U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

SEP 23 1999

Madeline Roanhorse, Director
Navajo UMTRA Program
Division of Natural Resources
P.O. Box 1875
Window Rock, Arizona 86515

Subject: Environmental Sciences Laboratory Results for *Contaminants in Soils and Sediments* and *Column Leaching of Floodplain Sediments With Synthetic San Juan River Water* (Shiprock, New Mexico, Site)

Dear Ms. Roanhorse:

Enclosed are bound reports developed by our Environmental Sciences Laboratory (ESL) for the UMTRA Ground Water Project at Shiprock, New Mexico (September 1999).

Contaminants in Soils and Sediments:

The purpose of this report is to show the locations of the samples, to describe the methods used, and to provide the results of the laboratory analyses. Samples were collected December 9, 1998, through April 7, 1999. Acid leaching was performed in the ESL in January and May 1999. Twenty-six samples were analyzed. These data results are validated and reside in our electronic database (SEE UMTRA).

Column Leaching of Floodplain Sediments With Synthetic San Juan River Water:

This laboratory study was intended to examine the effectiveness of the San Juan River water to leach uranium and other contaminants of potential concern from floodplain alluvium sediments. The purpose of this report is to show the locations of the samples, to describe the methods used, and to provide the results of the laboratory analyses. Samples were collected during the drilling program from October through November 1998. Laboratory work was performed in the ESL from May 19 through June 7, 1999. Six columns were run. These data results are validated and reside in our electronic database (SEE UMTRA).

These reports are, in essence, "geochemistry calculations sets." This report format will be used for reporting future UMTRA Ground Water Project sites' ESL data collection needs.

Sincerely,

Donald R. Metzler
Technical/Project Manager

Enclosures

cc w/enclosures:
L. Gardner & Associates
K. Kloc, Gardner & Associates
M. Layton, NRC
J. Oberdorfer, San Jose State University
R. Williamson, San Jose State University
Shiprock Public Library
S. Morrison, MACTEC-ERS

cc w/o enclosures:
Project File GWSHP13.1 (P. Taylor)

drm\shpecl-1.doc

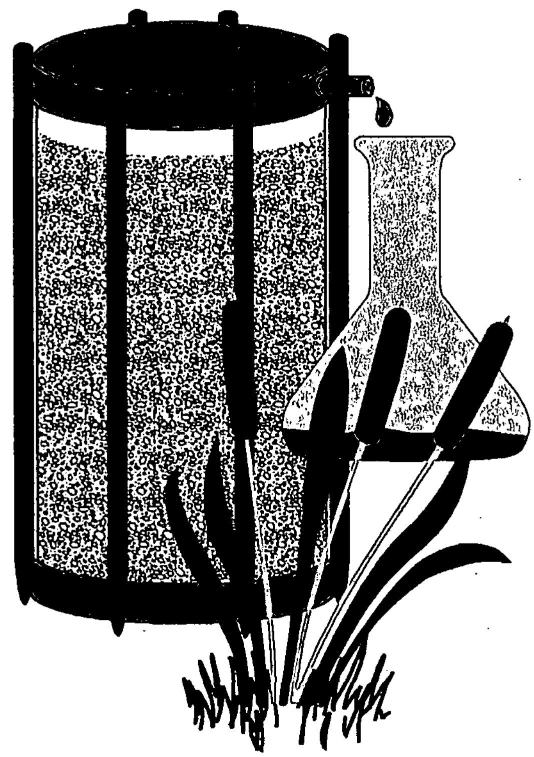
ESL–RPT–99–05

Environmental Sciences Laboratory

Column Leaching of Floodplain Sediments With Synthetic San Juan River Water

UMTRA Ground Water Project
Shiprock, New Mexico, Site

September 1999



Prepared by
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office
Grand Junction, Colorado

Work Performed Under DOE Contract No. DE–AC13–96GJ87335
DOE Task Order No. MAC99–05

ESL–RPT–99–05

Column Leaching of Floodplain Sediments with Synthetic San Juan River Water

UMTRA Ground Water Project
Shiprock, New Mexico, Site

September 1999

Prepared by
Environmental Sciences Laboratory
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office
Grand Junction, Colorado

Project Number UGW–511–0020–08–000
Document Number U0067400

This page intentionally blank

Signature Page

Column Leaching of Floodplain Sediments with Synthetic San Juan River Water

UMTRA Ground Water Project
Shiprock, New Mexico, Site

September 1999

Prepared By: Stan Morrison

Stan Morrison, Manager
Environmental Sciences Laboratory

Reviewed By: Craig Goodknight

Craig Goodknight, Technical Lead
UMTRA Shiprock Site

Approved By:

Donald R. Metzler, Project/Technical Manager
U.S. Department of Energy

Contents

Tables

Figures

Appendices

Acronym List

ACL	Analytical Chemistry Laboratory
As	arsenic
Cd	cadmium
CFR	U.S. Code of Federal Regulations
COPC	contaminants of potential concern
DOE	U.S. Department of Energy
ESL	Environmental Sciences Laboratory
GJO	Grand Junction Office
Mg	magnesium
$\mu g/L$	micrograms per liter
mg/L	milligrams per liter
mL	milliliters
mL/min.	milliliters per minute
Mn	manganese
N_2	nitrogen gas
Na	sodium
NH_3	ammonia
NH_4	ammonium
NO_2	nitrite
NO_3	nitrate
ORP	oxidation reduction potential
Sb	antimony
Se	selenium
SO_4	sulfate
SOWP	Site Observational Work Plan
Sr	strontium
U	uranium
UMTRA	Uranium Mill Tailings Remedial Action

This page intentionally blank

1.0 Introduction

This laboratory study was intended to examine the effectiveness of San Juan River water to leach uranium and other contaminants of potential concern (COPC) from floodplain alluvial sediments. The purpose of this report is to show the locations of the samples, to describe the methods used, and to provide the results of the laboratory analyses. Samples were collected during the drilling program from October through November 1998. Laboratory work was performed in the Environmental Sciences Laboratory (ESL) from May 19 through June 7, 1999. Six columns were run. Sampling locations are shown in Figure 1. Appendix A contains the ESL work submittal for this project; Appendix B, copies of the ESL notes; and Appendix C, raw data.

The Shiprock Uranium Mill Tailings Remedial Action (UMTRA) Project site is on the Navajo Indian Reservation (Navajo Nation) near the town of Shiprock in northwestern New Mexico. Uranium ores were milled at the site from 1954 through 1968. The UMTRA site at Shiprock currently consists of a stabilized disposal cell that covers approximately 77 acres. The disposal cell was completed in 1986. Ground water at the Shiprock UMTRA site contains constituents in concentrations that exceed the ground-water protection standards established in Title 40, *U.S. Code of Federal Regulations* Part 192 (40 CFR 192).

The contaminated ground water is in a terrace south of the San Juan River and within an alluvial aquifer in the floodplain that is hydraulically connected to the San Juan River. A 50- to 60-foot high escarpment separates the terrace from the floodplain. In the *Site Observational Work Plan for the UMTRA Project Site at Shiprock* (SOWP) (DOE 1995), the two compliance strategies considered appropriate for cleanup of the two ground-water systems are (1) for the terrace system, no remediation and the application of supplemental standards based on classification of the terrace ground-water system as limited-use ground water and (2) for the floodplain system, active remediation using one or more remediation techniques currently under evaluation.

The UMTRA project team determined that additional characterization data were required to complete the evaluation of ground-water remediation technologies. A work plan was prepared in June 1998 to address these characterization needs (DOE 1998). The laboratory study presented in this report addresses one of the data quality objectives defined in the Work Plan: "Characterize leachability conditions of alluvial material in several contaminated areas of the floodplain".

This page intentionally blank

2.0 Sample Locations and Collection Methods

Alluvial aquifer sediment was sampled from six borings (Figure 1). Three borings (locations 0854, 0856, and 0864) are in the contaminated portion of the millsite floodplain, and three (locations 0850, 0851, and 0852) are in the background floodplain. Lithologic logs of these borings showing the locations of the samples are provided in Appendix D.

The samples were collected by driving a split-spoon tube into the alluvial sediment. In some cases the split-spoon was incapable of retrieving a suitable sample and auger returns were used instead.

The samples from the millsite floodplain were selected from the most uranium-contaminated portion of the ground water plume. These samples are believed to be representative of those areas that are likely to release the most contamination from the alluvial sediments.

This page intentionally blank

3.0 Background on Column Leaching

The goal of this study was to determine the concentrations of COPC that are to be expected if San Juan River water were to flow through contaminated alluvial aquifer sediments in the floodplain. Therefore, a leaching solution comprised of the major ions in San Juan River water was used. Leaching with water of a different composition is likely to produce different concentrations in the effluent.

Column leaching is often used to estimate the concentrations of contaminants that will occur when a solution flows through contaminated sediments. Effluent concentration profiles over time can also provide information that indicates how rapidly the concentrations will decrease.

Contaminants can be present in sediment in different forms including: crystalline structure of minerals, adsorbed to mineral surfaces, and in immobile pore fluids. Some of the forms of contamination are more easily released than others. Complexing agents in the leach solution enhance the release of some contaminants. An example is uranium which desorbs more efficiently in a solution with high concentrations of dissolved carbonate. The pH and oxidation potential of the solution can also affect the leaching process. Therefore, the choice of leach solution is important.

This page intentionally blank

4.0 Methods of Analysis

The cores consisted of partially disaggregated floodplain alluvial sediment. Splits of the cores were placed in aluminum pie pans exposed to the air until visibly dry (about 5 days). The sediments were crushed lightly by hand to increase the drying rate. The dried sediment was sieved to less than 3 mesh (6 mm). The material was placed in the columns about 4 inches at a time using light tapping with a rubber mallet to compact it.

This study used a procedure similar to ESL standard column test procedure CB(CT□1) (DOE 1999). Columns (2-inch diameter) were constructed from clear acrylic (Figure 2). Nylon cloth filters sandwiched between two perforated plastic discs were placed at the bottom and top of the column. The sediment column was 18 inches in length. Synthetic San Juan River solution was pumped with a peristaltic pump set at 0.8 milliliters per minute (mL/min.) from bottom to top through the column. Effluent was collected in a flask.

The major-ion chemistry of San Juan River water collected at location 0546 was synthesized from reagent-grade chemicals. The recipe used to synthesize this water is provided in Appendix E. The pH of the synthetic solution was adjusted to about 8 using NaOH to match the pH of the river. Fresh solutions were prepared daily to prevent microbial buildup and evaporation loss.

Effluent samples were collected every 12 hours. Concentrations of uranium and nitrate, pH, electrical conductivity, oxidation-reduction potential, and alkalinity were measured in the ESL soon after sample collection using the procedures in DOE (1999). Samples were preserved and submitted to the Grand Junction Office (GJO) Analytical Chemistry Laboratory (ACL) for analysis of the COPC (arsenic, cadmium, magnesium, manganese, sodium, ammonium, nitrate, antimony, selenium, sulfate, strontium, and uranium). Analytical methods are listed in Table 1.

This page intentionally blank

5.0 Results and Discussion

The data are plotted as concentration versus the number of pore volumes (using midpoints) that have passed through the column (Figures 3a through 3l). A pore volume was calculated as the amount of solution used to fill each column. The data from the contaminated floodplain and background area are compared in this section.

5.1 Ammonium

Ammonium (NH_4^+) is a strong cation exchanger that often occupies exchange sites on clay minerals. At pH values (about 9) above those in San Juan River water, it will transform to ammonia (NH_3) and is volatile. Under oxidized conditions ammonium reacts to form nitrite (NO_2^-), nitrate (NO_3^-), or nitrogen gas (N_2).

The ammonium concentration in the first sample from column 0854 was 1,970 micrograms per liter (μg/L) (Figure 3a). The concentration decreased to 287 μg/L after 10 pore volumes. Effluent concentrations of ammonium from all the other columns were much lower with the highest value of 85.5 μg/L observed in effluent from background column 0851. Even the highest concentration of 1,970 μg/L is relatively low compared to ammonium concentrations observed in ground water at the site.

5.2 Antimony

The highest concentrations of antimony were in effluent from background column 0850 (Figure 3b). These results are consistent with the observation that elevated concentrations of antimony are rare in the floodplain ground water. Antimony will probably not be leached from the floodplain at concentrations above background with San Juan River water.

5.3 Arsenic

Arsenic occurs commonly in nature in two oxidation states, As^{+3} and As^{+5}. Under strongly anaerobic conditions it can also occur with a negative oxidation state and form arsenide minerals. It adsorbes strongly on sediment minerals such as iron oxyhydroxides.

Effluents from all three columns from the contaminated floodplain had higher concentrations of arsenic than the background columns (Figure 3c). The highest concentration was 8.3 μg/L from column 0856. Although the leachate concentrations from the millsite floodplain samples are higher than in background samples, the concentrations are well below the UMTRA MCL of 50 μg/L. These results suggest that arsenic will not be leached from the floodplain at concentrations above the MCL.

5.4 Cadmium

Concentrations of cadmium in all effluents from all columns were less than the detection limit of 1 μg/L (Figure 3d). These results are consistent with the relatively rare occurrences of elevated cadmium concentrations in the ground water at the mill site. Cadmium will probably not be

leached from the floodplain at concentrations above the MCL (10 μg/L) by San Juan River water.

5.5 Magnesium

Magnesium is a major cation that occurs as a component of many minerals such as carbonates. Its concentration in ground water is controlled primarily by precipitation and dissolution of these minerals.

The magnesium concentrations in effluents from the three background columns were only slightly higher than the concentration in the synthetic San Juan River water (2,990 μg/L) indicating that little magnesium was exchanged with the sediment. The first effluent sample from the 0854 column had a magnesium concentration of 265,000 μg/L (Figure 3e). It is likely that the magnesium in this first sample is derived from the dissolution of water-soluble salts in the sample. All other effluents had concentrations less than 50,000 μg/L and most were less than 20,000 μg/L. The three columns from the millsite floodplain had higher concentrations than the three background columns.

To help evaluate the significance of the magnesium concentration in the column effluents, they can be compared to concentrations in ground water from background wells and with San Juan River water. Samples from wells on the opposite side of the San Juan River from the disposal cell had magnesium concentrations ranging from 40,800 to 318,000 μg/L (DOE, 1998). Samples of river water at upstream locations 0888 and 0898 had magnesium concentrations of 32,300 and 12,200 μg/L, respectively, in March 1999. The magnesium concentrations in the column leachates are lower than those in background ground water and similar to those in the San Juan River. These results suggest that leaching of floodplain alluvial sediments with San Juan River water will not contribute a significant amount of magnesium.

5.6 Manganese

Manganese mobility is related to the oxidation reduction potential of a soil or sediment. Manganese forms oxide minerals under oxidizing conditions and is soluble under more reduced conditions. Therefore, the more oxidized a sediment, the more likely it is to have higher concentrations of manganese.

Manganese concentrations in all effluents from two of the columns (0856 and 0864) from the contaminated floodplain were less than 13.5 μg/L and are lower than in effluents from the background samples (Figure 3f). The manganese concentration in effluent from the other contaminated floodplain column (0854) was initially 552 μg/L, but decreased rapidly to about 40 μg/L. Effluents from all three background columns had manganese concentrations of about 60 μg/L.

These results suggest that manganese will not be leached appreciably from the floodplain alluvium by San Juan River water.

5.7 Nitrate

Most of the nitrate n the alluvial sediment is either adsorbed or in the crystalline structure of salt minerals. Under strongly reduced conditions nitrate can transform to nitrite, ammonium, or nitrogen gas.

The concentrations of nitrate in effluents from the mill floodplain columns are similar to those from the background columns (Figure 3g). The concentrations are much lower than nitrate concentrations observed in the ground water on the mill floodplain. Apparently, nitrate is strongly partitioned into the aqueous phase and little is associated with the solid particles.

5.8 Selenium

Selenium commonly occurs naturally in two oxidation states, Se^{+4} and Se^{+6}. It also occurs as selenide minerals in reduced sediments and rocks such as black shales.

