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**SUPPLEMENT TO THE OSTI
SITE OBSERVATIONAL WORK PLAN
FOR THE UMTRA PROJECT SITE
AT AMBROSIA LAKE, NEW MEXICO**

February 1996

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**SUPPLEMENT TO THE SITE OBSERVATIONAL WORK PLAN
FOR THE UMTRA PROJECT SITE
AT AMBROSIA LAKE, NEW MEXICO**

February 1996

**Prepared for
U.S. Department of Energy
Grand Junction Projects Office**

**Prepared by
Jacobs Engineering Group Inc.
Albuquerque, New Mexico**

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LIST OF ACRONYMS

<u>Acronym</u>	<u>Definition</u>
BGS	below ground surface
DOE	U.S. Department of Energy
MSL	mean sea level
RAP	remedial action plan
SOWP	site observational work plan
TAC	Technical Assistance Contractor
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action

1.0 INTRODUCTION

The purpose of this document is to provide additional and more detailed information to supplement review of the site observational work plan (SOWP) (DOE, 1995) for the Ambrosia Lake, New Mexico, Uranium Mill Tailings Remedial Action (UMTRA) Project site. This document includes a discussion of 1) the average linear velocity of the ground water in the alluvium; 2) the ground water quality of the alluvium, weathered Mancos Shale, and the Tres Hermanos-C Member of the Mancos Shale; and 3) the fate and transport of contaminants from the uppermost aquifer to the Westwater Canyon Member of the Morrison Formation. The data from a 1989 aquifer test were analyzed using the curve-matching software AQTESOLV (Geraghty and Miller, Inc., 1995) and then compared with the original results. A hydrograph of the ground water elevations in monitoring wells screened in the alluvium is presented to show how the ground water elevations change with time. Stiff and Piper diagrams were created to describe the changes in ground water geochemistry in the alluvium/weathered Mancos Shale unit, the Tres Hermanos-C Sandstone unit, the Tres Hermanos-B Sandstone unit, and the Dakota Sandstone. Background information on other related topics such as site history, cell construction, soil characteristics, and well construction are presented in the SOWP (DOE, 1995). Figure 1 is a geologic cross section depicting the conceptual model of the hydrostratigraphy and ground water chemistry of the Ambrosia Lake site. Table 1 presents hydrogeologic information of each hydrostratigraphic unit.

1.1 GROUND WATER VELOCITY

Estimating the average linear velocity of the ground water in the alluvium/weathered Mancos shale gives insight into the potential for advective contaminant transport. The equation used to estimate the average linear velocity is

$$V = \frac{K}{n_e} \frac{dh}{dl}$$

where V is the average linear velocity, K is the hydraulic conductivity, dh/dl is the hydraulic gradient which is the change in head divided by the distance over which the change occurs, and n_e is the effective porosity (Fetter, 1994).

Although the hydraulic conductivity and effective porosity are consistent over time, the hydraulic gradient varies. Therefore, any estimate of velocity should be considered with respect to the gradient during the period of interest. Here, the hydraulic gradient has been calculated using water levels measured after operations had ceased at the mines in the area of the Phillips processing site.

Table 2 presents the estimated average linear horizontal velocity of the ground water in the alluvium/weathered Mancos Shale underlying the Ambrosia Lake area. The velocity was calculated using hydraulic conductivity values from aquifer pumping tests that ranged from 70 feet (ft) (21 meters [m]) per year at the Ambrosia Lake site, to 38 ft (12 m) per year on the Quivira Mining Company

property. The ground water velocity calculated from the Ambrosia Lake aquifer pumping test used a hydraulic gradient of 0.025 and an effective porosity of 0.13, which were discussed in the remedial action plan (RAP) (DOE, 1991). The ground water velocity calculated from the Quivira Mining Company aquifer pumping test used a hydraulic gradient of 0.016 that was estimated from ground water levels taken in 1980 from monitoring wells located in the northern part of the plant property (Bostick, 1985). The effective porosity of the alluvium/weathered Mancos Shale was estimated to be 20 percent (Bostick, 1985). The hydraulic conductivity values from both aquifer pumping tests and hydraulic gradients estimated from water level measurements are appropriate for estimating horizontal ground water flow velocity.

A falling-head permeameter test was performed by Thomson and Heggen (1981) that was an estimate of the hydraulic conductivity with regard to vertical ground water flow. However, the vertical component of the velocity was not calculated because *in situ* vertical hydraulic gradient data were not available.

The differences between the velocity of ground water at the Ambrosia Lake site compared to the Quivira site are minor. The estimated hydraulic conductivities are very similar with some differences in hydraulic gradient and effective porosity.

2.0 BACKGROUND GROUND WATER QUALITY

Because there was originally no measurable water in the alluvium/weathered Mancos Shale unit or the Tres Hermanos-C Sandstone units, preoperational ground water quality data are not available for the Ambrosia Lake site. Consequently, background ground water quality in the alluvium/weathered Mancos Shale unit and the Tres Hermanos-C Sandstone units is considered to be the same as existing water quality because former mining and milling activities created the saturated conditions (Bostick, 1985). Geochemical modeling shows that the ground water within the alluvium/weathered Mancos Shale appears to be derived entirely from tailings seepage and mill-makeup water (DOE, 1991). The mill-makeup water was generated from mine pumping discharge and control of the ground water in the Westwater Canyon Member of the Morrison Formation. Details of the modeling results are presented in Table D.8.25 of the RAP (DOE, 1991). The concept of background ground water quality applies only to an aquifer that is sustained by ground water underflow from an upgradient source. Because there is no ground water underflow from an upgradient source to the uppermost aquifer at the Ambrosia Lake site, the existing water quality for the isolated pocket of saturation within the alluvium/weathered Mancos Shale unit and the basal saturation of the Tres Hermanos-C Sandstone units is defined as background.

