reynolds et al. (1985) for the same problem is:

$$Q = \frac{2\pi h^2 K_s}{C} \left[1 + \frac{C}{2} \left(\frac{a}{h} \right)^2 + \frac{1 - \exp(\alpha\psi)}{\alpha h} \right]$$

where:

Q = infiltration rate, L^3T^{-1}

K_s = saturated hydraulic conductivity, LT^{-1}

a = radius of borehole, L

h = height of water in borehole, L

$H = h/a$, dimensionless

ψ = initial pressure head, L

C = shape parameter, dimensionless

α = sorptive number, L^{-1} .

These solutions use the exponential representation of conductivity as a function of pressure head: $K(\psi) = K_s e^{\alpha\psi}$ where α is the slope of the natural log relative hydraulic conductivity versus pressure head curve. The sorptive number, α , is a measure of the capillary properties of the soil. Fine soils with strong capillary effects have small α values, with 0.2 m^{-1} a typical value, and coarse soils where capillary effects are less important have larger α values, with 5 m^{-1} a typical value (Philip, 1985).

The two analytic solutions give values of steady-state infiltration that are larger than the VAM2DH numerical simulation by factors of 4.5 (Philip) and about 7 (Reynolds et al.). Using values that are typical for the welded tuff in the U-19ba simulation: $K_s = 1.0 \text{ m/d}$, $a = 1.2 \text{ m}$, $h = 100.0 \text{ m}$, $\alpha = 5.0 \text{ m}^{-1}$, and $\psi = -50.0 \text{ m}$, the solution of Philip yields a steady-state infiltration rate of $10,150 \text{ m}^3/\text{d}$ and the solution of Reynolds et al., $15,365 \text{ m}^3/\text{d}$. A numerical simulation of a constant-head permeameter using VAM2DH and the same hydrologic properties as above yields a steady-state

infiltration rate of 2237 m³/d. With a large value for h, in this case, 100.0 m, it is only the first term on the right-hand side of both analytic solutions that significantly impacts the infiltration rate. In other words, in these analytic solutions the infiltration rate is only affected by the borehole geometry and the saturated conductivity and not by background pressures or capillary properties of the region. The numerical model is affected by the background pressure heads with infiltration rates of 1635 m³/d at -10 m, 3423 m³/d at -100 m and 6270 m³/d at -500 m. Philip and Reynolds et al. recognized that the infiltration rate is strongly dependent on the unsaturated soil properties and initial pressure heads. Their solutions were derived for relatively small boreholes of about 1 m or less and it is likely that the geometric assumptions made in the derivation of the analytic solutions are violated for large boreholes such as the one in this study.

The numerical simulation of a 1.0-m constant-head permeameter by Stephens and Neuman (1982) gives results that support the conclusions of this study. Using both a finite element code and a integrated finite difference code, they found that for a wide range of hydrologic properties only a small volume of soil in the immediate vicinity of the borehole is fully saturated with water. In addition, they show that the infiltration rate decreases with increasing initial pressure heads due to the corresponding reduction in hydraulic gradients. Based on the results of their computer simulation, they developed an empirical regression formula for steady-state infiltration:

$$\log\left(\frac{Q}{K_{sah}}\right) = 0.658\log H - 0.238\alpha^{1/2} - 0.398\log h + 1.343$$

Using the values from above, this formula gives a value of 2279 m³/d, which is in excellent agreement with the VAM2DH simulation.

APPENDIX D

SENSITIVITY ANALYSIS

The purpose of this analysis is to examine the effect of variability in hydrologic properties on the duration of return flow of infiltrated fluids from a standing column of water. The modeling is done in two sequential stages: 1) a steady-state solution with a simulated column of water 100 m deep, and 2) a restart, with the nodal values from the previous run, with the water column replaced with the seepage face boundary condition. The results are presented in graphical form in Figures 22, 23, 24 and 25. The maximum return flow duration is three days with a background pressure head of -1.0 m (saturation 0.999) and a saturated conductivity of 0.001 m/d (Figure 25). Return flow duration is not effected by the unsaturated characteristic curves (Figure 23) or by the saturated conductivity (Figure 22) unless the background pressures are above -10.0 m (Figure 24).