All three columns containing alluvium from the contaminated floodplain had effluent concentrations of selenium that were less than the detection limit of 2 μg/L (Figure 3h). Effluent from all three background columns had selenium concentrations of 7 to 11 μg/L, initially, and the concentrations decreased rapidly to between 1.8 to 3 μg/L.

The Mancos Shale is known to be a natural source of selenium which contaminates ground water. The higher concentrations of selenium in the effluents from the background samples is probably the result of the leaching of Mancos Shale.

5.9 Sodium

Sodium is a major component of many minerals. It often occurs in relatively high concentrations in ground water due to precipitation and dissolution of minerals, or from cation exchange on clay minerals.

The concentrations of sodium in effluent from column 0854 from the contaminated floodplain was initially 516,000 μg/L but the concentration decreased after the first sample to 54,900 μg/L (Figure 3i). The first effluent is probably affected by the initial dissolution of soluble salts. Sodium concentrations in all other columns was about 30,000 μg/L which is near the concentration (30,120 μg/L) in the synthetic San Juan River water. These results indicate that the sodium concentration may increase slightly initially, but no sustained increase in concentration of the San Juan River water is likely.

5.10 Strontium

Strontium is a major component of some minerals such as carbonates. Its concentration in ground water is largely controlled by precipitation and dissolution of these minerals.

Concentrations of strontium in effluents from the three contaminated floodplain columns (0854, 0856, and 0864) were higher (1,000 to 2,220 μg/L) initially than those from the background columns (Figure 3j). The concentrations in the contaminated columns decreased to about 500 μg/L after several pore volumes. Effluent from the background columns were about

150 μg/L initially but increased to about 500 μg/L after several pore volumes. These results suggest that a small amount of soluble strontium may be released from the alluvial sediment initially, but that no sustained contribution will occur.

Concentrations of strontium in the San Juan River from locations 0888 and 0898, upgradient of the millsite, are 1,290 and 786 μg/L, respectively. Since concentrations in the leachates are lower than the concentrations in the river, there is not likely to be a significant contribution of strontium to San Juan River water flowing through the alluvial aquifer.

5.11 Sulfate

Sulfate is a major component of many minerals. In arid environments such as at Shiprock, water-soluble sulfate minerals occur ubiquitously in soil and sediments. Concentrations in ground water are largely controlled by precipitation and dissolution of these minerals

The sulfate concentration in the first effluent from columns 0854, 0856, and 0864 from the contaminated floodplain were 3,200,000 μg/L, 576,000 μg/L, and 485,000 μg/L, respectively (Figure 3k). These high levels decreased to about 150,000 μg/L after 10 pore volumes. Concentrations of sulfate in the effluents of all three background columns were nearly constant at about 100,000 μg/L which is similar to the influent concentration (121,340 μg/L). The higher concentrations of sulfate from the millsite floodplain were probably due to dissolution of sulfate salts that were deposited in the alluvium from mill-related fluids.

These results suggest that an initial pulse of sulfate will be dissolved as San Juan River water flows through the millsite floodplain. The sulfate concentrations should decrease rapidly to background levels in the San Juan River.

5.12 Uranium

Most uranium in the alluvial sediment in the Shiprock floodplain is probably due to adsorption. Uranium adsorbs readily to common sediment minerals such as ferric oxyhydroxides. Uranium forms complexes with dissolved carbonate which causes more partitioning into the dissolved phase.

Effluents from all three columns containing alluvial aquifer sediments from the contaminated floodplain had higher uranium concentrations than those from the background columns (Figure 3l). One of the background columns (0850) however, had concentrations nearly the same as one of the contaminated columns. The first effluent from column 0854 had a uranium concentration of 72.9 μg/L. The concentration decreased rapidly and was less than the UMTRA MCL (44 μg/L) after about 4 pore volumes.

These results suggest that there is some mill-related uranium contamination in the alluvial sediments. Uranium released during flushing with San Juan River water is likely to be slightly above the UMTRA MCL initially, but should rapidly decrease to relatively low levels.

6.0 References

U.S. Department of Energy (DOE), 1995. *Site Observational Work Plan for the UMTRA Project Site at Shiprock, New Mexico*, DOE/AL/62350–158, Rev. 0, prepared by Jacobs Engineering Group Inc. for the U.S. Department of Energy UMTRA Project Office, Albuquerque, New Mexico.

———, 1998. *Work Plan for Characterization Activities at the Shiprock UMTRA Project Site*, MAC–GWSHP 1.8, prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

———, 1999. *Environmental Sciences Laboratory Procedures Manual*, Revision 0, MAC–3017, prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

This page intentionally blank

Table 1. Analytical Methods

	Procedure	Description
pH	*AP(pH-1) Rev 0	Electrode
ORP	*AP(ORP-1) Rev 0	Electrode
Conductivity	*AP(EC-1) Rev 0	Electrode
Alkalinity	*AP(Alk-1) Rev 0	Sulfuric Acid Titration
As	AS-4 Rev 02	Hydride-Generation AA
Cd	AS-6 Rev 06	ICP-MS
Mg	AS-5 Rev 06	ICP-AES
Mn	AS-5 Rev 06	ICP-AES
Na	AS-5 Rev 06	ICP-AES
NH_4	F-6 Rev 07	Spectrophotometry
NO_3	*AP(NO_3-2) Rev 0	Colorimetric
NO_3	D-3 Rev 13	Ion Chromatography
Sb	AS-6 Rev 06	ICP-MS
Se	AS-5 Rev 06	ICP-AES
SO_4	*AP(SO_4-2) Rev 0	Turbidimetric
SO_4	D-3 Rev 13	Ion Chromatography
Sr	AS-5 Rev 06	ICP-AES
U	*AP(U-2) Rev 0	Kinetic phosphorescence
U	AS-6 Rev 06	ICP-MS

*ESL procedures. All others are GJO ACL procedures.
AA = Atomic Absorption Spectrometry; **ICP-AES** = Inductively Coupled Plasma - Atomic Emission Spectroscopy; **ICP-MS** = Inductively Coupled Plasma - Mass Spectrometry; **ORP** = oxidation reduction potential

This page intentionally blank

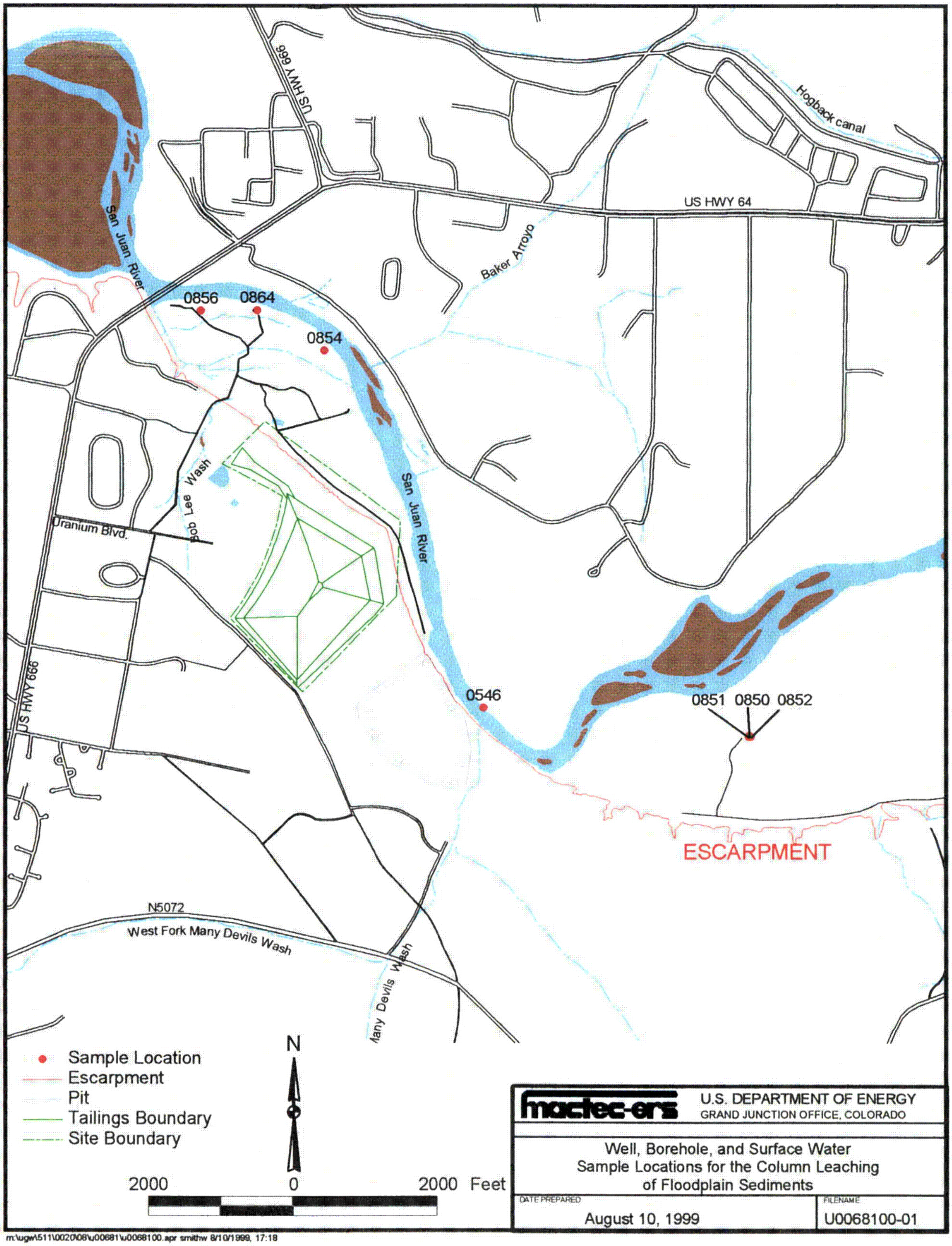


Figure 1. Location Map

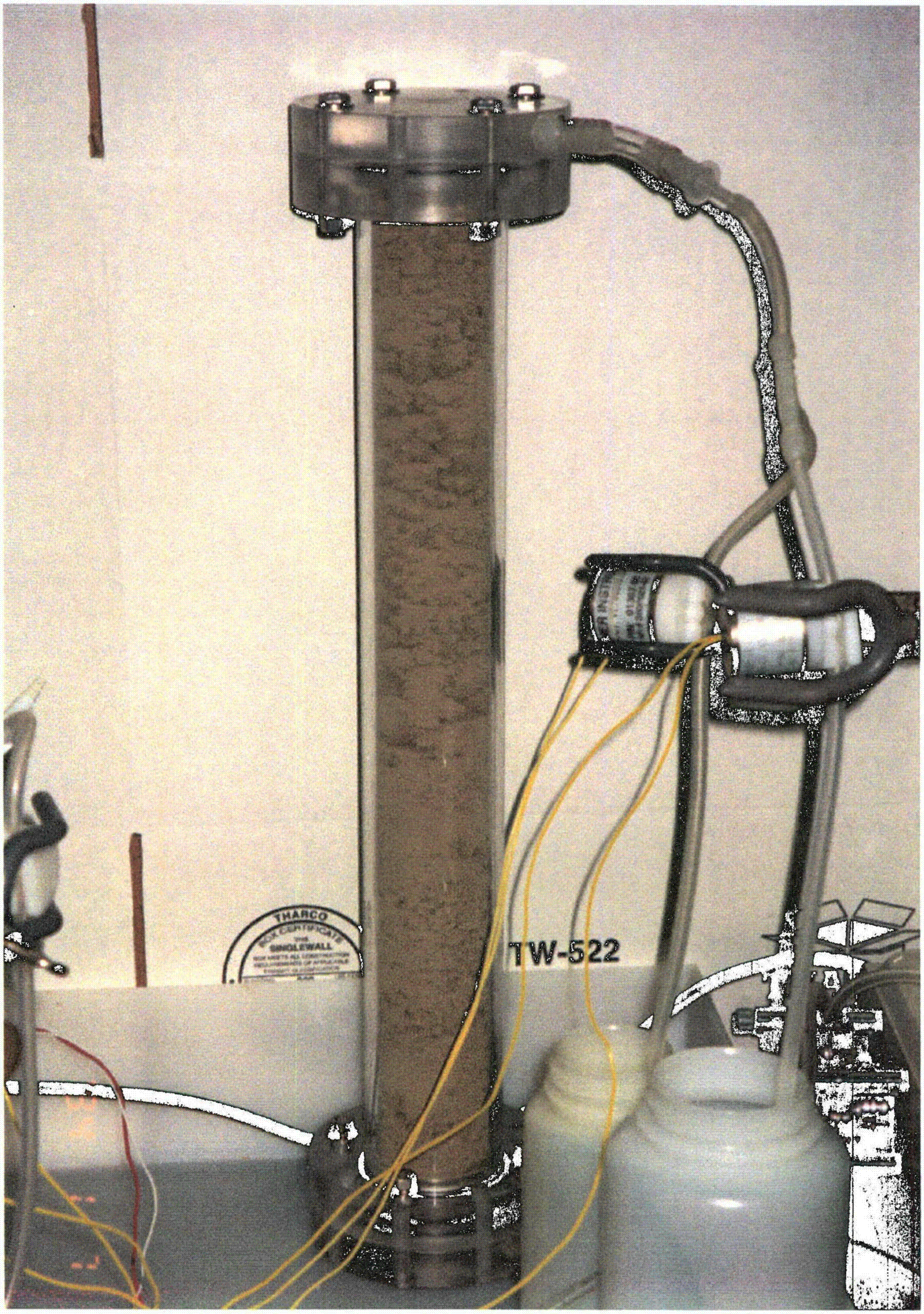


Figure 2. Experimental Setup

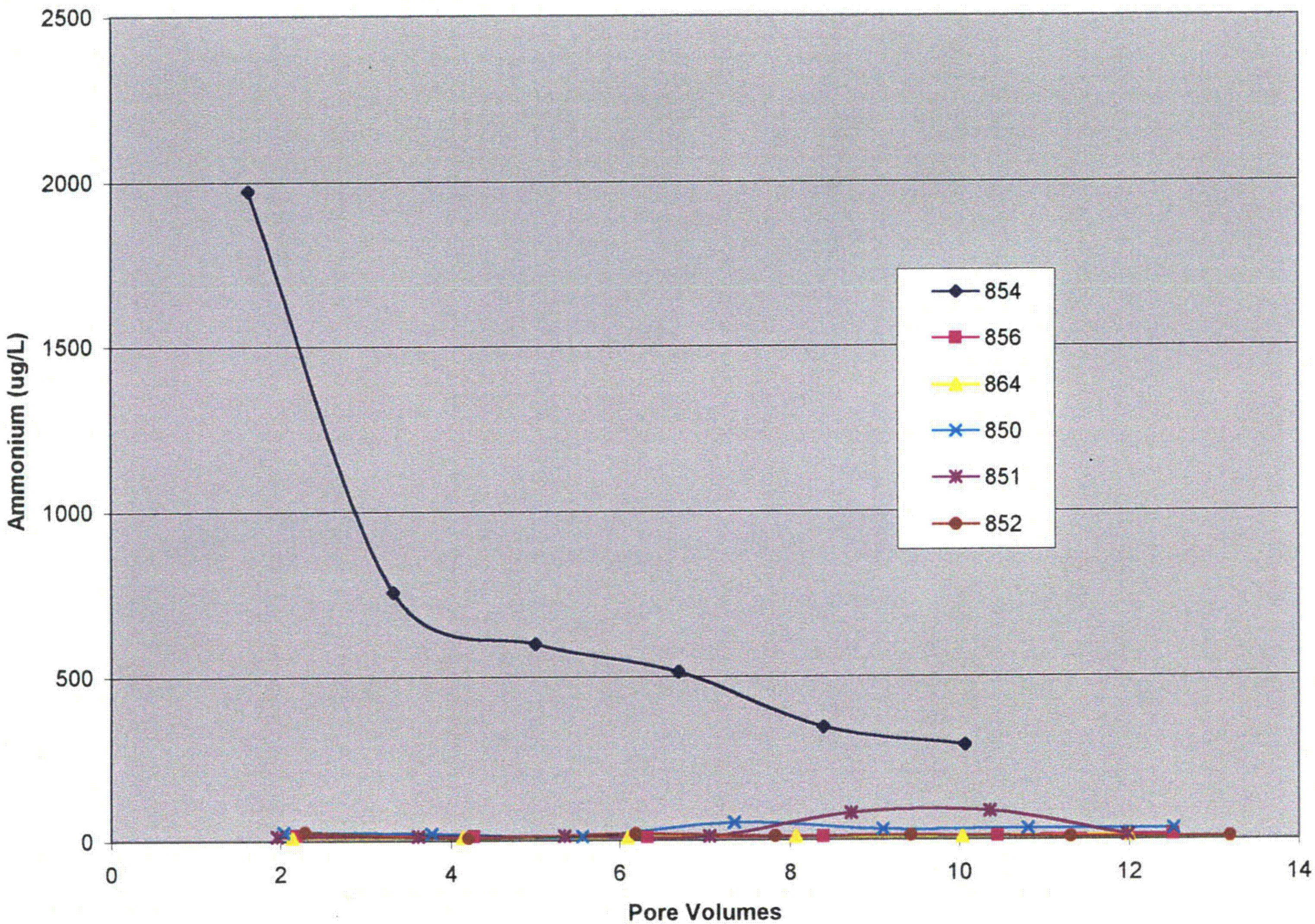


Figure 3a. Concentration Plot of Ammonium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