2.1 GROUND WATER QUALITY AND EXTENT OF CONTAMINATION

To define the extent of ground water contamination caused by the past uranium milling at the Ambrosia Lake site, water samples were periodically collected

from a U.S. Department of Energy (DOE) monitor well network (Figure 2) from 1980 through 1994.

The majority of the contaminated ground water contained in the alluvium/weathered Mancos Shale unit and Tres Hermanos-C Sandstone units in the area of the milling site was derived from water pumped from the Ann Lee Mine No. 1, Phillips mill-process waste water, and some tailings seepage. The discharge of water from the Quivira Mill to the outcrop of the Tres Hermanos-B Sandstone, Tres Hermanos-A Sandstone, and the Dakota Formation probably caused contamination of these units (Bostick, 1985).

2.2 CONTAMINANT FATE AND TRANSPORT

The Westwater Canyon Member of the Morrison Formation is the primary source of uranium ore in the area and was the focus of intense mining-related activity from the mid-1950s to the early 1980s. Development of the ore body necessitated dewatering of the Westwater Canyon Member.

The potentiometric surface of the Westwater Canyon Member has been modeled in the Ambrosia Lake area (Lyford et al., 1978). The results of this modeling indicate a potentiometric trough depressurized by several hundred feet (Figure D.8.15 of DOE, 1991). Ground water will continue to flow towards this trough for approximately the next 100 years as the Westwater Canyon Member starts to repressurize. Flow in the site area is probably downdip towards the Ann Lee Mine or towards the potentiometric depression to the southeast (Figure D.8.16 of DOE, 1991).

Recent ground water elevation data measured in mine shafts completed in the Westwater Canyon Member in the Ambrosia Lake area were provided by the Quivira Mining Company (Ferdinand, 1996). The data were collected from the Quivira Section 30 and Section 33 mines from November 1993 through November 1995. The mine shaft lithology for each mine was also provided. The Quivira Mining Company has performed limited, continuous pumping of ground water from the Section 30 mine during the period of water level measurement. The Section 30 mine is hydraulically connected with the Section 33 mine, Ann Lee No. 1 mine, and the Homestake-New Mexico Partners mine by a network of driftways. The location of each mine is shown in Figure 3.

Ground water elevation and mine shaft lithology data for the Section 30 and Section 33 mines are presented in Tables 3 and 4, respectively. The data show that the water table in each mine is situated at a considerable distance below the bottom of the aquitard that confines the Westwater Canyon aquifer. This indicates that a significant potentiometric trough is still present within the Westwater Canyon Member in the Ambrosia Lake area. Although limited pumping is still ongoing, a slow repressurization of the Westwater Canyon aquifer has occurred in the Section 30 mine area between November 1993 and November 1995. However, little or no repressurization of the aquifer has occurred in the Section 33 mine area during the same time period.

Because the large potentiometric depression created by mine pumping still exists in the Ambrosia Lake area, ground water from all overlying units will tend to migrate downward through mine shafts and vent holes into the Westwater Canyon Member. The downward migration of ground water cannot potentially contaminate any other overlying water-bearing formations because the mine shafts and vent holes are points of ground water discharge into the Westwater Canyon Member (DOE, 1991).

Regionally, mining activities not related to UMTRA Project site tailings seepage have also introduced many other sources of contamination into the Westwater Canyon Member. The DOE made a comparison of concentrations of contaminants in the Tres Hermanos-C Sandstone with the Westwater Canyon Member (Table D.8.26 of DOE, 1991) and concluded that, in general, concentrations of site contaminants in the Tres Hermanos-C Sandstone are lower. This suggests that the downward migration of ground water from the Tres Hermanos-C Sandstone will produce no increases in the concentrations of contaminants in the underlying Westwater Canyon Member.

3.0 AQUIFER TEST ANALYSIS

An aquifer pumping test was performed in 1989 on well AMB01-0675 and monitored in two observation wells designated OBS-1 and OBS-2. A complete description of the well logs, including borehole description and well completion records, is provided in the SOWP (DOE, 1995). Well 675 is completed in the alluvium and in the upper 14 ft (4.3 m) of the weathered Mancos Shale. Technical Assistance Contractor (TAC) calculation set AMB-03-88-15-01-01 describes the methods used in conducting the test and estimating the transmissivity and storativity (TAC, 1989). Pumping was stopped after 12 hours because the water level in the pumping well had fallen below the intake of the pump.

