GJO-MOA 19.1.2

Determination of Subpile Soil Concentrations

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MOAB PROJECT

U.S. Department of Energy Grand Junction Office

Calculation Cover Sheet

Calc. No. Moab 01-2003-02-05-00 **Discipline:** Hydrogeology **Number of Sheets:** 13

Project:

Moab Ground Water

Site:

Moab, Utah

Feature:

Determination of Subpile Soil Concentrations

Sources of Data:

Chemical analysis results (Requisition #18148)

Sources of Formulae and References:

GJO, 2002a. *Environmental Sciences Laboratory Procedures Manual*, U. S. Department of Energy Grand Junction Office, GJO-210, in revision.

GJO, 2002b. GJO Environmental Procedures Catalog, GJO 6, in revision.

Levinson, A.A., 1980. *Introduction to Exploration Geochemistry*, Applied Publishing Ltd., Wilmette, IL, 924 p.

McLean, J.E. and Bledsoe, B.E., 1992. *Behavior of Metals in Soils*, USEPA Office of Solid Waste and Emergency Response, EPA/540/S-92/018, October.

ORNL, (Oak Ridge National Laboratory), 1998. *Limited Ground Water Investigation of the Atlas Corporation, Moab Mill, Moab Utah,* prepared for the U.S. Fish and Wildlife Service, Salt Lake City, Utah.

Shepherd Miller, Inc. 2001. Site Hydrogeologic and Geochemical Characterization and Alternatives Assessment for the Moab Mill Tailings Site, Moab, Utah, April.

Steffen, Robertson and Kirsten (SRK), 2000. Dewatering Options for Placement of Cover, Moab Tailings Impoundment, June.

US Environmental Protection Agency, 2002. *EPA Region III Risk-Based Concentration Table* Memorandum from Jennifer Hubbard, Toxicologist, located at www.epa.gov/reg3hwmd/risk/index.htm.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** _____

Rev. No.	Revision	Calculation by	Date	Checked by	Date	Approved by	Date
		L Cummins	1-14-03	Kurt Kemp	1-14-03	Tod Hoffman	1/15/03

Problem Statement

As pore fluids drain from mill tailings piles, the fluids move through the soil below the pile ("subpile soil") and interact with the soil. Depending on the characteristics of the soils and the nature of contaminants in the pore fluids, contaminants may become adsorbed onto soils or precipitated from solution or they may move through soils in a nonreactive manner. If contaminants become concentrated in subpile soils, these soils can act as a long-term source of ground water contamination. Even if tailings and soils are removed to meet Uranium Mill Tailings Radiation Control Act (UMTRCA) radiological cleanup standards, residual nonradiological contamination could remain at levels that can affect ground water. To characterize the conditions in the subpile soils and evaluate the potential for these soils to act as long-term sources of ground water contamination, soil samples were collected and tested as described below.

Method of Solution

Subpile soil samples were collected during the summer 2002 field season from 3 borings advanced through the Moab tailings pile and from one background location (pile locations 437, 438, 439; background location 434; Figure 1). Lithologic logs for these borings are provided in Appendix A. Samples were collected from several depth intervals at each location; samples were subjected to a 5 percent acid leach (resulting in a solution pH of <2) according to Grand Junction Office (GJO) Environmental Sciences Laboratory (ESL) procedure CB(BT-1) (GJO 2002a). Decantate samples (i.e., fluids recovered from the subpile soils after the leaching procedure was complete) were submitted to the GJO analytical laboratory (requisition 18148) for analysis of ammonia, arsenic, iron, manganese, molybdenum, selenium, sulfate, uranium, and vanadium. These constituents were selected due to their prevalence in the tailings pore fluids as determined by previous analyses (SRK 2000). Laboratory results at the current study are provided in Table 1.

Analyses for radium-226 were completed on samples from the same boreholes (pile locations 437, 438, and 439 and background location 434) shown on Figure 1. These analyses were performed using the Opposed Crystal System (OCS) according to standard procedure RD-4(T) (GJO 2002b). See the procedure for details, including equations for calculating true concentrations of radium-226. Table 2 presents results of the OCS analysis, sample depths, and soil descriptions. The same samples were analyzed with two different instruments (MCB1 and MCB2) to cross check; analyses were similar for each.

Results of analyses completed as part of the 2002 field investigations were also compared with historical subpile soil data collected by several other organizations, which included Oak Ridge National Laboratory (ORNL); Steffen, Robertson and Kirsten (SRK); and Shepherd Miller, Inc. From these historical studies, a total of 15 analyses were performed on samples from 9 different locations. These results are summarized in Table 3 and sample locations are shown on Figure 1. Also provided for comparison are average concentrations of slime samples and pore fluid samples collected from within the tailings pile; these represent solids and liquids that could have a potential influence on subpile soil concentrations. The slimes were selected to represent tailings solids because these samples tended to have highest contaminant concentrations; comparison of slime and pore fluid analyses with subpile soil analyses may give some indication of how rapidly contaminants attenuate as fluids move vertically through the pile to the subpile below.