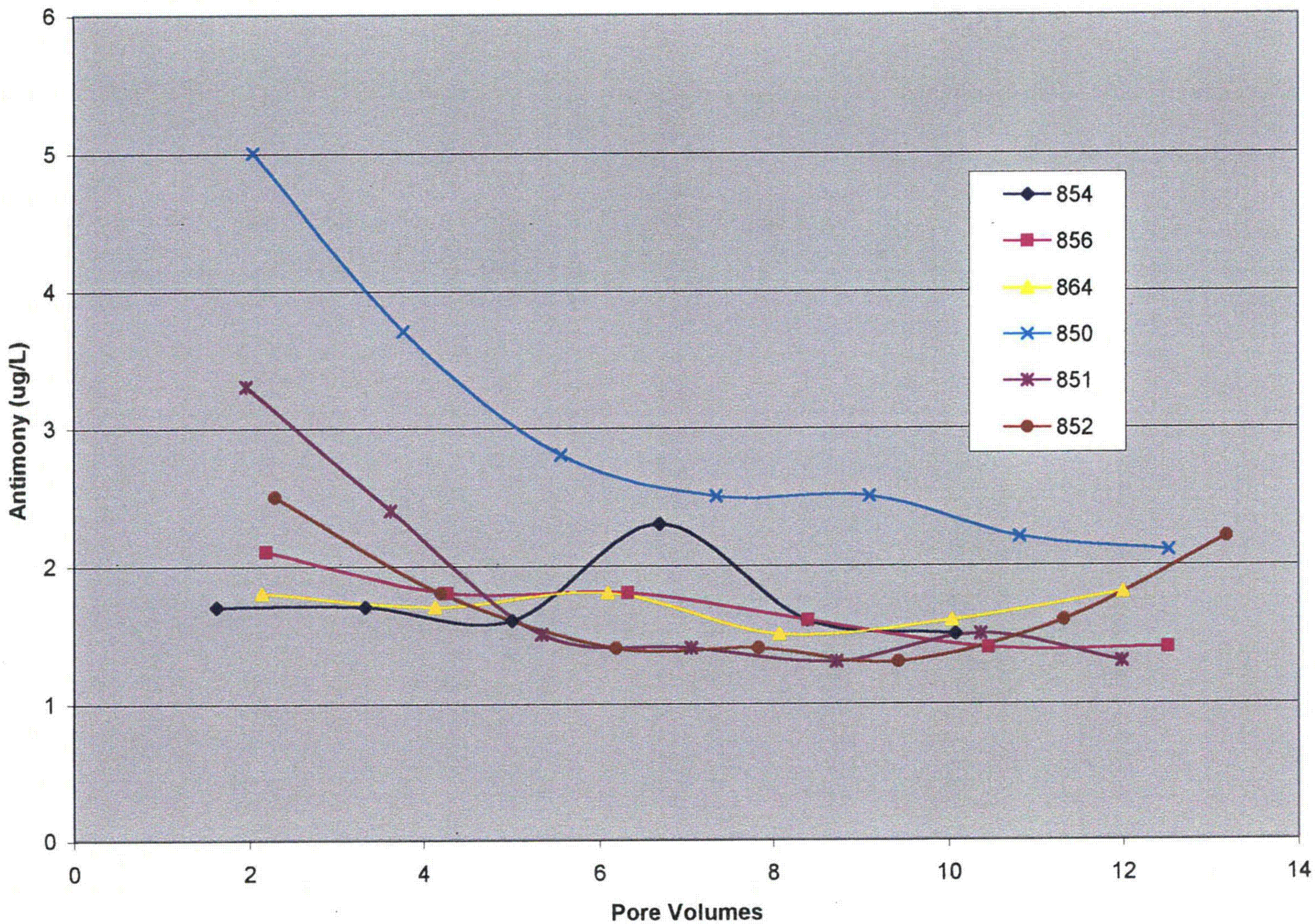


Figure 3b. Concentration Plot of Antimony
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

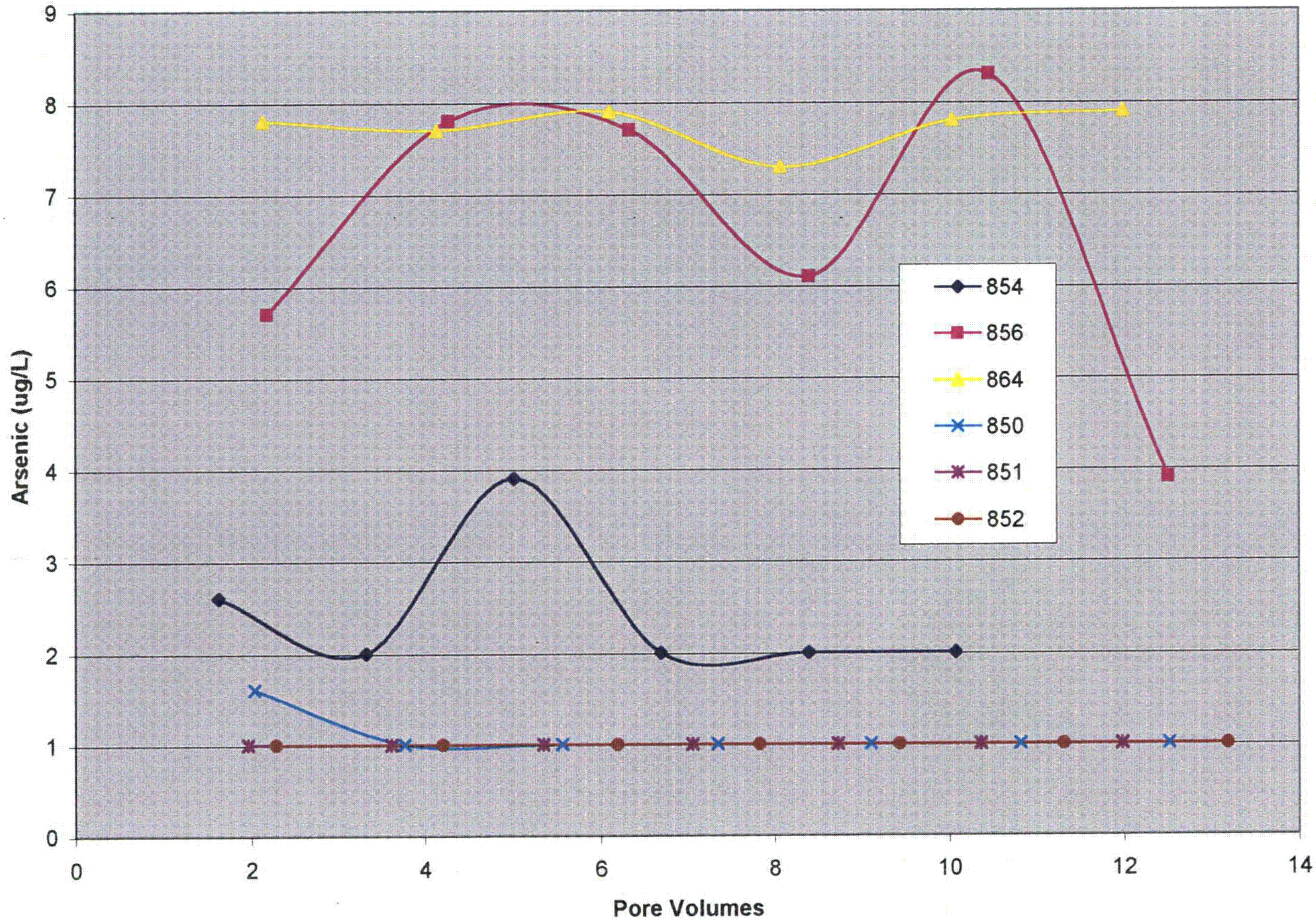


Figure 3c. Concentration Plot of Arsenic
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

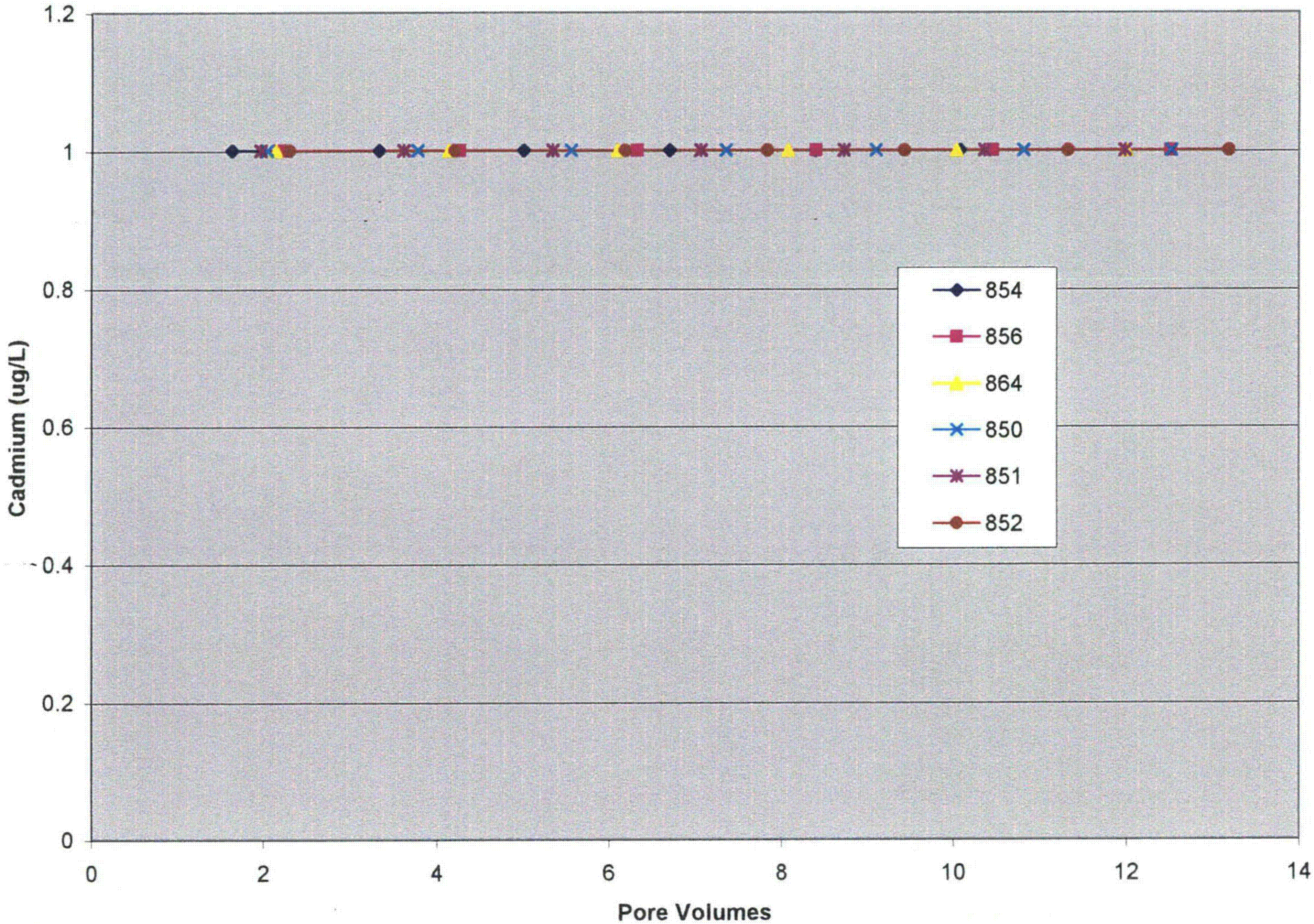


Figure 3d. Concentration Plot of Cadmium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

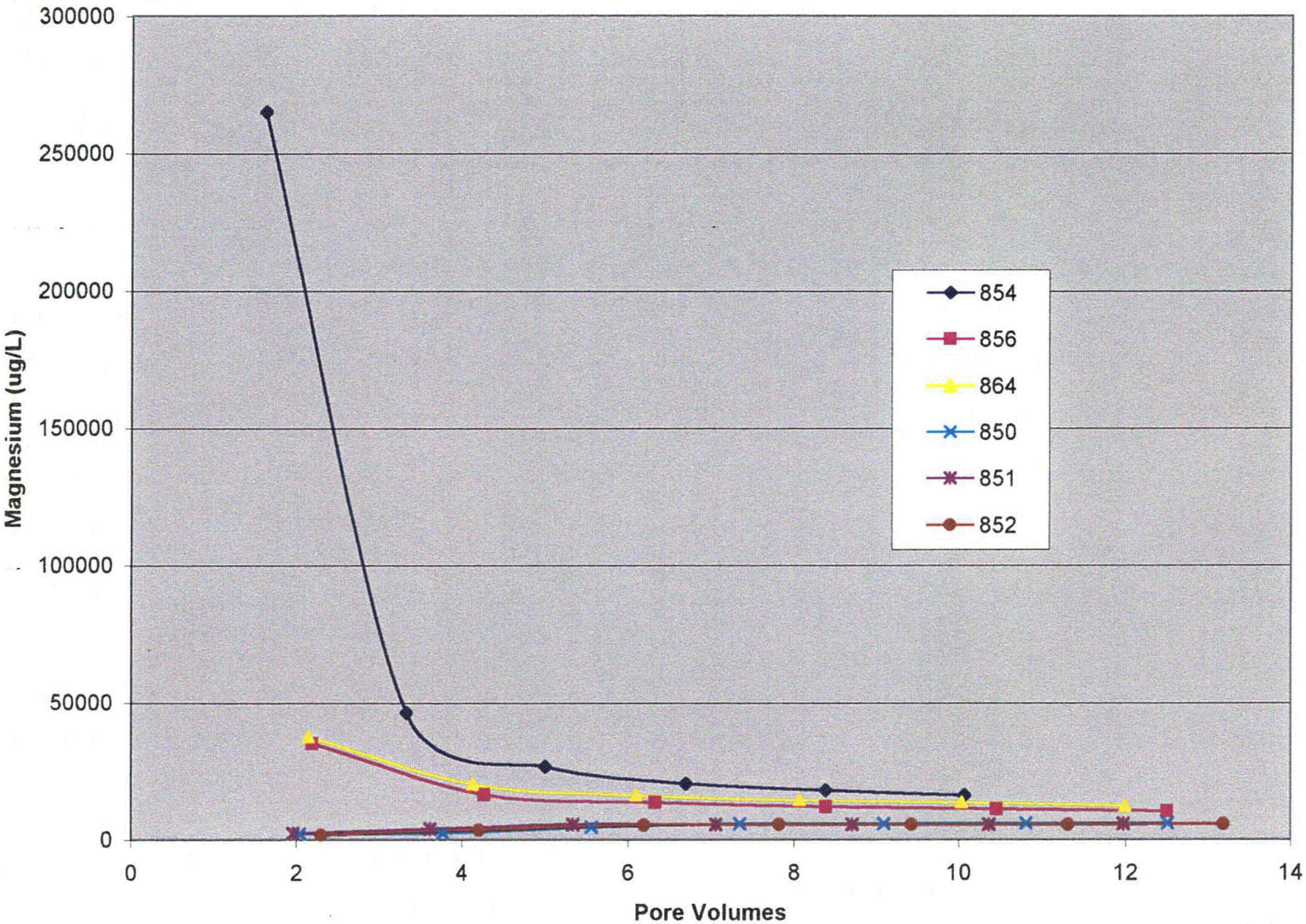


Figure 3e. Concentration Plot of Magnesium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