The data analysis software AQTESOLV developed by Geraghty and Miller, Inc. (1995), was used to analyze the data from the two observation wells and fit the best curve to the data. The time and drawdown data for each well were imported into AQTESOLV for comparison with the type curves for various aquifer conditions. The type curve used in the analysis was the Theis curve for confined aquifers (Theis, 1935). Although evidence suggests that the alluvium is unconfined, no analysis was done for unconfined ground water conditions because there were insufficient data to show the effects of delayed yield. The pumping rate at well 675 was 0.35 gallons (gal) (1.3 liters [L]) per minute. The initial saturated aquifer thickness was estimated to be 10 ft (3 m).

Aquifer test characteristics comparing the current analysis with the original analysis are presented in Table 5. The best match was obtained for data from well OBS-2 for the Theis solution (Attachment A). The Jacob (1950) solution was used for the original analysis presented in TAC calculation set AMB-03-88-15-01-01 and yielded results consistent with the Theis solution. The data from well OBS-1 yielded a poor match with the Theis theoretical curve. Early time-drawdown data resemble a curve showing the

effects of partial penetration of the well while middle time-drawdown data resemble the flat segment of a curve of data showing delayed yield (Kruseman and de Ridder, 1991).

A drawdown and recovery hydrograph (Attachment A) shows that recovery at OBS-1 began to occur once pumping had stopped. In the 8 hours of recovery after pumping had stopped ground water levels rose to within 1 ft (0.3 m) of the ground water level at the beginning of pumping. Recovery data were not recorded at OBS-2 due in part to the small amount of drawdown observed during pumping.

An aquifer pumping test was also conducted in the alluvium at the Quivira Mining Company and yielded a transmissivity ranging between 0.019 square feet (ft²) (0.0018 square meters [m²]) per minute to 0.023 ft² (0.0021 m²) per minute and a storativity of 0.2 in the vicinity of the Quivira mill (Bostick, 1985). These values are significantly higher than those calculated from the Ambrosia Lake aquifer pumping test. However, the Quivira pumping test was performed near Arroyo del Puerto and the alluvium in this area contains a greater saturated thickness than the alluvium at the Ambrosia Lake site and may receive some recharge from along the arroyo.

4.0 HYDROGRAPHS

Ground water levels were periodically collected between 1985 and 1995 from up to 31 DOE wells completed in the alluvium/weathered Mancos Shale unit. Many of these wells did not show the presence of ground water following installation that indicates they are located outside the perimeter of the saturated portion of this unit. As of August 1995 only wells 674, 675, 781, and 793 were producing water. In addition, water levels in some of the wells along the margins of saturation have diminished to an elevation below the base of the well screen. This indicates that the zone of saturation in the alluvium/weathered Mancos Shale unit has decreased in areal extent and declined in thickness over the 10-year period of measurement.

Selected water level data collected between 1985 and 1995 from monitor wells completed in the saturated portion of alluvium/weathered Mancos Shale unit (AMB01-0674, -0675, -0781, -0793) were retrieved from the SPEAR database (DOE, 1992) and used to create a hydrograph describing the changes in ground water elevation over the time period (Attachment B). Water levels have generally decreased in well 674 since 1988, and in well 793 since 1993. Water levels have remained relatively constant in well 781 since 1986. However, recent water level rises have occurred in well 675, located near the southern edge of the disposal cell, that may be the result of infiltration of toe drain runoff from the disposal cell completed in June 1995.

5.0 STIFF AND PIPER DIAGRAMS

The most comprehensive suite of inorganic geochemical data was collected in 1991. These data were used to create Stiff (1951) and Piper (1944) diagrams with the software

PLOTCHER (Tecsoft, Inc., 1993). These plots provide a graphical means to characterize ground water quality. Diagrams describing the ground water in the alluvium/weathered Mancos Shale unit, the Tres Hermanos-C Sandstone unit, the Tres Hermanos-B Sandstone unit, and the Dakota Sandstone were produced from the data. In addition, plots illustrating the changes in concentrations of total dissolved solids (TDS) with time and the changes in nitrate concentrations with time were produced from the data at each of these units.

Of the five monitoring wells completed in the alluvium/weathered Mancos Shale unit, three wells (AMB01-620, -674, and -675) are located downgradient of the disposal cell, and two (AMB01-792 and -793) are located upgradient of the disposal cell (Figure 2).

Stiff and Piper diagrams for all wells screened in the alluvium showed similar water types (Attachment C). Wells 620, 793, and 794 exhibited calcium-sodium sulfate type waters, while wells 674 and 675 (both downgradient) exhibited sodium-sulfate type waters. The concentrations of TDS in the downgradient wells ranged from approximately 6000 to 7000 milligrams per liter (mg/L) while the concentrations in the upgradient wells were approximately 4000 mg/L.

The geochemical data from four monitoring wells screened in the Tres Hermanos-C Sandstone units were also used to produce Stiff and Piper diagrams. Three of the wells (AMB01-0778, -0785, and -0786) are located upgradient from the disposal cell while one well (AMB01-0677) is located downgradient from the disposal cell (Figure 2). Well 786 is screened in the Tres Hermanos-C₁ Sandstone unit while the remaining wells are screened in the Tres Hermanos-C₂ Sandstone unit. The ground water data from 1991 were used to create these plots.