Figure 22. Duration of return flow vs. saturated conductivity. Constant pressure head of -50 m and welded tuff characteristic curves.

Figure 23. Duration of return flow vs. unsaturated characteristic curves. Constant pressure head of -50 m and saturated conductivity of 1.0 m/d.

Figure 24. Duration of return flow vs. pressure head. Constant saturated conductivity of 1.0 m/d and welded tuff characteristic curves.

Figure 25. Duration of return flow vs. pressure head. Constant saturated conductivity of 0.001 m/d and welded tuff characteristic curves.

APPENDIX E

**COMPUTER INPUT FILES FOR THE PROGRAM VAM2D, VERSION 2.1,
PURCHASED FROM HYDROGEOLOGIC, INC.**

group	3
group	4
group	5
group	6
group	8

[illegible]

[illegible]

5	5	5	5	5	5	5	5				
1.0	10.0	0.0	0.0	0.0	0.0	20	20				
4.0e-2	4.0e-3	0.0	0.0	0.0	0.0	20	20				
1.0e-4	1.0e-5	0.0	0.0	0.0	0.0	20	20				
0.1	0.1	0.0	0.0	0.0	0.0	20	20				
1.0e-3	1.0e-3	0.0	0.0	0.0	0.0	20	20				
1.0e-3	1.0e-3	0.0	0.0	0.0	0.0	20	20				
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2				
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1				
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1				
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1				
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0				
0.04	2.032e-5	0.1	3.54e-4	0.2	3.309e-3	0.3	1.239e-2				
0.4	3.199e-2	0.5	6.764e-2	0.6	1.264e-1	0.7	2.180e-1				
0.8	3.573e-1	0.84	4.317e-1	0.88	5.209e-1	0.9	5.724e-1				
0.92	6.298e-1	0.94	6.945e-1	0.96	7.690e-1	0.98	8.591e-1				
0.99	9.152e-1	0.995	9.492e-1	0.999	9.847e-1	1.0	1.0				
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3				
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2				
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1				
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1				
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0				
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2				
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1				
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1				
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1				
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0				
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2				
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1				
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1				
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1				
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0				
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2				
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1				
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1				
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1				
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0				
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3				
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2				
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1				
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1				
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0				
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2				
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0				
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0				
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0				
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0				
0.041	-1.0e6	5.158e-2	-300.0	5.883e-2	-250.0	7.469e-2	-200.0				
8.641e-2	-180.0	1.042e-1	-160.0	1.326e-1	-140.0	1.801e-1	-120.0				
2.632e-1	-100.0	3.272e-1	-90.0	5.198e-1	-70.0	6.477e-1	-60.0				
7.798e-1	-50.0	8.394e-1	-45.0	8.905e-1	-40.0	9.310e-1	-35.0				
9.605e-1	-30.0	9.800e-1	-25.0	9.914e-1	-20.0	1.0	0.0				

0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
71	21	100.0	10.0	0	0		group 14
5.0	10.0	1000.0	700.0	1.2	1.0	1.2	0.0
21	21	0	0				group 19a
1	1	0	0.0				
2	1	0	0.0				
3	1	0	0.0				
4	1	0	0.0				
5	1	0	0.0				
6	1	0	0.0				
7	1	0	0.0				
8	1	0	0.0				
9	1	0	0.0				
10	1	0	0.0				
11	1	0	0.0				
12	1	0	0.0				
13	1	0	0.0				
14	1	0	0.0				
15	1	0	0.0				
16	1	0	0.0				
17	1	0	0.0				
18	1	0	0.0				
19	1	0	0.0				
20	1	0	0.0				
21	1	0	0.0				
1471	1	0	7.696e-5				
1472	1	0	4.458e-4				
1473	1	0	1.167e-3				