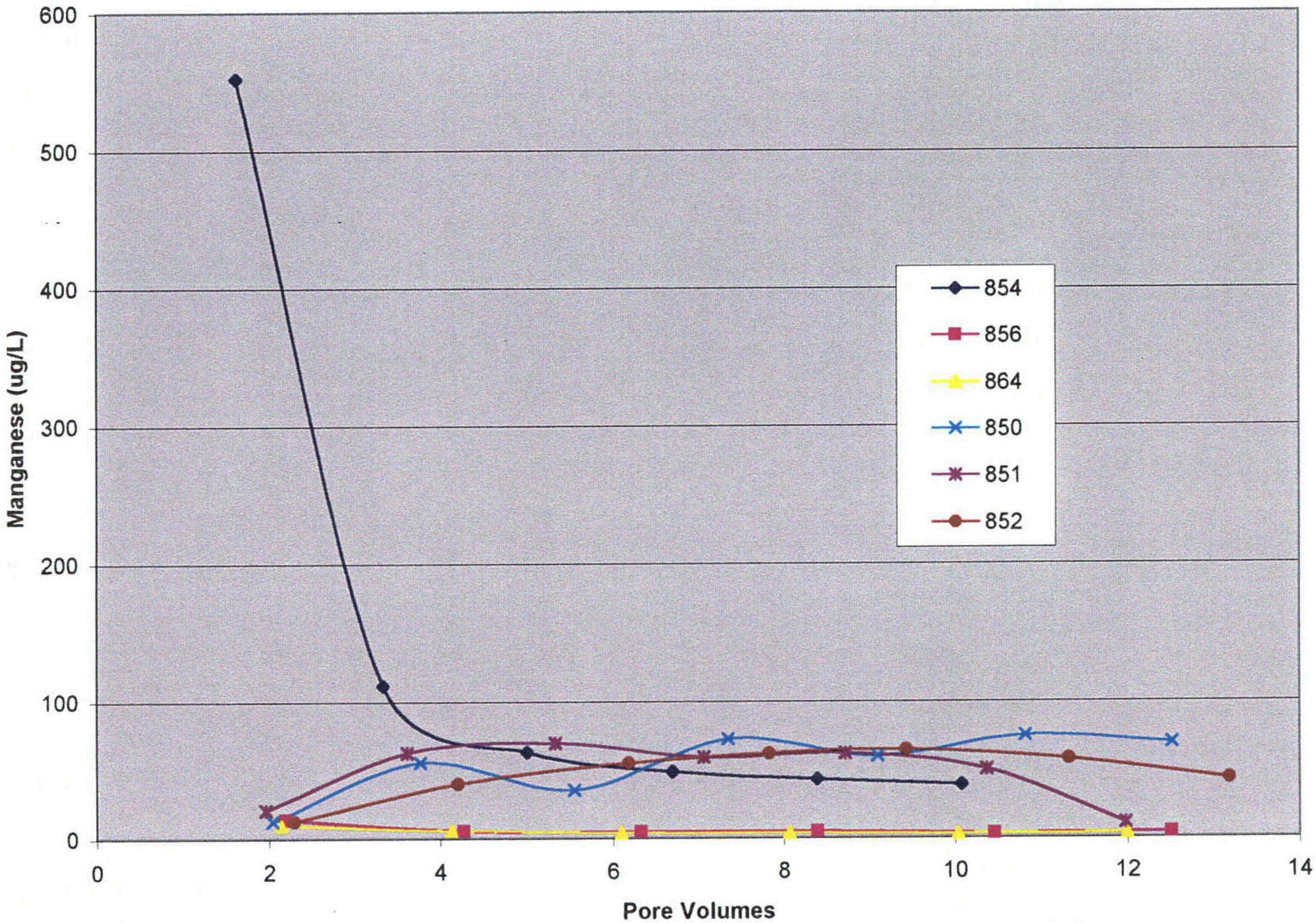


Figure 3f. Concentration Plot of Manganese
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

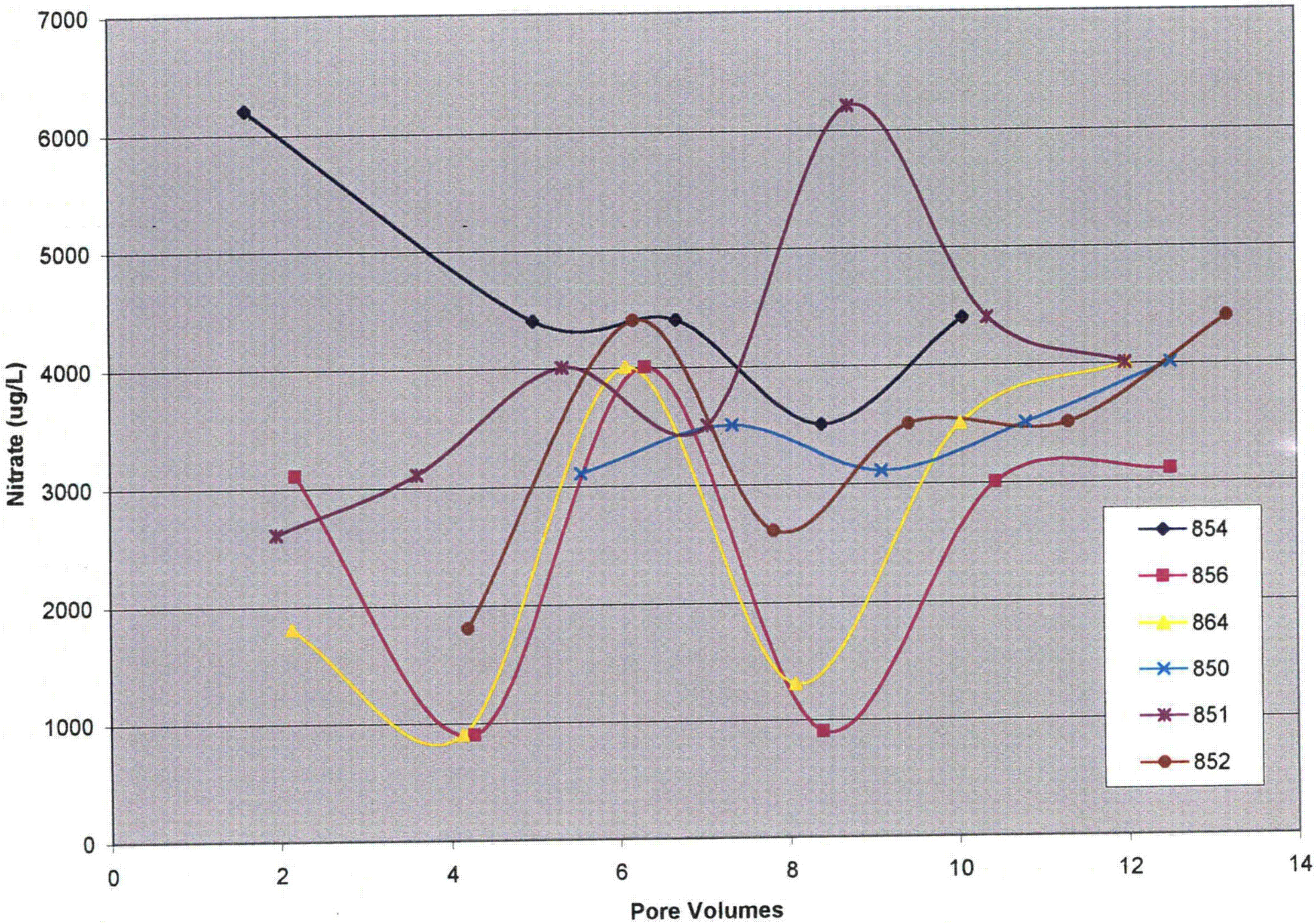


Figure 3g. Concentration Plot of Nitrate
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

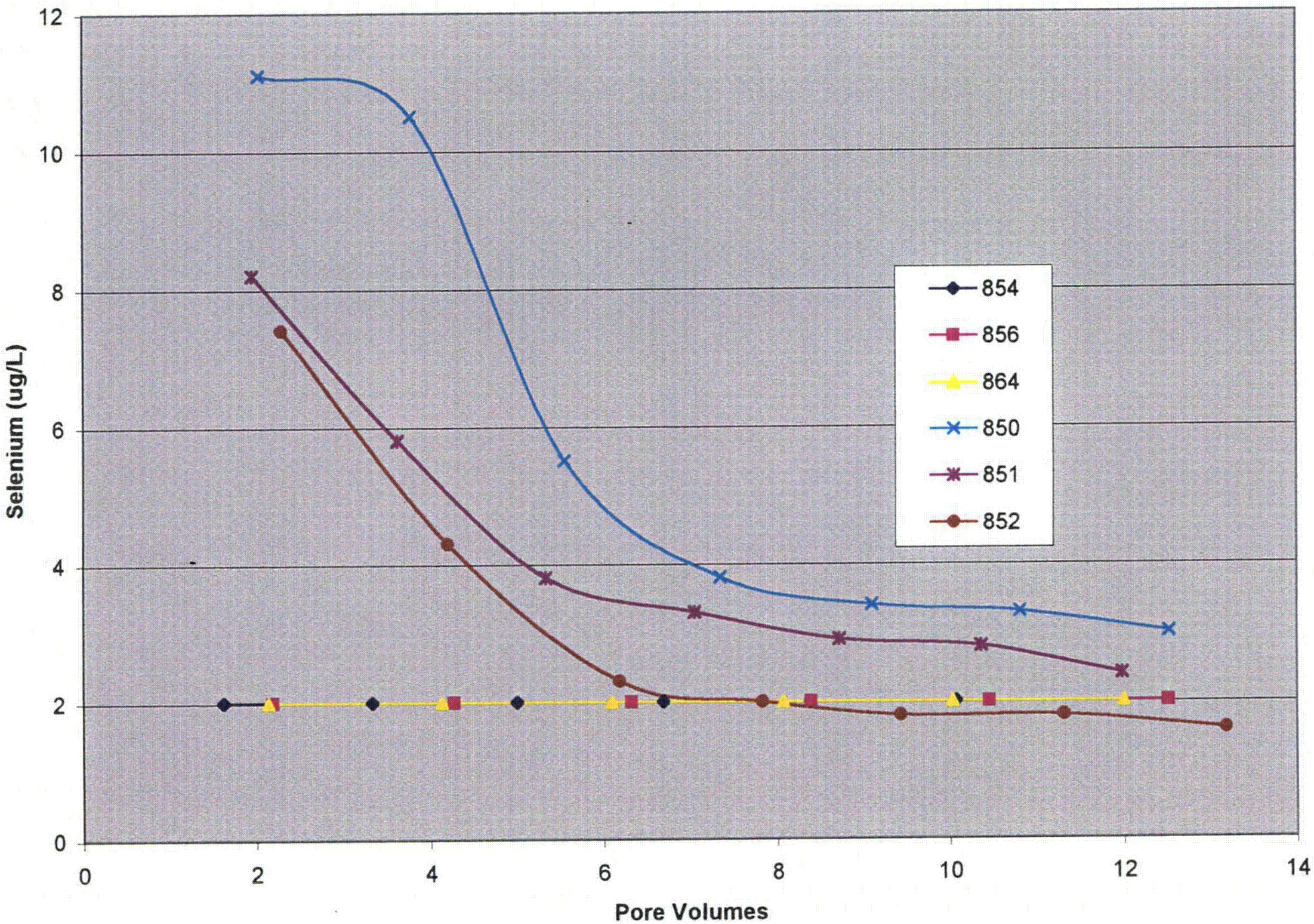


Figure 3h. Concentration Plot of Selenium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

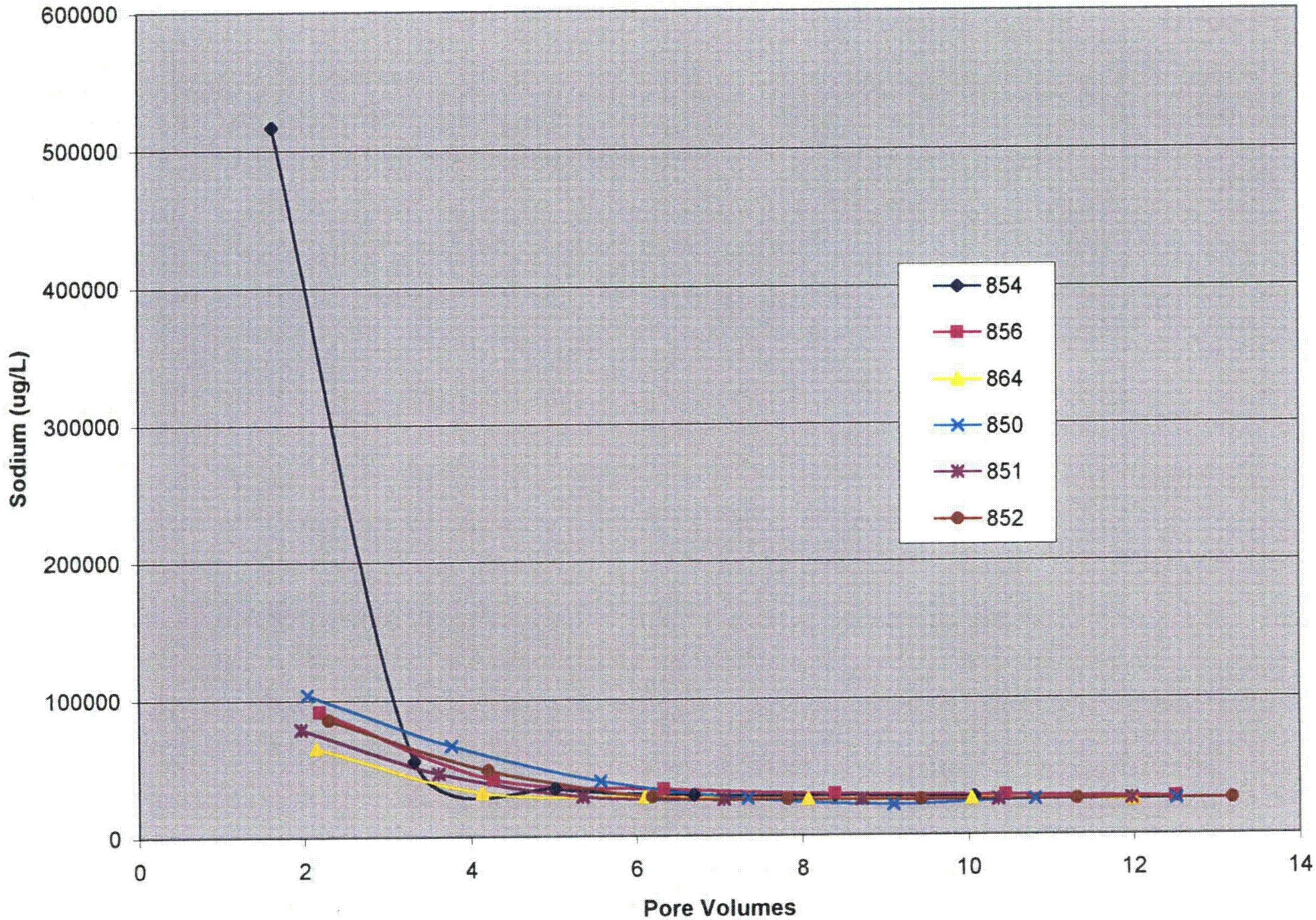


Figure 3i. Concentration Plot of Sodium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