The ground water of the Tres Hermanos-C Sandstone unit was similar in water type to that of the alluvium/weathered Mancos Shale unit (Attachment C). All wells show a strong sodium-sulfate type water. The concentrations of the TDS in the upgradient wells varied between 5000 and 7000 mg/L while the concentration in the downgradient well was approximately 3500 mg/L. These values support the conceptual model that the ground water from the alluvium/weathered Mancos Shale unit is recharging the Tres Hermanos-C Sandstone unit. Nitrate concentrations in well 778 range from 200 to 450 mg/L; however, the other wells exhibit nitrate concentrations ranging from 0 to 50 mg/L.

The ground water chemistry in the alluvium/weathered Mancos Shale unit gradually changes from a calcium-sodium sulfate type ground water to a sodium-sulfate ground water as it moves beneath the site. Sodium and sulfate were major process chemicals; thus, seepage from the mill tailings could provide the additional sodium and sulfate to the ground water. Ground water in the alluvium/weathered Mancos Shale unit flows into the Tres Hermanos-C Sandstone units in the subcrop area. The ground water at well 785 (near the subcrop contact) exhibits the highest concentrations of TDS, but concentrations decrease as the ground water travels downgradient (Figure 1). This is the expected response which is the result of the infiltration and migration of process water.

Three wells completed in the Tres Hermanos-B unit were considered for geochemical analysis. These include upgradient well AMB01-777 and downgradient wells AMB01-681

and AMB01-678 (Figure 2). Data used to produce the plots were obtained from sample collection in 1991.

The Stiff and Piper diagrams show that the ground water of the Tres Hermanos-B unit is a sodium-sulfate type water (Attachment C). Plots of TDS with time show well 678 has greater concentrations than the other two wells. Samples from well 678 also shows nitrate concentrations increasing from 500 mg/L to 3500 mg/L in the period between 1989 and 1993.

Nitrate levels are increasing in monitor well 678, completed in the Tres Hermanos-B Sandstone (3410 mg/L in December 1992) (DOE, 1995). This increase is not related to uranium processing at the Ambrosia Lake site because nitrate concentrations are much higher than average concentrations found in tailings pore fluids at the Ambrosia Lake site (approximately 1400 mg/L). Furthermore, the Tres Hermanos-B Sandstone may be hydrologically isolated from the alluvium/weathered Mancos Shale unit at the site. Relatively high nitrate levels are most likely related to the nearby Quivira Mining Company tailings pile.

Well AMB01-680 is the only well at the site that is completed in the Dakota Sandstone (Figure 2). It is located south of the disposal cell. The data used to produce the plots were obtained from ground water samples collected in 1991. The Stiff and Piper diagrams generated from the geochemical data indicate a calcium-sulfate type water (Attachment C). TDS vary in concentrations from 3250 mg/L to 5500 mg/L. Nitrate concentrations remain low at this well.

6.0 REFERENCES

- Bostick, K., 1985. *Ground Water Discharge Plan Analysis for Kerr-McGee Nuclear Corporation, Ambrosia Lake Uranium Mill, Quivira Mining Company*, February 1985, Ground Water Sections, Ground Water Quality and Hazardous Waste Bureau, New Mexico Environmental Improvement Division, Santa Fe, New Mexico.
- Brod, R. C., 1979. "Hydrogeology and Water Resources of the Ambrosia Lake-San Mateo Area, McKinley and Valencia Counties, New Mexico," master's thesis, New Mexico Institute of Mining and Technology.
- Brod, R. C., and W. J. Stone, 1981. *Hydrogeology of Ambrosia Lake-San Mateo Area, McKinley and Cibola Counties, New Mexico*, Hydrologic Sheet 2, New Mexico Bureau of Mines and Mineral Resources.
- DOE (U. S. Department of Energy), 1995. *Site Observational Work Plan for the UMTRA Project Site at Ambrosia Lake, New Mexico*, UMTRA-DOE/AL-62350-159, February 1995, Rev. 0, prepared by the U. S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

- DOE (U.S. Department of Energy), 1992. Software Program for Environmental Analysis and Reporting (SPEAR) System, September 1992, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- DOE (U. S. Department of Energy), 1991. *Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Sites at Ambrosia Lake, New Mexico*, UMTRA-DOE/AL-050516.0000, November 1991, final, prepared by the U. S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Ferdinand, B., 1996. Letter to Eric Larsen (TAC) from Bill Ferdinand, Quivira Mining Company, dated January 26, 1996, UPDCC No. 16.19.2.5.3.
- Fetter, C. W., 1994. *Applied Hydrogeology*, third edition, Macmillian College Publishing Company, New York.
- Geraghty and Miller, Inc., 1995. AQTESOLV-Aquifer Test Solver, Version 2.01, Geraghty and Miller Modeling Group, Reston, VA.
- Jacob, C. E., 1950. "Flow of Ground Water," in *Engineering Hydraulics*, H. Rouse, ed., John Wiley & Sons, New York, pp. 321-386.
- Kelly et al. (T. E. Kelly, R. L. Link, and M. R. Schipper), 1980. "Effects of Uranium Mining on Ground Water in Ambrosia Lake Area, New Mexico," in *Geology and Technology of the Grants Uranium Region 1979: New Mexico Bureau of Mines and Mineral Resources*, Mem. 38, pp. 313-319.
- Kruseman, G. P., and N. A. de Ridder, 1991. *Analysis and Evaluation of Pumping Test Data*, Reprint 1991, 2nd ed. (1990), Publication 47. The Netherlands: International Institute for Land Reclamation and Improvement, 377 pp.
- Lyford et al., (F. Lyford, P. Frenzel, and W. Stone), 1978. "Modeled Effects of Uranium Mine Dewatering on Water Resources in Northwestern New Mexico," Final San Juan Basin Regional Uranium Study.
- Piper, A. M., 1944. A Graphic Procedure in the Geochemical Interpretation of Water Analyses, American Geophysical Union, *Transactions*, Vol. 25, 99. 914-923.
- Purtymun et al. (W. D. Purtymun, C. L. Weinke, and D. R. Dreesen), 1977. "Geology and Hydrology in the Vicinity of the Inactive Uranium Mill Tailings Pile, Ambrosia Lake, New Mexico," UC-11; Informal report LA-6839-MS, Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico.