1474	1	0	1.967e-3
1475	1	0	3.400e-3
1476	1	0	5.578e-3
1477	1	0	8.850e-3
1478	1	0	1.373e-2
1479	1	0	2.094e-2
1480	1	0	3.157e-2
1481	1	0	4.718e-2
1482	1	0	6.996e-2
1483	1	0	1.032e-1
1484	1	0	1.515e-1
1485	1	0	2.216e-1
1486	1	0	3.236e-1
1487	1	0	4.710e-1
1488	1	0	6.438e-1
1489	1	0	1.090e+0
1490	1	0	1.872e+0
1491	1	0	1.201e+0

42																
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
17	18	19	20	21	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	
1482	1483	1484	1485	1486	1487	1488	1489	1490	1491							

[illegible]

5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5
1.0	10.0	0.0	1.0e-5	0.1	0.0	20	20						
4.0e-2	4.0e-3	0.0	1.0e-5	0.4	0.0	20	20						
1.0e-4	1.0e-5	0.0	1.0e-5	0.3	0.0	20	20						
0.1	0.1	0.0	1.0e-5	0.1	0.0	20	20						
1.0e-3	1.0e-3	0.0	1.0e-5	0.1	0.0	20	20						
1.0e-3	1.0e-3	0.0	1.0e-5	0.3	0.0	20	20						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.04	2.032e-5	0.1	3.54e-4	0.2	3.309e-3	0.3	1.239e-2						
0.4	3.199e-2	0.5	6.764e-2	0.6	1.264e-1	0.7	2.180e-1						
0.8	3.573e-1	0.84	4.317e-1	0.88	5.209e-1	0.9	5.724e-1						
0.92	6.298e-1	0.94	6.945e-1	0.96	7.690e-1	0.98	8.591e-1						
0.99	9.152e-1	0.995	9.492e-1	0.999	9.847e-1	1.0	1.0						
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3						
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2						
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1						
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1						
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3						
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2						
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1						
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1						
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0						
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2						
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0						
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0						
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0						
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0						
0.041	-1.0e6	5.158e-2	-300.0	5.883e-2	-250.0	7.469e-2	-200.0						
8.641e-2	-180.0	1.042e-1	-160.0	1.326e-1	-140.0	1.801e-1	-120.0						
2.632e-1	-100.0	3.272e-1	-90.0	5.198e-1	-70.0	6.477e-1	-60.0						
7.798e-1	-50.0	8.394e-1	-45.0	8.905e-1	-40.0	9.310e-1	-35.0						

9.605e-1	-30.0	9.800e-1	-25.0	9.914e-1	-20.0	1.0	0.0
0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
71	21	100.0	10.0	0	0		group 14
5.0	10.0	1000.0	700.0	1.2	1.0	1.2	0.0
94	20	0	0				group 19a
1471	1	0	0.0				
1450	1	0	10.0				
1429	1	0	20.0				
1	1	0	0.0				
2	1	0	0.0				
3	1	0	0.0				
4	1	0	0.0				
5	1	0	0.0				
6	1	0	0.0				
7	1	0	0.0				
8	1	0	0.0				
9	1	0	0.0				
10	1	0	0.0				
11	1	0	0.0				
12	1	0	0.0				
13	1	0	0.0				
14	1	0	0.0				
15	1	0	0.0				
16	1	0	0.0				
17	1	0	0.0				
18	1	0	0.0				
19	1	0	0.0				
20	1	0	0.0				

21	1	0	0.0
42	1	0	-9.851
63	1	0	-19.68
84	1	0	-29.47
105	1	0	-39.22
126	1	0	-48.95
147	1	0	-58.66
168	1	0	-68.66
189	1	0	-78.66
210	1	0	-88.66
231	1	0	-98.66
252	1	0	-108.7
273	1	0	-118.7
294	1	0	-128.7
315	1	0	-138.7
336	1	0	-148.7
357	1	0	-158.7
378	1	0	-168.7
399	1	0	-178.7
420	1	0	-123.8
441	1	0	-89.55
462	1	0	-64.29
483	1	0	-44.64
504	1	0	-29.55
525	1	0	-18.56
546	1	0	-11.16
567	1	0	-5.338
588	1	0	-0.9685
609	1	0	-10.94
630	1	0	-20.90
651	1	0	-30.87
672	1	0	-40.82
693	1	0	-50.74
714	1	0	-60.60
735	1	0	-70.32
756	1	0	-79.78
777	1	0	-89.77
798	1	0	-99.77
819	1	0	-109.8
840	1	0	-119.8
861	1	0	-129.8
882	1	0	-139.8
903	1	0	-149.8
924	1	0	-159.8
945	1	0	-169.8
966	1	0	-179.8
987	1	0	-189.7