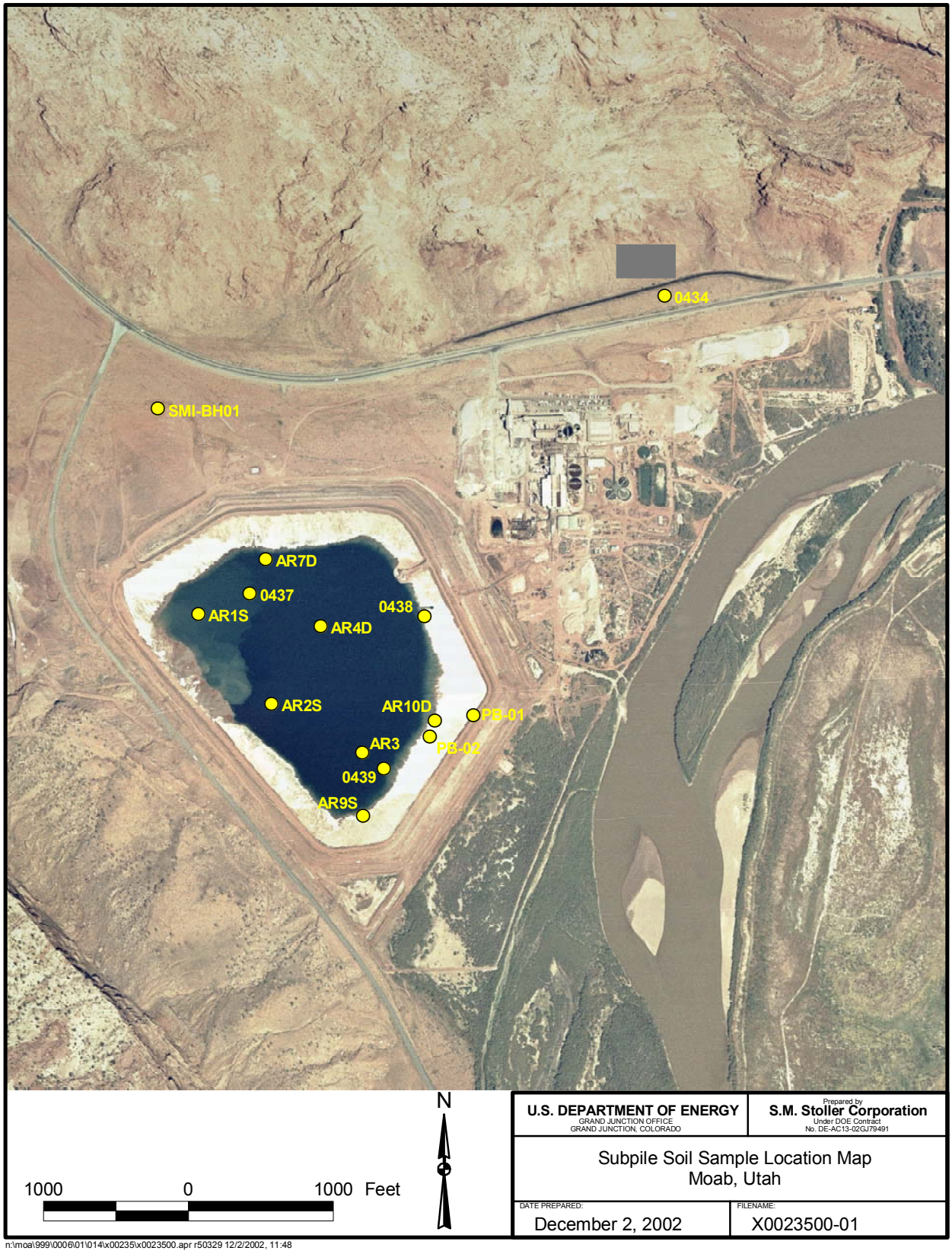


Figure 1. Subpile Soil Sample Location Map
(Photo date is September 3, 1980)

Table 1. Analytical Results for Subpile Soil Decantate[a]