Stiff, H. A., 1951. "The Interpretation of Chemical Water Analyses by Means of Patterns," *Journal of Petroleum Technology*, Vol. 3, pp. 15-17.

TAC (Technical Assistance Contractor), 1989. Calculation of Transmissivity and Storativity Within Alluvium/Weathered Mancos Shale Using Jacob Straight-Line Method, Calculation No. AMB-03-88-15-01-01, UPDCC File Location No. 16.19.2.7, U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Tecsoft, Inc., 1993. PLOTCHER, Version 6.3.

Theis, C. V., 1935. "The Lowering of the Piezometer Surface and the Rate and Discharge of a Well Using Ground Water Storage," American Geophysical Union, *Transactions*, Vol. 16, pp. 519-524.

Thomson, B. M., and R. J. Heggen, 1981. "Contaminant Transport From Uranium Mill Tailings in Ambrosia Lake, New Mexico," in *Proceedings of the Fourth Annual Symposium on Uranium Mill Tailings Management*, 26 through 27 October 1981, Civil Engineering Department, Colorado State University, Fort Collins, Colorado.

SW

Ground water recharge
in outcrop areas

Quivira
tailings
pile

Ambrosia Lake
disposal cell

Arroyo del
Puerto

Alluvium

Mine tunnels
and drifts

Hydrogeologic characteristics

- Alluvium
- Aquitard, confining unit
- Saturated aquifer
- Unsaturated aquifer
- Ore body
- Weathered Mancos Shale
- Exploratory boreholes
and vents

Figure 1
Conceptualized Regional
Geologic Cross Section
Ambrosia Lake, New Mexico, Site

Modified from DOE, 1991.

Table 1 Summary of hydraulic properties of hydrostratigraphic units, Ambrosia Lake, New Mexico, disposal site

Hydro-stratigraphic unit	Geologic unit formation/member	Lithology	Depth to top of unit in boring at well 680 (ft bgs)	Thickness of units at well 680 (ft)	Porosity (percent)	Approximate saturated thickness (ft)			Hydraulic conductivity (cm/s)	Typical yield (gpm)	TDS (mg/L)
						Well No.	1989	1995			
Alluvium/ Weathered Mancos Shale	Alluvium/Weathered Mancos Shale	Clay, silt, sand and gravel	0	58	13 ^a	675	10.8	15.5	8E-05 ^a	<5	592-14,000 ^b
Boundary	Shale	Shale	58	62 ^c	NA	NA	NA	NA	NA	NA	3340 ^d
Boundary	Tres Hermanos-C ₁	Fine marine sandstone	NA		5 ^a	778	7.5	7.1	2.5E-04 ^{a,e}	NA	NA
	Shale	Shale	NA		NA	NA	NA	NA		NA	NA
	Tres Hermanos-C ₂	Fine marine sandstone	NA	↓	5 ^a	785	3.2	1.6	↓	NA	NA
Boundary	Shale	Shale	120	30	NA	NA	NA	NA	4.3E-08 ^a	NA	NA
Boundary	Tres Hermanos-B	Fine marine sandstone	150	7	NA	777	10.5	NM	5E-04 ^f	NA	1480-12,700 ^g
	Shale	Shale	157	63	NA	NA	NA	NA	1E-05 ^g	NA	NA
	Tres Hermanos-A	Fine marine sandstone	220	7	NA	679	0	24.0	NA	2000 (max) ^b	120-2940 ^g 2500-9000 ^b
Boundary	Shale	Shale	227	78	NA	NA	NA	NA	NA	NA	NA
Dakota	Dakota	Fine-med. marine sandstone	305	38	10 ^g	680	13.2	30.7	5.7E-04 ^b	10 ^d	310-6270 ^g 2500-9000 ^b
Brushy Basin	Brushy Basin Member	Mudstone w/ss lenses	343	NA	NA	NA	NA	NA	NA	NA	NA
Westwater Canyon	Westwater Canyon Member	Fine-coarse fluvial sandstone	NA	NA	10 ^f	NA	NA	NA	1E-06 ^a 4.3E-04 ^h	80-730 ^d	360-2200 ^b

Table 1 Summary of hydraulic properties of hydrostratigraphic units, Ambrosia Lake, New Mexico, disposal site (Concluded)

Hydro- stratigraphic unit	Geologic unit formation/ member	Lithology	Depth to top of unit in boring at well 680 (ft bgs)	Thickness of units at well 680 (ft)	Porosity (percent)	Approximate saturated thickness (ft)			Hydraulic conductivity (cm/s)	Typical yield (gpm)	TDS (mg/L)
						Well No.	1989	1995			
Recapture	Recapture Member	Siltstone w/sh and ss lenses	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bluff Sandstone	Fine-medium eolian sandstone	NA	NA	NA	NA	NA	NA	4.7E-07 ^b	10 ^d	2300 ^b

^aDOE, 1991.