1008	1	0	-199.7
1029	1	0	-209.7
1050	1	0	-219.7
1071	1	0	-229.7
1092	1	0	-239.7
1113	1	0	-249.7
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1176	1	0	-279.7
1197	1	0	-289.7
1218	1	0	-299.7
1239	1	0	-309.7
1260	1	0	-319.7
1281	1	0	-329.7
1302	1	0	-338.8
1323	1	0	-347.8
1344	1	0	-356.9
1365	1	0	-365.9
1386	1	0	-375.9
1407	1	0	-385.9
1428	1	0	-394.7
1449	1	0	-403.5
1470	1	0	-412.2
1491	1	0	-420.9
1472	1	0	4.458e-4
1473	1	0	1.167e-3
1474	1	0	1.967e-3
1475	1	0	3.400e-3
1476	1	0	5.578e-3
1477	1	0	8.850e-3
1478	1	0	1.373e-2
1479	1	0	2.094e-2
1480	1	0	3.157e-2
1481	1	0	4.718e-2
1482	1	0	6.996e-2
1483	1	0	1.032e-1
1484	1	0	1.515e-1
1485	1	0	2.216e-1
1486	1	0	3.236e-1
1487	1	0	4.710e-1
1488	1	0	6.438e-1
1489	1	0	1.090e+0
1490	1	0	1.872e+0
1491	1	0	1.201e+0
0.000E+00	0.000E+00	0.000E+00	0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00 0.000E+00 0.000E+00-0.985E+01-0.985E+01-0.985E+01

[illegible]

[illegible]

[illegible]

102

1471	1450	1429	1408	1387	1366	1345	1324	1303	1282	1261	1	2	3	4	5
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357

11

378 399 420 441 462 483 504 525 546 567 588 609 630 651 672 693
714 735 756 777 798 819 840 861 882 903 924 945 966 987 1008 1029
1050 1071 1092 1113 1134 1155 1176 1197 1218 1239 1260 1281 1302 1323 1344 1365
1386 1407 1428 1449 1470 1491

[illegible]

[illegible]

5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5
1.0	10.0	0.0	1.0e-5	0.1	0.0	20	20						
4.0e-2	4.0e-3	0.0	1.0e-5	0.4	0.0	20	20						
1.0e-4	1.0e-5	0.0	1.0e-5	0.3	0.0	20	20						
0.1	0.1	0.0	1.0e-5	0.1	0.0	20	20						
1.0e-3	1.0e-3	0.0	1.0e-5	0.1	0.0	20	20						
1.0e-3	1.0e-3	0.0	1.0e-5	0.3	0.0	20	20						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.04	2.032e-5	0.1	3.54e-4	0.2	3.309e-3	0.3	1.239e-2						
0.4	3.199e-2	0.5	6.764e-2	0.6	1.264e-1	0.7	2.180e-1						
0.8	3.573e-1	0.84	4.317e-1	0.88	5.209e-1	0.9	5.724e-1						
0.92	6.298e-1	0.94	6.945e-1	0.96	7.690e-1	0.98	8.591e-1						
0.99	9.152e-1	0.995	9.492e-1	0.999	9.847e-1	1.0	1.0						
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3						
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2						
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1						
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1						
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.1	4.43e-4	0.3	1.43e-2	0.4	3.62e-2	0.5	7.51e-2						
0.6	1.38e-1	0.7	2.34e-1	0.8	3.77e-1	0.82	4.13e-1						
0.84	4.53e-1	0.86	4.95e-1	0.88	5.42e-1	0.90	5.93e-1						
0.92	6.499e-1	0.94	7.132e-1	0.96	7.854e-1	0.98	8.713e-1						
0.99	9.237e-1	0.996	9.621e-1	0.999	9.869e-1	1.0	1.0						
0.11	3.71e-7	0.3	1.31e-4	0.4	7.20e-4	0.5	2.77e-3						
0.6	8.63e-3	0.7	2.36e-2	0.8	6.07e-2	0.82	7.33e-2						
0.84	8.86e-2	0.86	1.07e-1	0.88	1.31e-1	0.90	1.60e-1						
0.92	1.98e-1	0.94	2.497e-1	0.96	3.233e-1	0.98	4.443e-1						
0.99	5.520e-1	0.999	7.958e-1	9.999e-1	9.113e-1	1.0	1.0						
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2						
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0						
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0						
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0						
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0						
0.041	-1.0e6	5.158e-2	-300.0	5.883e-2	-250.0	7.469e-2	-200.0						
8.641e-2	-180.0	1.042e-1	-160.0	1.326e-1	-140.0	1.801e-1	-120.0						
2.632e-1	-100.0	3.272e-1	-90.0	5.198e-1	-70.0	6.477e-1	-60.0						
7.798e-1	-50.0	8.394e-1	-45.0	8.905e-1	-40.0	9.310e-1	-35.0						