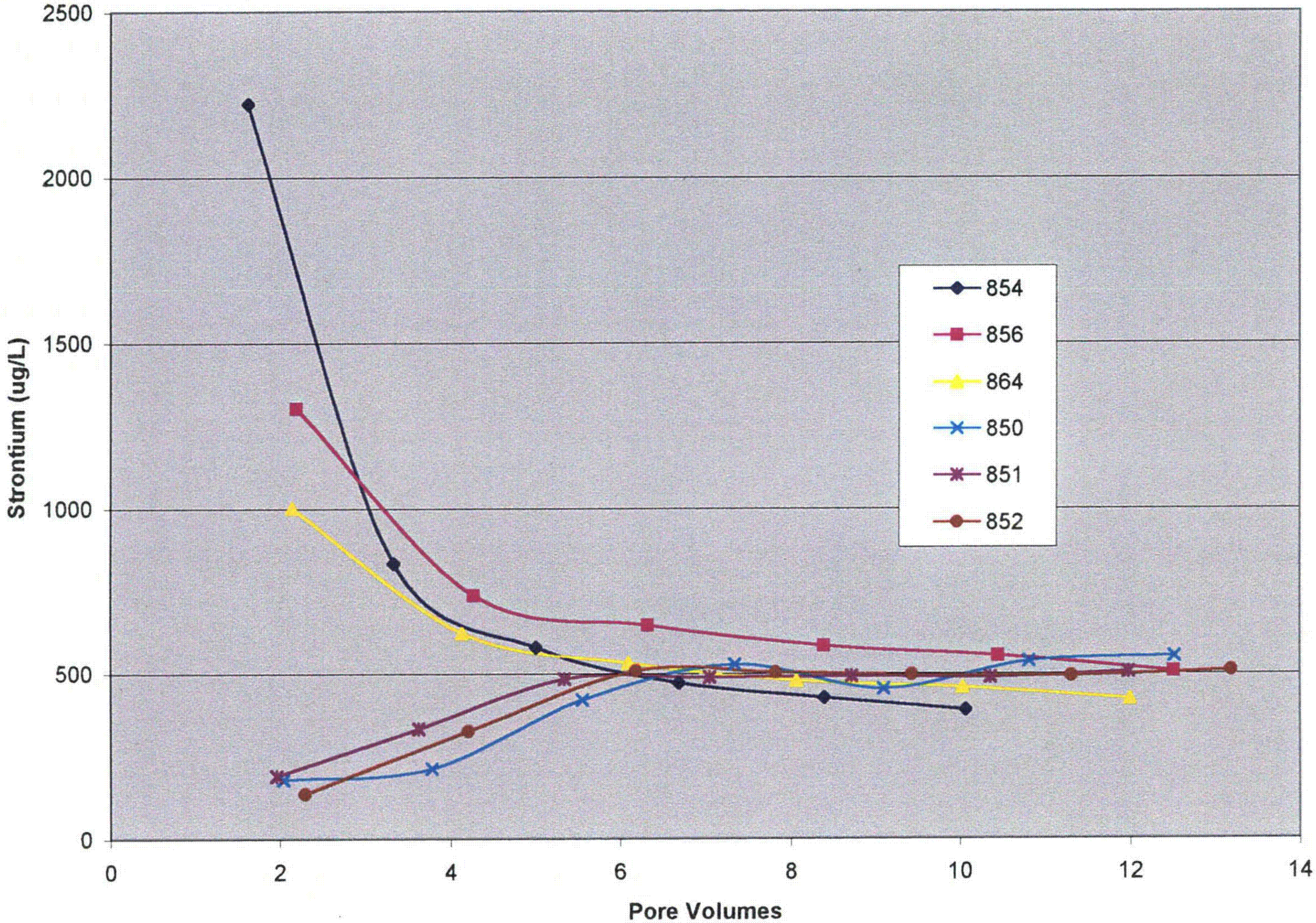


Figure 3j. Concentration Plot of Strontium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

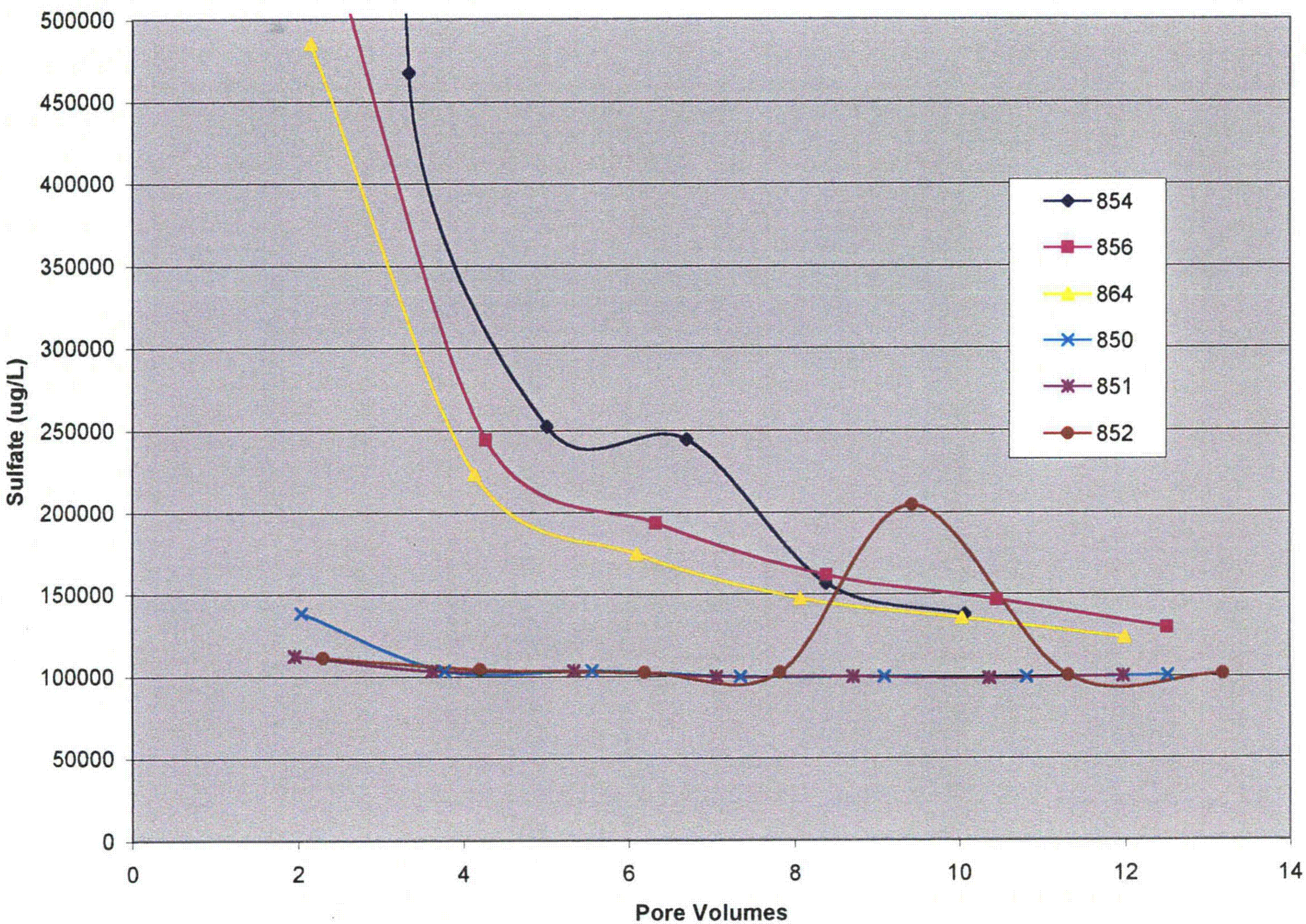


Figure 3k. Concentration Plot of Sulfate
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

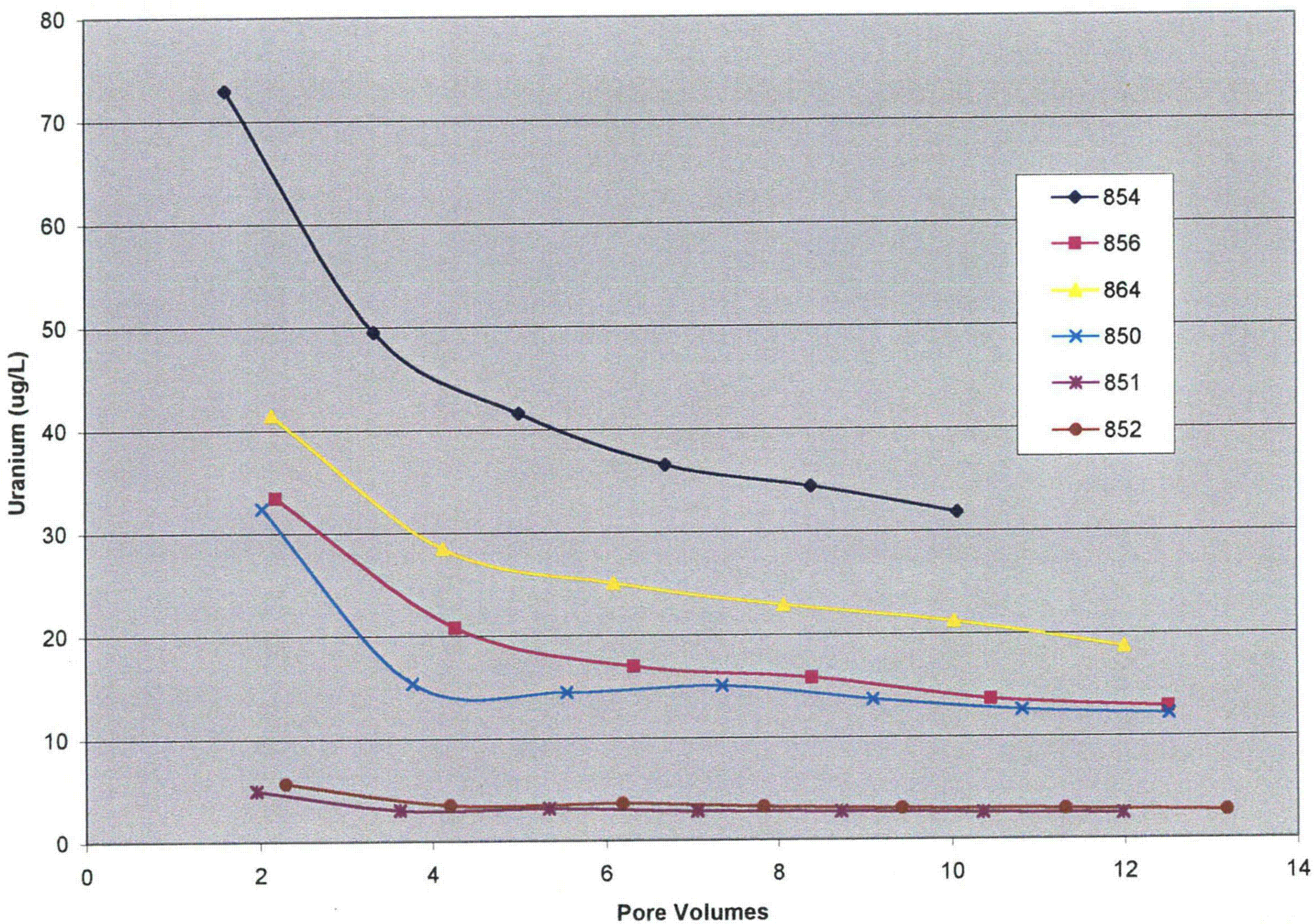


Figure 3l. Concentration Plot of Uranium
(850, 851, and 852 = Background Floodplain, 854, 856, and 864 = Contaminated Floodplain)

Appendix A

Environmental Sciences Laboratory Work Submittal

This page intentionally blank

WORK SUBMITTAL TO ENVIRONMENTAL SCIENCES LABORATORY

Submittal Date 5/22/99 Date Required ASAP

Submitted By Craig Goodknight Signature Craig Goodknight

Formal Report Required (check one)? Yes X No ___

Project: UMTRA - Shiprock Charge No. 331405001

Analysis Type (check one): Kd ___ Leaching X Other ___

6 Columns

Sample Numbers 854 11-13', 856 14', 864 5-7', [850 10-15', 851 11-12', 852 12-13'] - bkgd Combine 864 @ 10' & 864 @ 5-7' per C Goodknight

Analytes Sb, As, Cd, Mg, Mn, NO_3, Se, Na, Sr, SO_4, U, NH_4
pH, ORP, DO, EC, Alkalinity

Solution Composition simulated San Juan river water (location 546), recipe attached

Comments (attach procedure if needed)
See attached procedure for DQO 3 (Floodplain system)
5/20/99 Add'l mat'l needed for columns 856 and 864 Per C Goodknight returned SHP 856 @ 9' and SHP 864 @ 14.5-15.0' from Cheney. Placed in trays to dry. Will combine with other splits prior to packing columns SM

Tracking (ESL use only):

Actual Labor Hours (ESL use only):

This page intentionally blank

To: C. Goodknight, S. Morris
From: S. Morrison
December 28, 1998

Subject: Minutes From Meeting on Shiprock on December 28, 1998
Attendees: C. Goodknight, S. Morris, and S. Morrison
Cc: M. Kautsky, S. Marutzky

This meeting was held to discuss the laboratory tests that are to be conducted on the Shiprock samples in the Environmental Science Laboratory (ESL). Each DQO presented in the "Work Plan for Characterization Activities at the Shiprock UMTRA Project Site" that will utilize the ESL was reexamined in light of the samples now available from the field sampling. In most cases, the work will be performed exactly as presented in the workplan but for some tasks it was necessary to slightly modify the scope.

The schedule in the workplan indicates that all analyses were to have been completed by October 15, 1998. This schedule is being revised by C. Goodknight. All samples are expected to be submitted to the ESL by January 15, 1999. The following notes represent the consensus of the group:

DQO 1 (Terrace System): Characterize contaminant sorption in the terrace system ground water.
Kd values will be determined on Mancos Shale samples from 2 wells (800 and 802). Two samples (one from weathered and one from unweathered Km) from each well will be analyzed (total of 4 samples). The weathered samples are 800 21.3-21.7 and 802 32.7-33; the unweathered samples are 800 60.5-60.9 and 802 60.4-60.8. Five point isotherms will be determined for samples 800 21.3-21.7 and 800 60.5-60.9. Single-point Kds will be determined on the other 2 samples. Laboratory water with major-ion composition modeled after well 602 and spiked appropriately (to simulate the contaminant plume) with Cd, Se, NH_4, and U will be used. The standard ESL procedure for Kds including air drying and sieving to < 2 mm will be followed.

DQO 2 (Floodplain System): Characterize contaminant sorption in the floodplain alluvial aquifer.
Kd values will be determined for 2 samples each from 3 borings (total of 6 samples). One sample from each boring from immediately below the water table (the shallow sample) and one from the deeper sand/gravel alluvium (the deep sample) will be analyzed. Borings 850, 851, and 852 will be used. The "deep" samples are: 850 10-15, 851 12, and 852 12-13; the shallow samples are 850 2-4, 851 2-3, and 852 6-7. Five point isotherms will be conducted on the 2 samples from boring 852. Single-point Kd measurements will be made on the other 4 samples. Laboratory water with major-ion composition modeled after well 619 and spiked appropriately (to simulate the contaminant plume) with Cd, Se, NH_4, and U will be used. The standard ESL procedure for Kds including air drying and sieving to < 2 mm will be followed.