^bBrod and Stone, 1981.

^cCombined thickness of Tres Hermanos-C₁, -C₂, and Mancos Shale.

^dPurtymun et al., 1977.

^eCombined hydraulic conductivity of Tres Hermanos-C₁ and -C₂ Sandstone units.

^fBrod, 1979.

^gBostick, 1985.

^hKelly et al., 1980.

bgs – below ground surface.

cm/s – centimeters per second.

gpm – gallons per minute.

NA – not available.

NM – no ground water elevations were measured.

sh – shale.

ss – sandstone.

Table 2 Comparison of average linear horizontal velocities in the alluvium/weathered Mancos Shale unit estimated from hydraulic conductivities of the Ambrosia Lake, New Mexico, area

Sample/test location	Test method	Hydraulic conductivity (cm/s)	Average hydraulic gradient (ft/ft)	Average porosity (ft ³ /ft ³)	Average linear velocity (ft/year)
Well 675, Ambrosia Lake UMTRA Project site	Aquifer pumping test	0.00035 ^a	0.025 ^a	0.13 ^a	70
Quivira Mining Company	Aquifer pumping test	0.0005 ^b	0.016 ^b	0.2 ^b	38 ^b
Ambrosia Lake mining district	Falling-head permeameter test	0.005 ^c	NA	NA	N/A

^aDOE, 1991.

^bBostick, 1985.

^cThomson and Heggen, 1981.

cm/s – centimeters per second.

N/A – not applicable.

The following conversion factor was used to calculate the values in Table 2:

$$V_x = \frac{K}{N_e} \frac{dh}{dl} = \left(\frac{0.00035 \text{ cm / sec}}{0.13 \text{ ft}^3 / \text{ft}^3} \right) \left(\frac{0.025 \text{ ft}}{\text{ft}} \right) \left(\frac{0.0328 \text{ ft}}{\text{cm}} \right) \left(\frac{3.17 \text{ E}07 \text{ sec}}{\text{yr}} \right) = 70 \text{ ft / yr}$$

Figure 2
Location of Monitor Wells and Former/Current Site Features
Ambrosia Lake, New Mexico, Site

Modified from DOE, 1991.

MAC: SITE/AMB/SOWP SUPPLEMENT/BASE/MONWELLLOC

Figure 3
Location of Local Uranium Mines in the Ambrosia Lake Area

MAC: SITE/AMB/SOWP SUPPLEMENT/LOCMINES

**Table 3 Water level evaluations within the Westwater Canyon Member
collected from the Section 30 and Section 33 mines near the Ambrosia
Lake, New Mexico, site**

Date	Water level elevation (ft above MSL)	
	Section 30 mine	Section 33 mine
November 1993	6331.2	6258.0
November 1994	6337.1	6258.0
November 1995	6337.2	6258.4

Note: Data provided by Quivira Mining Company (Ferdinand, 1996).

MSL – mean sea level.

Table 4 Mine shaft lithology of Section 30 and Section 33 mines near the Ambrosia Lake, New Mexico, site

Lithologic unit	Depth interval (ft BGS)
Section 30 mine (collar elevation = 6972 ft above MSL)	
Alluvium	0-38
Mancos Shale	28-92
Tres Hermanos-B Sandstone	92-143
Mancos Shale	143-170
Tres Hermanos-A Sandstone	170-212
Dakota Sandstone	212-331
Brushy Basin Member	331-418
Westwater Canyon Member	418-
Section 33 mine (collar elevation = 6972 ft above MSL)	
Alluvium	0-65
Mancos Shale	65-115
Tres Hermanos-B Sandstone	115-153
Mancos Shale	153-202
Tres Hermanos-A Sandstone	228-276
Dakota Sandstone	276-350
Brushy Basin Member	350-415
Westwater Canyon Member	415-

Note: Data provided by Quivira Mining Company (Ferdinand, 1996).

MSL – mean sea level.

BGS – below ground surface.

**Table 5 Alluvium/weathered Mancos Shale aquifer properties
reanalysis using AQTESOLV software, 1989 aquifer
test, Ambrosia Lake, New Mexico, site**

Parameter	OBS-2
Distance from well 675, ft	29.5
Saturated thickness, ft	10
Theis method	
(Confined, nonleaky aquifer analysis)	
T, ft ² /min	0.0027
S	0.005
Jacob method	
(Confined, nonleaky aquifer analysis)	
T, ft ² /min	0.0065
S	0.0004

ft²/min – square feet per minute.

T – transmissivity.

S – storativity.