9.605e-1	-30.0	9.800e-1	-25.0	9.914e-1	-20.0	1.0	0.0
0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.080	-1.0e6	1.167e-1	-1.0e4	3.060e-1	-1.0e3	4.559e-1	-5.0e2
7.214e-1	-2.0e2	7.981e-1	-150.0	8.399e-1	-125.0	8.825e-1	-100.0
8.993e-1	-90.0	9.158e-1	-80.0	9.317e-1	-70.0	9.467e-1	-60.0
9.606e-1	-50.0	9.730e-1	-40.0	9.836e-1	-30.0	9.919e-1	-20.0
9.977e-1	-10.0	9.993e-1	-5.0	9.999e-1	-1.0	1.0	0.0
0.117	-1.0e6	2.223e-1	-1.0e4	2.390e-1	-8.0e3	2.632e-1	-6.0e3
3.049e-1	-4.0e3	3.409e-1	-3.0e3	4.020e-1	-2.0e3	4.534e-1	-1.5e3
5.369e-1	-1.0e3	5.876e-1	-800.0	6.557e-1	-600.0	6.992e-1	-500.0
7.508e-1	-400.0	8.119e-1	-300.0	8.820e-1	-200.0	9.187e-1	-150.0
9.540e-1	-100.0	9.987e-1	-10.0	9.999e-1	-1.0	1.0	0.0
71	21	100.0	10.0	0	0		group 14
	5.0	10.0	1000.0	700.0	1.2	1.0	0.0
91	20	0	0				group 19a
1	1	0	0.0				
2	1	0	0.0				
3	1	0	0.0				
4	1	0	0.0				
5	1	0	0.0				
6	1	0	0.0				
7	1	0	0.0				
8	1	0	0.0				
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16	1	0	0.0				
17	1	0	0.0				
18	1	0	0.0				
19	1	0	0.0				
20	1	0	0.0				
21	1	0	0.0				
42	1	0	-9.851				
63	1	0	-19.68				

84	1	0	-29.47
105	1	0	-39.22
126	1	0	-48.95
147	1	0	-58.66
168	1	0	-68.66
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567	1	0	-5.338
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609	1	0	-10.94
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777	1	0	-89.77
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1008	1	0	-199.7
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1071	1	0	-229.7				
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1176	1	0	-279.7				
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1323	1	0	-347.8				
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1365	1	0	-365.9				
1386	1	0	-375.9				
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1428	1	0	-394.7				
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1470	1	0	-412.2				
1491	1	0	-420.9				
1472	1	0	4.458e-4				
1473	1	0	1.167e-3				
1474	1	0	1.967e-3				
1475	1	0	3.400e-3				
1476	1	0	5.578e-3				
1477	1	0	8.850e-3				
1478	1	0	1.373e-2				
1479	1	0	2.094e-2				
1480	1	0	3.157e-2				
1481	1	0	4.718e-2				
1482	1	0	6.996e-2				
1483	1	0	1.032e-1				
1484	1	0	1.515e-1				
1485	1	0	2.216e-1				
1486	1	0	3.236e-1				
1487	1	0	4.710e-1				
1488	1	0	6.438e-1				
1489	1	0	1.090e+0				
1490	1	0	1.872e+0				
1491	1	0	1.201e+0				
0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
-0.983E+01	-0.985E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01
-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01	-0.986E+01
-0.987E+01	-0.985E+01	-0.181E+02	-0.196E+02	-0.192E+02	-0.195E+02	-0.196E+02	-0.197E+02