DQO 3 (Floodplain System): Characterize leachability conditions of alluvial material in several contaminated areas of the floodplain.
This task requires 6 samples, 3 from the contaminated floodplain and 3 from the background floodplain. For best results, the contaminated samples should have as high of contamination as possible and an effort was made to select the most contaminated samples. Samples 854 11-13, 856 14, and 864 5-7 will be used to represent the contaminated floodplain. Groundwater from borehole 864 had uranium measured in the field at 0.461 mg/L indicating relatively high levels of contamination; groundwater from boreholes 854 and 856 have not been measured but their location within the plume indicates high levels of contaminants are to be expected. Samples 850 10-15, 851 11-12, and 852 12-13 will be used to represent the background floodplain.

Each sample will be placed in a 4-inch diameter column (the length of the sediment column will be at least 6 inches) and leached with simulated San Juan river water (modeled after a water analysis collected at location 546, in the San Juan River upgradient of the site). The first water to exit the columns will be sampled. Thence, samples will be collected after an additional 1, 2, and 3 pore volumes. These 4 samples from each column (total 24 samples) will be analyzed for all 12 COPCs (Sb, As, Cd, Mg, Mn, NO_3, Se, Na, Sr, SO_4, U, and NH_4). After these first 4 samples are collected, up to 5 additional samples from each

column will be collected as long as U or NO_3 remain above their MCL (based on real-time measurements in the ESL). These samples will also be analyzed for all 12 COPCs. Whether or not to sieve the sample (the sample will probably be sieved to less than #4 mesh to remove any large pebbles) will be determined by the analyst upon inspecting the sample. The flow rate through the columns will be prescribed so that 7 pore volumes will have passed through in about 3 to 4 days.

DQO 4 (Floodplain System): Characterize soils as a source of continuing contamination.
There was much discussion as to the intent of this DQO. It was decided that these samples will need to be collected during the next site visit. The samples will be from the shallow soils (in most cases probably no deeper than 1 or 2 feet) that are most likely to be contaminated. The samples will be collected from four locations: (1) soils that laid below an old pond observed on air photos (near proposed sampling location P892), (2) possible residual contaminated soils near well 736, (3) near the central part of the plume area (P890 area), and (4) in an area where elevated radiometric counts were encountered during the last field visit. Two samples will be collected at each of these locations (total of 8 samples). The samples will be selected after examining the layout and geomorphology of the location and will reflect best judgement to collect samples most likely to have been contaminated by the milling. Four locations on the background floodplain will also be sampled. One sample will be collected from each location (total of 4 samples) using the same procedures as were used at the contaminated floodplain.

These samples will be leached in 5 % HCl (5 % HNO_3 is specified in the workplan but this would interfere with NO_3 and NH_3 analyses). Although indicated in the workplan, alkalinity will not be measured because these are acidic solutions. All COPCs (Sb, As, Cd, Mg, Mn, NO_3, Se, Na, Sr, SO_4, U, and NH_4) will be measured on these leachates (the workplan specifies only specific COPCs, but in response to stakeholders' concerns all will be measured).

DQO 5 (Floodplain System): Determine if millsite-related contamination has entered the San Juan River and affected its water and sediment.
The ESL portion of this DQO involves only the sediment. Sediments were sampled from 9 locations: 884, 887, 888, and 893-898. Eight of these are from the San Juan River and one (884) is from an irrigation ditch. All 9 samples will be analyzed.

The samples will be leached in 5 % HCl (5 % HNO_3 is specified in the workplan but this would interfere with NO_3 and NH_3 analyses). All COPCs (Sb, As, Cd, Mg, Mn, NO_3, Se, Na, Sr, SO_4, U, and NH_4) will be measured on the leachates.

DQO 6 (Terrace System) (This DQO is additional, it was not in the workplan): Determine if there is nitrogen in the Mancos Shale that might have contributed to the NO_3 signature observed in the groundwater.

One sample of weathered Km (800 19.8-20) and one of unweathered Km (800 61.2-61.7) will be submitted to the Analytical Chemistry Laboratory for analysis of Kjeldahl N. A sample of the white efflorescent material near Km seeps in Many Devils Wash will be collected during the next sampling. This sample will be water leached (exact procedure yet to be determined) and the leachate analyzed for N compounds.

Appendix B

Environmental Sciences Laboratory Notes

This page intentionally blank

AMPAD EFFICIENCY LINE • 22-210

Shiprock

SHP01-10-01

5/19/99 Fill 2" column c̄ SHP854 @ 11-13' Sieved < 3 mesh Tare wgt. of column = 1263.1g
net wgt of soil = 1472.4g

5/19 Attempt to fill columns w/ SHP856 @ 14' and SHP864 @ 5-7' and 10'. Not enough small fraction (< 3 mesh) material. Ckd c̄ Craig Goodknight. Instructed
5/20 1400 to add 856 @ 9' and 864 @ 14.5-15'. Went to Cheney to retrieve.

1500 Placed SHP856 @ 9 and SHP864 @ 14.5-15' in pans to air dry. When dry will combine with other splits of same boring and fill columns w/ their respective homogenized.

SHP01-10-02

5/24/99 Started prep work on Shiprock columns: SHP 854, SHP 864 & SHP 856

→ Tare wt. of column only (SHP-854) ≃ 1589.6, wt of added soil 1511.4g, Gross wt. 3055.8

→ Tare wt of column only (SHP-864) ≃ 1602.4g, wt. of added soil ≃ 1642.6g, Gross wt. 3206.2

→ Tare wt. of column only (SHP 856) ≃ 1600.7g, wt. of added soil ≃ 1631.5g, Gross wt. ~~3189~~ 3198.9 g

1700 Primed all 3 columns to fill H_2O to bottom of columns.

1730 All 3 columns started @ 0.8 ml/min

5/25/99 @ 0600 Pulled sample from all 3 columns, approx 250 ml each.

6/1/99 ENDCUT on columns. #854 = 7.3 lbs, #856 ≃ 7.6 lbs, #864 ≃ 7.6 lbs.

EFFICIENCY LINE 22-210

SHP01-10-03

SHP 854

DATE/Time	ET (hrs.)	Vol (ml)	Vol. range	Cumm. Vol.	Time (min)	ml/min (Collection rate)	≃ (Pore Vol.)	lab # (Chem)	U mg/L	PH	EC (µS/cm)	ORP	AlK	NO_3 mg/L
5/24/99 @ 730	Start flow													
5/25/99 @ 0600	12.5	259.4	0 – 259.4	259.4	750	0.35	—	—	—	—	—	—	—	—
5/25/99 @ 1800	24	588.4	259.4–847.8	847.8	720	0.82	538	NDZ538	38.62	8.28	+119	1050	52	6.2
5/26/99 @ 0600	36	573.6	847.8–1421.4	1421.4	720	0.80	536	NDZ536	77.91	7.86	+111	4930	52	90.2
5/26/99 @ 1800	48	571.1	1421.4–1992.5	1992.5	720	0.79	539	NDZ539	38.00	8.25	+126	520	56	4.4
5/27/99 @ 0600	60	581.1	1992.5–2573.6	2573.6	720	0.81	[illegible]	NDZ542	35.69	8.32	+115	530	60	4.4
5/27/99 @ 1800	72	571.8	2573.6–3145.4	3145.4	720	0.79	[illegible]	NDZ544	31.18	8.25	+92	480	66	3.5
5/28/99 @ 0600	84	575.4	3145.4–3720.8	3720.8	720	0.80	[illegible]	NDZ546	22.94	8.35	+90	440	56	4.4

Actual ... #7 (SJM) ?

Suspect columns reversed (SJM)

6/25/99
Pore Volume Estimate (SJM)

Assuming 0.8 ml/min, first sample had 259 mL in 750 min

$\frac{259}{0.8} = 324$ min 750 − 324 = 426 min. So it took 426 min to fill the column

$426 \times 0.8 \frac{mL}{min} = 341$ mL

AMPAD EFFICIENCY LINE 22-210

SHP 856

SHP01-10-04

Date / Time	ET (hrs)	Vol (ml)	Vol. range	Cumm. Vol.	Time (min)	Collection Rate (ml/min)	Por. Vol. ≈	chem. lab. #	U µg/L	pH	EC (µS/cm)	ORP	Alk	Nb mg/L
5/24/99 @ 1730	Start	Flow												
5/25/99 @ 0600	12.5	319.6	0-319.6	319.6	750	0.43		NDES46	20.16	—	—	—	—	—
5/25/99 @ 1800	24	588.4	319.6-908.0	908.0	720	0.82	541	NDES41	31.99 32.0	8.15	+83	620	45	3.1
5/26/99 @ 0600	36	575.8	908.0-1483.8	1483.8	720	0.80	545	NDES45	14.60 20.16	7.82	+93	1210	46	0.9
5/26/99 @ 1800	48	576	1483.8-2059.8	2059.8	720	0.80	543	NDES43	15.12 15.1	8.19	+100	500	68	4.0
5/27/99 @ 0600	60	579.3	2059.8-2639.1	2639.1	720	0.80	542	NDES42	13.00 14.6	8.19	+103	530	51	0.9
5/27/99 @ 1800	72	573	2639.1-3212.1	3212.1	720	0.80	544	NDES44	12.00 13	8.20	+90	450	78	3.0
5/28/99 @ 0600	84	578.7	3212.1-3790.8	3790.8	720	0.80	540	NDES40	12.0	8.19	+89	420	64	3.1

OK

Por Vol estimate (STM)
319.6 ÷ 0.8 = 400 min   750 - 400 = 350 min
350 min × 0.8 mL/min = 280 mL

AMPAD EFFICIENCY LINE® 22-210

SHP 864

SHP01-10-05

Collection Rate Pore Vol. Chem. U ($\mu S/cm$) NO_3

Date / Time	1 ET(hrs)	2 Vol(ml)	3 Vol Range	4 Cum Vol.	5 Time(min)	6 ml/min	7	8 Lab #	9 µg/L	10 PH	11 EC	12 ORP	Alk	mg/L
5/24/99 @ 1730	~~12.5~~	~~START FLOW~~ →												
5/25/99 @ 0600	12.5	318.2	0-318.2	318.2	750	0.42	—	—	—	—	—	—	—	—
5/25/99 @ 1800	24	571.4	318.2-889.6	889.6	720	0.79		NDE546	24.65	8.34	1188	590	61	1.8
5/26/99 @ 0600	36	551.7	889.6-1441.3	1441.3	720	0.77		NDE548	43.14	8.02	1190	1030	67	0.9
5/26/99 @ 1800	48	555.2	1441.3-1996.5	1996.5	720	0.77		NDE549	39.51	8.24	1107	460	64	4.0
5/27/99 @ 0600	60	555.8	1996.5-2552.3	2552.3	720	0.77		NDE550	26.35	8.22	1104	510	60	1.3
5/27/99 @ 1800	72	552.9	2552.3-3105.2	3105.2	720	0.77		NDE626	20.55	8.23	1189	440	59	3.5
5/28/99 @ 0600	84	555.1	3105.2-3660.3	3660.3	720	0.77		NDE547	25.21	8.03	1193	420	61	4.0

Pore Volume Estimate (SJM)

318 ÷ .8 = 398 min   750 - 398 = 352 min

352 min × $\frac{0.8\ ml}{min}$ = 282 mL

AMPAD EFFICIENCY LINE™ 22-210

SHP 850

SHP01-10-06

Date / Time	ET (hrs)	Vol (ml)	Vol Range	Cum. Vol.	Collection Rate: Time (min)	Collection Rate: ml/min	Por Vol	Chem. ID #	U µg/L	pH	EC (µS/cm)	ORP	Alk	NO3
6/3/99 @ 1515	First flow pulled 0600	Started Flow	0-382.3		885	0.93	→							
6/4/99 @ 1800	12	382.3	382.3-945.2	945.2	720	.78		NDE 651	22.45	7.94	+135	550	119	0
6/5/99 @ 0600	24	562.9	945.2-1513.3	1513.3	720	.79		NDE 652	9.86	7.37	+110	400	75	0
6/5/99 @ 1800	36	568.1	1513.3-2112.2	2112.2	720	.83		NDE 653	9.34	7.85	+103	380	64	3.1
6/6/99 @ 0600	48	598.9	2112.2-2677.3	2677.3	720	.78		NDE 654	11.00	7.98	+098	370	71	3.5
6/6/99 @ 1800	60	565.1	2677.3-3251.4	3251.4	720	.80		NDE 655	5.71	8.09	+100	370	60	3.1
6/7/99 @ 0600	72	574.1	3251.4-3794.7	3794.7	720	.75		NDE 656	7.23	8.10	+100	370	67	3.5
6/7/99 @ 1800	84	543.3	3794.7-4363	4363	720	.80		NDE 657	8.70	8.10	+97	370	80	4.0
		568.3												

Column started 6/3/99 @ 1515

Column wt. Gross = 3083.2 g

Soil wt. dry = 1477.5 g

End wt. Gross = 7.5 lbs.

Pore Volume Estimate (SJM)

6/3/99 1515 to 6/4/99 0600 = 885 min

$382 \text{ mL} \cdot \frac{\text{min}}{0.8 \text{ mL}} = 478 \text{ min}$

885 − 478 = 407 min

$407 \times 0.8 \frac{\text{mL}}{\text{min}}$ = 326 mL

EFFICIENCY LINE® 22-210

SHP 851

SHP01-10-07

								Pore Vol. Chem.			(µS/cm)		mg/L	
Date/Time	Eff (hrs)	Vol (mL)	Vol Range	Cum. Vol.	Time (min)	mL/min	T=	Lab #	µg/L	pH	EC	ORP	Alk	NO_3
6/3/99 @1515	Pulled @ 0600 Started	Flow		~~378~~	~~885~~	→								
6/4/99 @ 1800	12	538	378 – 916	916	720	.75		NDE 658	2.89	8.08	100	460	57	2.6
6/5/99 @ 0600	24	554.6	916 – 1470.6	1470.6	720	.77		NDE 659	3.60	8.05	100	390	68	3.1
6/5/99 @ 1800	36	586.1	1470.6 – 2056.7	2056.7	720	.81		NDE 660	3.61	7.97	107	370	68	4.0
6/6/99 @ 0600	48	544	2056.7 – 2600.7	2600.7	720	.76		NDE 661	3.40	8.02	100	360	84	3.5
6/6/99 @ 1800	60	553.1	2600.7 – 3153.8	3153.8	720	.77		NDE 662	3.06	7.96	102	380	60	6.2
6/7/99 @ 0600	72	526.3	3153.8 – 3680.1	3680.1	720	.73		NDE 663	2.78	8.01	99	360	69	4.4
6/7/99 @ 1800	84	545.8	3680.1 – 4225.9	4225.9	720	.76		NDE 664	2.52	8.02	99	370	68	4.0

Column started 6/3/99 @1515

Column wt. Gross = 3152.8 g

Soil wt dry = 1550.6 g

End wt. Gross = 7.6 lbs.