ATTACHMENT A

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	COMPANY: UMTRA
--	----------------

LOCATION: Ambrosia Lake, NM	
-----------------------------	--

Aquifer Test Analysis -- OBS2

DATA SET:
AMBOBS2.DAT
11/21/95

AQUIFER MODEL:
Confined
SOLUTION METHOD:
Theis

TEST DATA:
Q = 0.35 gal/min
r = 29.9 ft
r_c = 0.3 ft
r_w = 0.4 ft
b = 10. ft

PARAMETER ESTIMATES:
T = 0.002736 ft²/min
S = 0.004839

AQTESOLV

Developed by Glenn M. Duffield
(c) 1988-1995 Geraghty & Miller, Inc.

14:34:43

```
Data set..... AMBOBS1.DAT
Output file..... AMBOBS1.OUT
Data set title.... Aquifer Test Analysis -- OBS1
Company..... UMTRA
Location..... Ambrosia Lake, NM
Test well..... Well 675
Obs. well..... Well OBS1
```

```
Length..... ft
Time..... min
Pumping rate... gal/min
```

```

Well No. 1
Well identification..... Well 675
X location..... 0
Y location..... 0
Casing radius..... 0.3
Wellbore radius..... 0.4
Well penetration..... Full
Number of pumping periods..... 1
Period      Pumping Rate
-----
      1              0.35

```

Well identification.....	OBS1
X location.....	10
Y location.....	0
Distance from pumping well #1....	10
Well penetration.....	Full
No. of observations.....	40

Theis (Confined Aquifer) Fully Penetrating Wells

A-5

	Estimate	Std. Error
T =	1.7251E-003 +/-	6.0460E-005 ft^2/min
S =	1.0547E-003 +/-	5.7654E-005

ANALYSIS OF MODEL RESIDUALS

residual = observed - calculated
weighted residual = residual * weight

Weighted Residual Statistics:

Number of residuals.....	40
Number of estimated parameters....	2
Degrees of freedom.....	38
Residual mean.....	0.08722
Residual standard deviation.....	0.2396
Residual variance.....	0.05741

Model Residuals:

Time	Observed	Calculated	Residual	Weight
1.5	0.015	7.2886E-006	0.014993	1
1.75	0.031	3.6001E-005	0.030964	1
2	0.047	0.0001211	0.046879	1
2.5	0.079	0.0006818	0.078318	1
3	0.095	0.0022167	0.092783	1
3.5	0.127	0.0052427	0.12176	1
4	0.159	0.010135	0.14886	1
4.5	0.19	0.017099	0.1729	1
5	0.222	0.026193	0.19581	1
5.5	0.254	0.037368	0.21663	1
6	0.286	0.050511	0.23549	1
6.5	0.334	0.065468	0.26853	1
7	0.365	0.082069	0.28293	1
7.5	0.397	0.10014	0.29686	1
8	0.429	0.1195	0.3095	1
8.5	0.477	0.14001	0.33699	1
9	0.509	0.1615	0.3475	1
9.5	0.54	0.18385	0.35615	1
10	0.572	0.20692	0.36508	1
20	1.129	0.71548	0.41352	1
30	1.447	1.1836	0.26339	1
40	1.654	1.5827	0.071341	1
50	1.781	1.9247	-0.14369	1
60	1.909	2.2223	-0.31329	1
70	2.099	2.485	-0.38605	1
80	2.338	2.72	-0.38198	1
90	2.593	2.9323	-0.33927	1
100	2.831	3.1258	-0.29482	1
150	3.786	3.8977	-0.1117	1
200	4.518	4.466	0.051993	1
250	5.059	4.9157	0.14326	1
300	5.409	5.2879	0.12113	1
350	5.663	5.6052	0.057765	1
400	6.045	5.8819	0.1631	1
450	6.347	6.1271	0.21989	1
500	6.586	6.3473	0.2387	1
550	6.665	6.5471	0.1179	1

Drawdown and Recovery Data for OBS-1 Ambrosia Lake Site

A-7

ATTACHMENT B

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Hydrograph Showing Ground Water Elevation Trends in Monitor Wells Completed in the Alluvium/Weathered Mancos Shale Hydrostratigraphic Unit

Static Ground Water Levels
Site: AMB01 Ambrosia Lake

Location ID	North Coordinate (ft)	East Coordinate (ft)	Formation of Completion	Flow Code	Casing Elevation (ft, NGVD)	Ground Elevation (ft, NGVD)	Log Date	Log Time	Depth from Top of Casing (ft)	Depth from Ground (ft)	Ground-water elevation (ft, NGVD)
674	53795.77	58785.81	AI	D	6973.3	6972.92	2/1/89	14:00	45.65	45.27	6927.65
							9/14/89	15:30	46.32	45.94	6926.98
							4/6/90	12:00	46.86	46.48	6926.44
							1/9/91	16:15	47.57	47.19	6925.73
							12/3/92	13:20	41.95	41.57	6931.35
							7/13/94	14:32	44.6	44.22	6928.7
							3/7/95	15:11	45.55	45.17	6927.75
							8/22/95	11:38	46.46	46.08	6926.84
675	53182.54	59915.9	KM	D	6966.65	6965.96	2/2/89	8:25	22.2	21.51	6944.45
							9/13/89	12:10	22.35	21.66	6944.3
							4/11/90	12:30	22.58	21.89	6944.07
							1/16/91	13:30	22.54	21.85	6944.11
							7/13/94	11:03	22.35	21.66	6944.3
							3/7/95	16:40	17.81	17.12	6948.84
							8/22/95	13:45	17.77	17.08	6948.88
781	53253.5	59156.3	AI	D	6968.4	6965.1	9/19/85	9:17	37.2	33.9	6931.2
							9/25/85	10:52	39.79	36.49	6928.61
							10/8/85	11:15	39.87	36.57	6928.53
							4/29/86	13:24	40.43	37.13	6927.97
							4/3/88	10:05	Dry	Dry	Dry
							7/13/94	11:55	39.64	36.34	6928.76
							3/7/95	16:45	39.1	35.8	6929.3
							8/22/95	10:54	40	36.7	6928.4
793	55493	60225.7	AI	U	6998.6	6996.6	10/8/85	14:18	21.4	19.4	6977.2
							4/29/86	11:35	22.03	20.03	6976.57
							5/17/86	9:50	23.38	21.38	6975.22
							4/4/88	15:10	22.49	20.49	6976.11