-0.896E+02-0.896E+02-0.896E+02-0.896E+02-0.896E+02-0.896E+02-0.896E+02-0.896E+02-0.896E+02
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-0.895E+02-0.186E+02-0.562E+02-0.641E+02-0.643E+02-0.643E+02-0.643E+02-0.643E+02-0.643E+02
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-0.444E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02
-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02-0.446E+02
-0.446E+02-0.446E+02-0.446E+02-0.114E+02-0.229E+02-0.292E+02-0.296E+02-0.296E+02-0.296E+02
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-0.655E+01-0.862E+01-0.169E+02-0.185E+02-0.186E+02-0.186E+02-0.186E+02-0.186E+02-0.186E+02
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273	294	315	336	357	378	399	420	441	462	483	504	525	546	567	588
609	630	651	672	693	714	735	756	777	798	819	840	861	882	903	924
945	966	987	1008	1029	1050	1071	1092	1113	1134	1155	1176	1197	1218	1239	1260
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U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Richard Pearl
Environmental Protection Division
Nevada Operations Office
U.S. Dept. of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

U.S. Department of Defense

David Bedsun
Defense Nuclear Agency
U.S. Department of Defense
P.O. Box 98539
Las Vegas, NV 89193-8539

Lawrence Livermore National Laboratory

Greg Nimz
Lawrence Livermore National Laboratory
P.O. Box 808, MS L233
Livermore, CA 94550

Los Alamos National Laboratory

Joe Thompson
Los Alamos National Laboratory
INC-11, MS J514
P.O. Box 1663
Los Alamos, NM 87545

U.S. Geological Survey

Virginia Glanzman
U.S. Geological Survey
Box 2506, MS 913
Denver Federal Center
Denver, CO 80225

Randy Laczniaik
U.S. Geological Survey
Water Resources Division
6770 S. Paradise Rd.
Las Vegas, NV 89119

Paul Orkild
U.S. Geological Survey
Box 2506, MS 913
Denver Federal Center
Denver, CO 80225

Doug Trudeau
U.S. Geological Survey
Water Resources Division
6770 S. Paradise Rd.
Las Vegas, NV 89119

Desert Research Institute

Roger Jacobson
Desert Research Institute
Water Resources Center
P.O. Box 19040
Las Vegas, NV 89132-0040

Marjory Jones
Desert Research Institute
Water Resources Center
P.O. Box 60220
Reno, NV 89506-0220

Paul Seaber
Desert Research Institute
Water Resources Center
P.O. Box 19040
Las Vegas, NV 89132-0040

Reynolds Electrical & Engineering Co.

Martha DeMarre
Chief, Document Research Section
Health Protection Dept.
Reynolds Electrical & Engineering Co.
P.O. Box 98521
Las Vegas, NV 89193-8521

Brian Dozier
Reynolds Electrical & Engineering Co.
2501 Wyandotte
Mercury, NV 89102

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Las Vegas, NV 89132-0040

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Las Vegas, NV 89154

Annie Kelley
State Documents Department
Nevada State Library
Capitol Complex
Carson City, NV 89710

**Water Resources Research Archives
University of California
Room 40, North Gate Hall
Berkeley, CA 94720**

International Technology Corp.

**Rick Waddell
Geotrans
c/o IT
4330 Valley View
Suite 112
MS-439
Las Vegas, NV 89103**

**Joe Yeasted
International Technology Corp.
4330 Valley View
Suite 112
MS-439
Las Vegas, NV 89103**

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