Pore Volume Estimate (5 cm)

$378\ mL \times \frac{min}{0.8\ mL} = 473\ min$ $\quad 885 - 473 = 412\ min$

$412\ min \times 0.8\ \frac{mL}{min} = 330\ mL$

AMPAD EFFICIENCY LINE • 22-210

SHP 852

SHP01-10-08

					Collection Rate		Pore Vol.	Chem	U		(µS/cm)		mg/L	
Date / Time	Et (hrs)	Vol (ml)	Vol. Range	Cumm. Vol	Time (min)	ml/min	=	lab #	mg/L	pH	EC	ORP	Alk	NO3
6/3/99 @ 1515	Start Flow			407.3	885	→						→		
6/4/99 @ 1800	12	565.6	407.3 – 972.9	972.9	720	.79		NDE 665	4.93	8.25	+92	460	97	0
6/5/99 @ 0600	24	586.1	972.9 – 1559.0	1559	720	.81		NDE 666	3.09	8.11	+94	390	68	1.8
6/5/99 @ 1800	36	607.4	1559 – 2166.4	2166.4	720	.84		NDE 667	3.16	8.07	+98	370	72	4.4
6/6/99 @ 0600	48	378.2	2166.4 – 2544.6	2544.6	720	.53		NDE 668	2.76	8.15	+95	360	63	2.6
6/6/99 @ 1800	60	583.8	2544.6 – 3128.4	3128.4	720	.81		NDE 669	2.68	8.18	+97	360	64	3.5
6/7/99 @ 0600	72	551.1	3128.4 – 3679.5	3679.5	720	.77		NDE 670	2.49	8.20	+99	360	60	3.5
6/7/99 @ 1800	84	578.3	3679.5 – 4257.8	4257.8	720	.80		NDE 671	2.32	8.16	100	370	61	4.4

Column started 6/3/99 @ 1515

Column wt. Gross 3143.5 g

Soil wt dry = 1559 g

End wt gross = 7.5 lbs

Pore Volume Estimate (SVM)

$407 \text{ mL} \times \frac{\text{min}}{0.8 \text{ mL}} = 509 \text{ min}$ $\quad 885 - 509 = 376 \text{ min}$

$376 \text{ min} \times \frac{0.8 \text{ mL}}{\text{min}} = 301 \text{ mL}$ (circled)

Appendix C

Raw Data

This page intentionally blank

[redacted]

Column 850, soil wgt = 1477.5 g																			
PV = 326 ml, Flow Rate = 0.8 ml/min																			
Background																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
382.3	1.17	0.59																	
945.2	2.90	2.04	7.94	550	119	135	1.6	1	2090	12.6	103000	25	5	11.1	138000	177	32.3	22.45	
1513.3	4.64	3.77	7.37	400	75	110	1	1	2260	55	65600	20.5	3.7	10.5	103000	210	15.3	9.86	
2112.2	6.48	5.56	7.85	380	64	103	1	1	4460	35	39600	9.2	2.8	5.5	103000	418	14.4	9.34	3100
2677.3	8.21	7.35	7.98	370	71	98	1	1	5580	71.8	26300	51.9	2.5	3.8	99200	525	15	11	3500
3251.4	9.97	9.09	8.09	370	60	100	1	1	5670	59.3	21500	29.4	2.5	3.4	99400	452	13.6	5.71	3100
3794.7	11.64	10.81	8.10	370	67	100	1	1	5770	74.3	25200	31.7	2.2	3.3	98900	534	12.5	7.23	3500
4363	13.38	12.51	8.1	370	60	97	1	1	5790	69	25300	31.7	2.1	3	100000	549	12.1	8.7	4000

Column 851, soil wgt = 1550.6 g																			
PV = 330 ml, Flow Rate = 0.8 ml/min																			
Background																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
378	1.15																		
916	2.78	1.96	8.08	460	87	100	1	1	2260	20.4	78100	11.5	3.3	8.2	112000	189	4.9	2.89	2600
1470.6	4.46	3.62	8.05	390	68	100	1	1	3780	62.3	45800	11.5	2.4	5.8	103000	331	3	3.6	3100
2056.7	6.23	5.34	7.97	370	68	107	1	1	5400	69	28600	11.5	1.5	3.8	103000	481	3.1	3.61	4000
2600.7	7.88	7.06	8.02	360	84	100	1	1	5500	58.4	25900	9.2	1.4	3.3	99300	486	2.8	3.4	3500
3153.8	9.56	8.72	7.96	380	60	102	1	1	5460	61.4	25700	81	1.3	2.9	99100	489	2.7	3.06	6200
3680.1	11.15	10.35	8.01	360	69	99	1	1	5440	49.9	25400	85.5	1.5	2.8	98400	487	2.5	2.78	4400
4225.9	12.81	11.98	8.02	370	68	99	1	1	5650	10.6	25600	11.5	1.3	2.4	99600	503	2.4	2.52	4000

Column 852, soil wgt = 1559 g																			
PV = 301 ml, Flow Rate = 0.8 ml/min																			
Background																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
407.3	1.35																		
972.4	3.23	2.29	8.25	460	97	92	1	1	1560	12.4	85000	25	2.5	7.4	111000	136	5.6	4.93	
1559	5.18	4.20	8.11	390	68	94	1	1	3410	39.6	48200	7	1.8	4.3	104000	325	3.5	3.09	1800
2166.4	7.20	6.19	8.07	370	72	98	1	1	5160	54.4	27900	18.2	1.4	2.3	102000	506	3.6	3.16	4400
2544.6	8.45	7.83	8.15	360	63	95	1	1	5360	61.2	26000	9.2	1.4	2	102000	501	3.2	2.76	2600
3128.4	10.39	9.42	8.18	360	64	97	1	1	5320	64.3	25800	11.5	1.3	1.8	204000	494	3	2.68	3500
3679.5	12.22	11.31	8.20	360	60	99	1	1	5410	57.5	25600	7	1.6	1.8	100000	491	2.9	2.49	3500
4257.8	14.15	13.18	8.16	370	61	100	1	1	5580	42.9	25500	7	2.2	1.6	101000	508	2.7	2.32	4400

Column 854@11-13, sieved < 3 mesh, soil wgt = 1511.4 g																			
PV = 341 ml, Flow Rate = 0.8 ml/min																			
Contaminated Floodplain																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
259.4	0.76																		
847.8	2.49	1.62	8.28	1050	52	119	2.6	1	265000	552	516000	1970	1.7	2	3200000	2220	72.9	38.6	6200
1421.4	4.17	3.33	7.86	4930	52	111	2	1	46200	111	54900	753	1.7	2	467000	830	49.4	77.9	90200
1992.5	5.84	5.01	8.25	520	56	126	3.9	1	26400	62.5	34400	597	1.6	2	252000	576	41.5	38	4400
2573.6	7.55	6.70	8.32	530	60	115	2	1	20300	48.2	29400	512	2.3	2	244000	469	36.4	35.7	4400
3145.4	9.22	8.39	8.25	480	66	92	2	1	17800	42.4	28300	342	1.6	2	156000	424	34.3	31.2	3500
3720.8	10.91	10.07	8.35	440	56	90	2	1	16100	38.6	27300	287	1.5	2	137000	387	31.7	22.9	4400
Column 856@14 + 856@9 combined, sieved < 3 mesh, soil wgt = 1630.5 g																			
PV = 280 ml, Flow Rate = 0.8 ml/min																			
Contaminated Floodplain																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
319.6	1.14																		
908	3.24	2.19	8.15	620	45	83	5.7	1	34900	13.5	91200	15.3	2.1	2	576000	1300	33.3	20.2	3100
1483.8	5.30	4.27	7.82	1210	46	93	7.8	1	16300	5.2	41300	11.7	1.8	2	244000	734	20.7	32	900
2059.8	7.36	6.33	8.19	500	68	100	7.7	1	13400	4.5	33600	8.1	1.8	2	193000	643	16.9	14.6	4000
2639.1	9.43	8.39	8.19	530	51	103	6.1	1	11800	4.4	29600	8.1	1.6	2	161000	581	15.7	15.1	900
3212.1	11.47	10.45	8.20	450	78	90	8.3	1	11000	2.7	28300	9.9	1.4	2	146000	551	13.6	13	3000
3790.8	13.54	12.51	8.19	420	64	89	3.9	1	10300	3.7	26800	13.5	1.4	2	129000	505	12.8	12	3100
Column 864@5-7, 864@10, and 864@14.5-15 combined, sieved < 3 mesh, soil wgt = 1642.6 g																			
PV = 282 ml, Flow Rate = 0.8 ml/min																			
Contaminated Floodplain																			
Cum.	Pore	Pore	pH	EC	ALK	ORP	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ACL	ESL	ESL
Vol	Vols	Vols			CaCO3		As	Cd	Mg	Mn	Na	NH4	Sb	Se	SO4	Sr	U	U	NO3
mL		Mid pt		uS/cm	mg/l	mv	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
318.2	1.13																		
889.6	3.15	2.14	8.34	590	61	88	7.8	1	37200	9.5	64400	9.9	1.8	2	485000	1000	41.4	24.7	1800
1441.3	5.11	4.13	8.02	1030	67	90	7.7	1	20100	5.6	31600	9.9	1.7	2	223000	620	28.4	43.1	900
1996.5	7.08	6.10	8.24	460	64	107	7.9	1	16100	4.2	27900	8.1	1.8	2	174000	529	25	39.5	4000
2552.3	9.05	8.07	8.22	510	60	104	7.3	1	14200	3.7	26100	9.9	1.5	2	147000	476	22.8	26.4	1300
3105.2	11.01	10.03	8.23	440	59	89	7.8	1	13400	3	25900	8.1	1.6	2	135000	456	21.1	20.6	3500
3660.3	12.98	12.00	8.03	420	61	93	7.9	1	12300	3.1	24900	11.7	1.8	2	123000	421	18.6	25.2	4000

Appendix D

Lithologic Logs

This page intentionally blank

MONITORING WELL COMPLETION LOG SHP01-0850

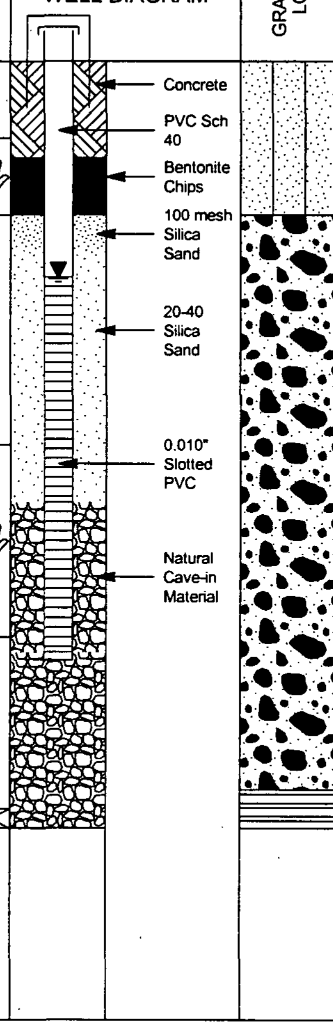
PROJECT UMTRA GROUND WATER	**NORTH COORD. (FT)** 2098486.21	**DATE DRILLED** 10/23/98	
LOCATION SHIPROCK, NM	**EAST COORD. (FT)** 256685.04	**SURFACE ELEV. (FT NGVD)** 4904.99	
SITE SHIPROCK	**HOLE DEPTH (FT)** 20.00	**TOP OF CASING (FT)** 4907.51	
WELL NUMBER 0850	**WELL DEPTH (FT)** 15.60	**MEAS. PT. ELEV. (FT)** 4907.51	
		SLOT SIZE (IN) 0.010	
		BIT SIZE(S) (IN) 8.0	

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.52	to	5.6
WELL SCREEN:	2 in. Machine Slotted PVC	5.6	to	15.4
SUMP/END CAP:	2 in. PVC Sch 40	15.4	to	15.6
SURFACE SEAL:	Concrete	-0.5	to	2.5
GROUT:				
SEAL:	Bentonite Chips	2.5	to	4.0
UPPER PACK:	100 mesh Silica Sand	4.0	to	5.0
LOWER PACK:	20-40 Silica Sand	5.0	to	11.5

DRILLING METHOD HOLLOW STEM AUGER
SAMPLING METHOD GRAB, SPLIT SPOON
DATE DEVELOPED 10/23/98
WATER LEVEL (FT BTOC) 8.17 on 11/20/98
LOGGED BY M. Kautsky
REMARKS Natural formation cave-in material from 11.5 ft. to 20 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT
			2-4 ft.	
5	4900			
10	4895		10-15 ft.	
15	4890			
20	4885		19.5-20 ft.	

WELL DIAGRAM / GRAPHIC LOG



LITHOLOGIC DESCRIPTION

0-4 ft. SILTY SAND (SM), grayish brown (10YR 5/2), loose, moist.

4-19 ft. SANDY GRAVEL (GW), saturated at 7 ft.

19.0-20.0 ft. MANCOS SHALE, gray (2.5Y N5/1) slightly weathered, hard.

Total Depth 20.0 ft.

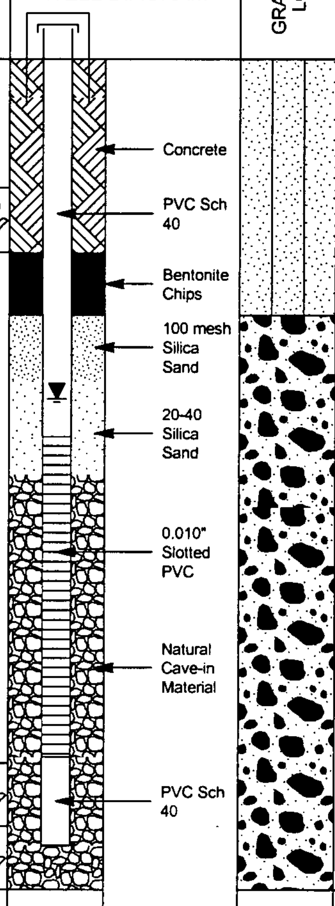
MONITORING WELL COMPLETION LOG SHP01-0851

PROJECT	UMTRA GROUND WATER	**NORTH COORD. (FT)**	2098473.35	**DATE DRILLED**	10/21/98 to 10/22/98
LOCATION	SHIPROCK, NM	**EAST COORD. (FT)**	256679.18	**SURFACE ELEV. (FT NGVD)**	4904.63
SITE	SHIPROCK	**HOLE DEPTH (FT)**	13.00	**TOP OF CASING (FT)**	4906.45
WELL NUMBER	0851	**WELL DEPTH (FT)**	12.30	**MEAS. PT. ELEV. (FT)**	4906.45
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	8.0

	WELL INSTALLATION	**INTERVAL (FT)**		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-1.82	to	6.0
WELL SCREEN:	2 in. Machine Slotted PVC	6.0	to	11.0
SUMP/END CAP:	2 in. PVC Sch 40	11.0	to	12.3
SURFACE SEAL:	Concrete	-0.5	to	3.0
GROUT:				
SEAL:	Bentonite Chips	3.0	to	4.0
UPPER PACK:	100 mesh Silica Sand	4.0	to	5.0
LOWER PACK:	20-40 Silica Sand	5.0	to	6.5

DRILLING METHOD HOLLOW STEM AUGER
SAMPLING METHOD GRAB
DATE DEVELOPED 10/23/98
WATER LEVEL (FT BTOC) 7.13 on 11/20/98
LOGGED BY C. Goodknight
REMARKS Natural formation cave-in material from 6.5 to 13 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
			2-3 ft.				0-4 ft. SILTY SAND (SM), yellowish brown (10YR5/4), fine to medium grained with less than 5% pebbles up to 1 inch in diameter, some silt-sized material, no plasticity, damp.
5	4900						4-13 ft. SANDY GRAVEL (GW), grayish brown (10YR 5/2), 50% pebbles and cobbles, 50% medium to coarse grained sand and some silt, saturated at 7 to 8 ft. Below 7 ft., less pebbles and cobbles, 30%.
10	4895		11-12 ft.				
			12-13 ft.				
	4890						Total Depth 13.0 ft



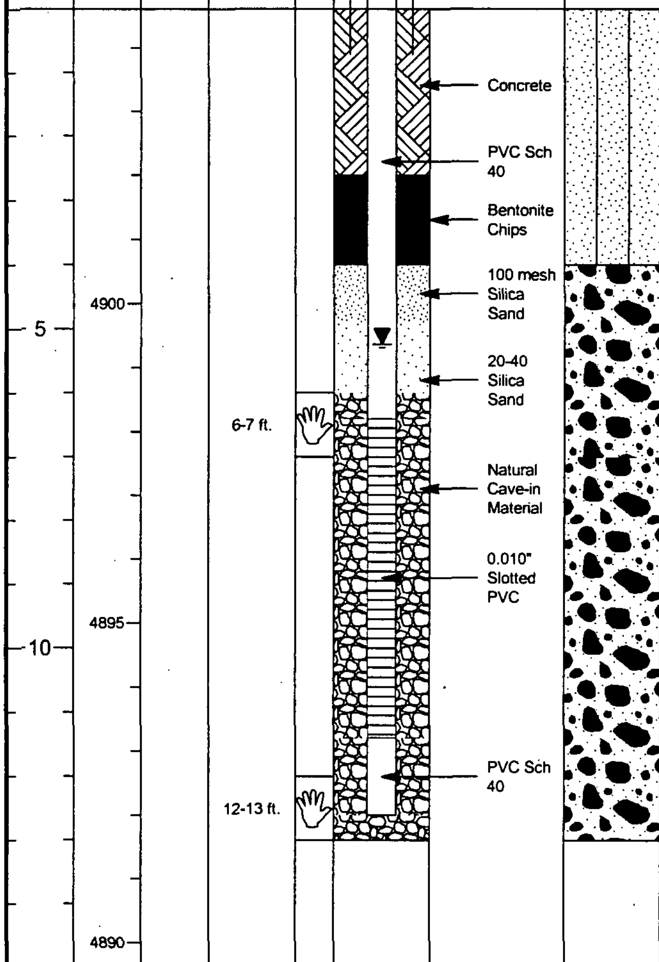
MONITORING WELL COMPLETION LOG SHP01-0852

PROJECT	UMTRA GROUND WATER	**NORTH COORD. (FT)**	2098472.49	**DATE DRILLED**	10/22/98
LOCATION	SHIPROCK, NM	**EAST COORD. (FT)**	256707.25	**SURFACE ELEV. (FT NGVD)**	4904.61
SITE	SHIPROCK	**HOLE DEPTH (FT)**	13.00	**TOP OF CASING (FT)**	4907.37
WELL NUMBER	0852	**WELL DEPTH (FT)**	12.60	**MEAS. PT. ELEV. (FT)**	4907.37
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	8.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.76	to	6.4
WELL SCREEN:	2 in. Machine Slotted PVC	6.4	to	11.4
SUMP/END CAP:	2 in. PVC Sch 40	11.4	to	12.6
SURFACE SEAL:	Concrete	-0.5	to	2.6
GROUT:				
SEAL:	Bentonite Chips	2.6	to	4.0
UPPER PACK:	100 mesh Silica Sand	4.0	to	4.9
LOWER PACK:	20-40 Silica Sand	4.9	to	6.0

DRILLING METHOD HOLLOW STEM AUGER
SAMPLING METHOD GRAB
DATE DEVELOPED 10/23/98
WATER LEVEL (FT BTOC) 8.0 on 11/20/98
LOGGED BY C. Goodknight
REMARKS Natural formation cave-in material from 6 ft. to 13 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION



0-4 ft. SILTY SAND (SM), yellowish brown (10YR5/4), fine to medium grained with less than 5% pebbles up to 1 inch in diameter, some silt-sized material, no plasticity, damp.