Location ID	North Coordinate (ft)	East Coordinate (ft)	Formation of Completion	Flow Code	Casing Elevation (ft, NGVD)	Ground Elevation (ft, NGVD)	Log Date	Log Time	Depth from Top of Casing (ft)	Depth from Ground (ft)	Ground-water elevation (ft, NGVD)
793	55493	60225.7	A1	U	6998.6	6996.6	7/12/88	13:45	22.72	20.72	6975.88
							1/6/89	13:44	22.7	20.7	6975.9
							9/13/89	15:50	23.74	21.74	6974.86
							3/29/90	17:50	24.05	22.05	6974.55
							1/9/91	13:00	24.76	22.76	6973.84
							11/24/92	8:55	25.71	23.71	6972.89
							7/13/94	14:51	27.55	25.55	6971.05
					6993.63 (a)	~ 6991.0 (a)	8/22/95	12:21	22.72	20.72	6970.91 (a)

Formation of Completion Code:

A1 - Alluvium

KM - Mancos Shale

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(a) revised data based on modification of monitor well casing elevation

ATTACHMENT C

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GEOCHEMISTRY OF SELECTED ALLUVIAL WELLS -- AMBROSIA LAKE SITE

1 0620
2 0674
3 0676
4 0792
5 0793

DATA FROM 1991

GEOCHEMISTRY OF WELL AMB01-0793

AMBROSIA LAKE SITE

DATA FROM 1991

GROUNDWATER QUALITY DATA SITE: AMB01
LOCATION: 0620, 0674, 0675, 0781, 0792, 0793

C-4

GROUNDWATER QUALITY DATA SITE: AMB01
LOCATION: 0620, 0674, 0675, 0781, 0792, 0793

GEOCHEMISTRY OF SELECTED WELLS SCREENED IN TRES HERMANOS-C

1 0677
2 0778
3 0785
4 0786

DATA FROM 1991

GEOCHEMISTRY OF WELL AMB01-0677

AMBROSIA LAKE SITE

GEOCHEMISTRY OF AMB01-0778

AMBROSIA LAKE SITE

GEOCHEMISTRY OF AMB01-0785

AMBROSIA LAKE SITE

GEOCHEMISTRY OF AMB01-0786

AMBROSIA LAKE SITE

DATA FROM 1991

8-C

GROUNDWATER QUALITY DATA

SITE: AMB01

LOCATION: 0677, 0778, 0785, 0786

GROUNDWATER QUALITY DATA SITE: AMB01
 LOCATION: 0677, 0778, 0785, 0786

GEOCHEMISTRY OF SELECTED WELLS SCREENED IN TRES HERMANOS-B

1 0878
2 0681
3 0777

DATA FROM 1991

GEOCHEMISTRY OF WELL AMB01-0678
AMBROSIA LAKE SITE

GEOCHEMISTRY OF WELL AMB01-0681
AMBROSIA LAKE SITE

GEOCHEMISTRY OF WELL AMB01-0777
AMBROSIA LAKE SITE

DATA FROM 1991

GROUNDWATER QUALITY DATA

SITE: AMB01

LOCATION: 0678, 0681, 0777

GROUNDWATER QUALITY DATA SITE: AMB01
 LOCATION: 0678, 0681, 0777

GEOCHEMISTRY OF WELL SCREENED IN THE DAKOTA SANDSTONE

1 0680

DATA FROM 1991

CATIONS

% OF TOTAL MEQ/L
1 SAMPLES

ANIONS

GEOCHEMISTRY OF WELL AMB01-0680 AMBROSIA LAKE SITE

Ion	meq/L	meq/L
Na ⁺ +K ⁺	14.65	
Ca ²⁺	29.69	
Mg ²⁺	18.26	
Fe ²⁺	.08	
NO ₃ ⁻		.07
SO ₄ ²⁻		50.59
HCO ₃ ⁻		3.44
Cl ⁻		1.95
	-----	-----
	62.69	56.05

DATA FROM 1991

SAMPLE 1

GROUNDWATER QUALITY DATA
LOCATION: 0680

SITE: AMB01

C-16
TOTAL DISSOLVED SOLIDS (MG/L)

0680
X

GROUNDWATER QUALITY DATA SITE: AMB01
LOCATION: 0680