4-7 ft. SANDY GRAVEL (GW), grayish brown (10YR 5/2), 50% pebbles and cobbles, 50% medium to coarse grained sand and some silt, saturated at 7 to 8 ft. Below 7 ft., less pebbles and cobbles, 30%.

Total Depth 13.0 ft.

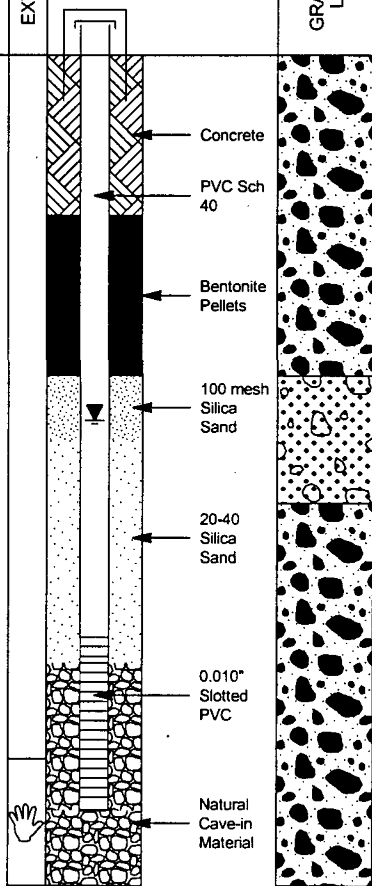
MONITORING WELL COMPLETION LOG SHP01-0854

PROJECT UMTRA GROUND WATER	**NORTH COORD. (FT)** 2103848.58	**DATE DRILLED** 10/25/98	
LOCATION SHIPROCK, NM	**EAST COORD. (FT)** 250820.77	**SURFACE ELEV. (FT NGVD)** 4888.35	
SITE SHIPROCK	**HOLE DEPTH (FT)** 13.00	**TOP OF CASING (FT)** 4890.75	
WELL NUMBER 0854	**WELL DEPTH (FT)** 11.80	**MEAS. PT. ELEV. (FT)** 4890.75	
		SLOT SIZE (IN) 0.010	
		BIT SIZE(S) (IN) 8.0	

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.4	to	9.1
WELL SCREEN:	2 in. Machine Slotted PVC	9.1	to	11.6
SUMP/END CAP:	2 in. PVC Sch 40	11.6	to	11.8
SURFACE SEAL:	Concrete	-0.5	to	2.5
GROUT:				
SEAL:	Bentonite Pellets	2.5	to	5.0
UPPER PACK:	100 mesh Silica Sand	5.0	to	6.0
LOWER PACK:	20-40 Silica Sand	6.0	to	9.5

DRILLING METHOD HOLLOW STEM AUGER
SAMPLING METHOD GRAB
DATE DEVELOPED 10/26/98
WATER LEVEL (FT BTOC) 8.11 on 10/27/98
LOGGED BY M. Kautsky, L. Spencer
REMARKS Natural formation cave-in material from 9.5 ft. to 13 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5 ft. SANDY GRAVEL(GW), dark yellowish brown (10YR 4/4), loose and moist.
	4885						
5							5-7 ft. GRAVELLY SAND (SW), dark yellowish brown (10YR 4/4), loose.
							7-13 ft. SANDY GRAVEL (GW), loose.
	4880						
10							
			11-13 ft.				
	4875						Total Depth 13.0 ft.



mactec-ers U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

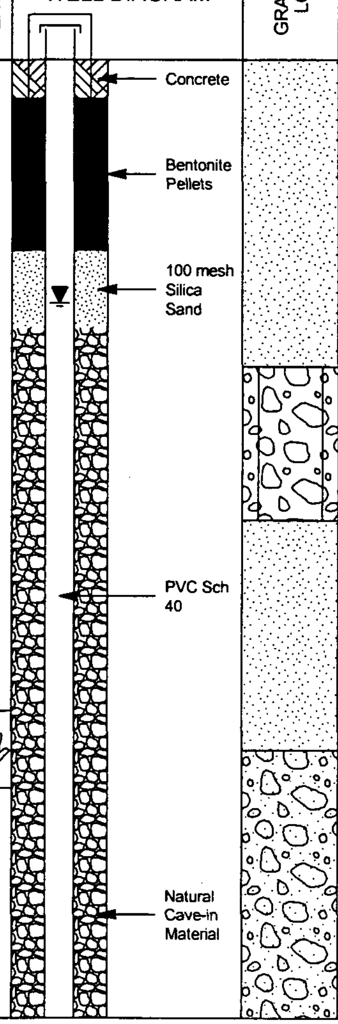
MONITORING WELL COMPLETION LOG SHP01-0856

PROJECT	UMTRA GROUND WATER	**NORTH COORD. (FT)**	2104395.65	**DATE DRILLED**	10/12/98
LOCATION	SHIPROCK, NM	**EAST COORD. (FT)**	249110.63	**SURFACE ELEV. (FT NGVD)**	4884.83
SITE	SHIPROCK	**HOLE DEPTH (FT)**	24.50	**TOP OF CASING (FT)**	4887.57
WELL NUMBER	0856	**WELL DEPTH (FT)**	24.10	**MEAS. PT. ELEV. (FT)**	4887.57
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	8.0

	WELL INSTALLATION	**INTERVAL (FT)**		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.74	to	18.8
WELL SCREEN:	2 in. Machine Slotted PVC	18.8	to	23.8
SUMP/END CAP:	2 in. PVC Sch 40	23.8	to	24.1
SURFACE SEAL:	Concrete	-0.5	to	0.5
GROUT:				
SEAL:	Bentonite Pellets	0.5	to	2.5
UPPER PACK:	100 mesh Silica Sand	2.5	to	3.5
LOWER PACK:	Natural Formation Cave-in	3.5	to	24.5

DRILLING METHOD HOLLOW STEM AUGER
SAMPLING METHOD GRAB, SPLIT SPOON
DATE DEVELOPED 10/26/98
WATER LEVEL (FT BTOC) 5.92 on 10/27/98
LOGGED BY C. Goodknight
REMARKS Natural formation cave-in material from 3.5 ft. to 24.5 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-4 ft. SAND (SP), brown (10YR 5/3), 92% very fine to fine grained, rounded to subrounded, quartzose, 5% silt, 3% pebbles, poorly graded, slight plasticity, slightly moist.
5	4880						4.0-6.0 ft. SILTY GRAVEL (GM), brown (10YR 4/3), 50% gravel up to boulder size (1 ft. diameter), 30% medium to coarse grained, subrounded quartzose sand, 20% silt with trace of clay, no plasticity, moist.
							6.0-9.0 ft. SAND (SP)
			9 ft.				9.0-23.0 ft. SANDY GRAVEL (GP), dark grayish brown (10YR 4/2), moist.
10	4875						

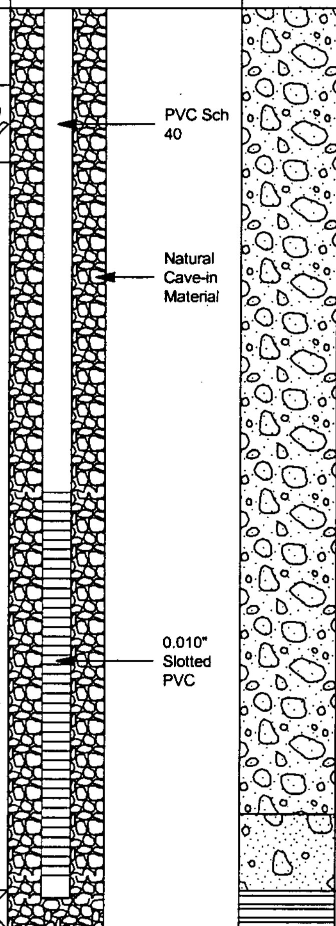


MONITORING WELL COMPLETION LOG SHP01-0856

PROJECT UMTRA GROUND WATER **WELL NUMBER** 0856
SITE SHIPROCK **DATES DRILLED** 10/12/98

Continued from Previous Page

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
			14 ft.				
15	4870						
20	4865						
							23.0-24.0 ft. SAND (SP), dark grayish brown (10YR 4/2), 80% medium to coarse grained, 20% gravel up to cobble size.
			24.0-24.5 ft.				24.0-24.5 ft. MANCOS SHALE, dark gray, weathered, fissile.
25	4860						Total Depth 24.5 ft.



BOREHOLE LOG SHP01-0864

PROJECT UMTRA GROUND WATER	**SURFACE ELEV. (FT NGVD)** 4885.85
LOCATION SHIPROCK, NM	**BIT SIZE(S) (IN)** 8.0
SITE SHIPROCK	**DRILLING METHOD** HOLLOW STEM AUGER
WELL NUMBER 0864	**SAMPLING METHOD** GRAB, SPLIT SPOON
NORTH COORD. (FT) 2104405.37	**WATER LEVEL (FT BGS)** 5.0 on 11/18/98
EAST COORD. (FT) 249891.07	**LOGGED BY** L. Spencer
HOLE DEPTH (FT) 15.30	**REMARKS** Natural formation cave-in material from 0 ft. to 15.3 ft.
DATE DRILLED 11/18/98	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
0	4885					0-7.0 ft. SILTY SAND (SM), yellowish brown (10YR 5/4), 70% fine to medium grained subrounded to subangular sand, 30% silt, poorly graded, no plasticity, saturated below 5 ft.
5	4880	2 2 2 3	5-7 ft.			
7						7.0-15.0 ft. SANDY GRAVEL (GP), brown (10YR 5/3), 60% subrounded gravel up to boulder size, 30% fine to coarse grained subrounded to subangular sand, 5% clay, well graded, slight plasticity, saturated.
10	4875	50	10-10.16 ft.			
14.5			14.5-15.0 ft.			
15	4870	75	15.0-15.3 ft.			
15.3						Total Depth of boring 15.3 ft.
20	4865					

This page intentionally blank

Appendix E

Synthetic Fluid Recipe

This page intentionally blank

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	SPF546 (San Juan River Water)																			
2		mL per																		
3		L of	Na	K	Ca	Mg	NH4	SO4	Cl	NO3	C	As	Cd	Mo	Pb	226Ra	Se	U	V	N3
4		Soln	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	mg/L	mg/L	mg/L	mg/L
5	Liquid Components																			
6	V2O5, V=998mg/L, 2%HNO3	0.00								0.00									0.00	
7	V2O5, V=1000mg/L, 5%HNO3	0.00								0.00									0.00	
8	V2O5, V=1000mg/L, 1.4%HNO3	0.00								0.00									0.00	
9	V2O5, V=1000mg/L, 2%HNO3	0.00								0.00									0.00	
10	Na2MoO4.2H2O, Mo=925mg/L	0.00	0.00											0.00						
11	Na2MoO4.2H2O, Mo=1000 mg/L,	0.00	0.00											0.00						
12	(NH4)2MoO4, 1006 mg/L Mo	0.00					0.00							0.00						
13	U3O8, U=10000mg/L, 3.5%HNO3	0.00								0.00								0.00		
14	U3O8, U=10000mg/L, 5.2%HNO3	0.00								0.00								0.00		
15	U Std, U=1000mg/L, 2% HNO3	0.00								0.00								0.00		
16	Ra Std, Ra=68.7pCi/mL, 2% HNO3	0.00								0.00						0.00				
17	As Std, As=999mg/L, 5%HNO3	0.00								0.00		0.00								
18	As Std, As=1000mg/L, 1.4%HNO3	0.00								0.00		0.00								
19	Se =999 mg/L 5% HNO3	0.00								0.00							0.00			
20	Cd Std = 1000mg/L, ~2% HNO3	0.00								0.00			0.00							
21																				
22	100g/L K2CO3	0.04.		2.26							0.35									
23	50g/L NaHCO3	2.20	30.12								15.71									
24	100g/L Na2SO4.10H2O	0.00	0.00					0.00												
25	100g/L Na2SO4.(0.89 H2O)	0.00	0.00					0.00												
26	500g/L (NH4)2SO4	0.00					0.00	0.00												
27	1.5g/L CaSO4.2H2O	145.00			50.66			121.34												
28	200g/L MgSO4.7H2O	0.00				0.00		0.00												
29	100g/L K2SO4	0.00		0.00				0.00												
30	conc H2SO4(36N)	0.00						0.00												
31	927.2 g/L CaCl2.2H2O	0.00			0.00				0.00											
32	92.72 g/L CaCl2.2H2O	0.00			0.00				0.00											
33	300g/L NaCl	0.00	0.00						0.00											
34	100g/L MgCl2.6H2O	0.25				2.99			8.73											
35	100g/L NH4Cl	0.00					0.00		0.00											
36	100g/L NaNO3	0.00	0.00							0.00										
37	2% HNO3	0.00								0.00										
38	mL 1N NaOH needed to neutralize	0.00	0.00																	
39	66.67 g/L NaN3	0.00	0.00																	0
40																				
41																				
42																				
43	Totals (mg/L)	147.49	30.12	2.26	50.66	2.99	0.00	121.34	8.73	0.00	18.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	ACTUAL (mg/L)		28.80	2.07	50.60	9.98	?	121.00	9.94	?	27.00	?	?	?	?	?	?	?	?	?
45	Totals (mol/L)		1.31E-03	5.79E-05	1.26E-03	1.23E-04	0.00E+00	1.26E-03	2.46E-04	0.00E+00	1.34E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46																				
47	ACTUAL pH	~8																		
48	Measured pH(no acid or base)	?																		
49	Measured pH (________ added)																			
50	ACTUAL Alk (mg/L CaCO3)	114.00																		
51	Measure Alk (no acid or base)	?																		
52	Measure Alk (________ added)																			
53	EQ Acid per Liter	0																		
54																				
55																				

This page intentionally blank