Sample ID[b]	NH_4 (µg/L)	As (µg/L)	Fe (µg/L)	Mn (µg/L)	Mo (µg/L)	Se (µg/L)	SO_4 (µg/L)	U (µg/L)	V (µg/L)	Description
MOA 434-39	34.6	7.1	5,160	2,210	6.6	0.11	2,350	27.2	20.8	Silty sand, red
MOA 434-41	41.5	13.6	16,600	2,820	<3	<0.1	3,100	7.8	37.6	Clayey silt, 5-ft below water
MOA 434-51	17.4	7.2	8,140	1,790	<3	<0.1	770	4.1	32.5	Sand, red, 15 ft below water
MOA 434-57	24.2	8.4	8,680	1,220	<3	<0.1	1,590	4.5	30	Sandy gravel, 21 ft below water
MOA 437-41	2,850	113	48,200	5,380	16.6	1.8	12,600	892	4,330	Tailings, at contact
MOA 437-43	409	19.8	2,650	2,620	8.7	0.56	2,700	69.8	416	Sand/Silt, 2 ft below contact
MOA 437-46	86.2	17.2	1,870	3,560	6.1	0.27	2,560	13.1	267	Sand/Silt, 5 ft below contact
MOA 437-51	31.6	8.1	1,350	2,250	4.6	0.48	1,910	14.6	151	Sand, 10 ft below contact
MOA 437-82	31.3	23	3,230	2,700	8.4	0.15	3,810	18.5	213	Silt, 50 ft below tailings, 6 ft above water
MOA 437-91	34.6	10.7	2,810	3,670	27.7	0.32	10,900	17.3	50.8	3 ft below water
MOA 437-110	28.6	5.5	6,350	1,310	6.8	0.6	5,740	14.1	13.8	Sandy gravel, sample biased with fines, 54 ft below tailings, 12 ft below water
MOA 438-72	5,620	124	16,500	332	464	2.1	1,430,000	971	2,180	Tailings at contact
MOA 438-75	1,290	8.8	4,590	4,740	13.4	0.49	75,900	34	108	Sand, red, 2 ft below tailings
MOA 438-80	628	3.2	987	3,420	5.4	<0.1	4,810	8.3	30.9	Sand, red 7 ft below tailings
MOA 438-90	556	5.6	7,150	4,680	11.6	<0.1	16,800	13.5	39	Sand, red, 12 ft below tailings, 6 ft above water
MOA 438-101	168	4	1,360	3,420	6.3	<0.1	6,210	6.6	13.4	Sand, red, 23 ft below tailings, 5 ft below water
MOA 438-110	124	2.6	5,710	1,170	<3	1.2	5,300	8.1	35.9	Sandy gravel, sample biased with fines, 14 ft below water
MOA 439-82	2,600	83.5	37,500	258	547	1.1	1,510,000	1,910	12,300	Tailings at contact
MOA 439-83	2,910	8.5	23,700	24,400	<3	0.24	82,200	18.2	36.4	Silty sand, 1 ft below contact
MOA 439-87	2,010	9	10,400	14,400	<3	0.32	93,300	23.8	93.3	Silty sand, 5 ft below contact
MOA 439-90	853	3.5	1,370	8,520	<3	0.1	13,100	9	25.4	Sand, 8 ft below contact
MOA 439-95	1,530	8.7	2,970	2,840	<3	<0.1	10,900	8.3	23.7	Sand, 13 ft below contact
MOA 439-100	796	4.4	1,130	2,640	3.5	0.14	11,200	7	21.5	Sand, 18 ft below contact, 2 ft below water
MOA 439-116	106	8.8	8,510	1,080	3.3	0.47	13,500	7.7	23.5	Sand, gy-br, 34 ft below contact, 18 ft below water
MOA 439-121	66.9	4.7	9,750	950	5	0.33	12,200	4.3	21.2	Gravel, sample biased with fines, 39 ft below contact, 23ft below water

[a]Liquid used to leach subpile soils.
[b]Last digits in sample identification indicate depth below ground surface (ft)
Notes:
NH_4 = ammonia; As = arsenic; Fe = iron; Mn = manganese; Se = selenium; U = uranium; V = vanadium; µg/L = micrograms per liter

Table 2. Ra-226 OCS Gamma Spectral Analysis of Solids

Sample Location	Radium-226 Concentration (pCi/g)			Depth (ft/bgs)	Soils Description
	Analysis 1	Analysis 2	Average		
434-39	1.5	0.8	1.2	39-39.25	silty sand, red
434-41	2.4	1.9	2.2	41-41.25	clayey silt
434-51	1.9	0.9	1.4	51-51.25	sand, red
434-57	2.8	2.6	2.7	57-57.25	sandy gravel
437-41	2,094.2	2,295.6	2,194.9	40.75-41	tailings
437-42	3.9	4.0	4.0	42-42.25	sand and silt, red
437-43	11.1	11.3	11.2	43-43.25	sand and silt, red
437-44	130.1	140.8	135.5	44-44.25	sand and silt, red
437-45	17.7	19.5	18.6	45-45.25	sand and silt, red
437-46	4.4	0.5	2.5	46-46.25	sand and silt, red
437-47	1.1	2.6	1.9	47-47.25	sand and silt, red
438-73	1,785.0	1,998.3	1,891.7	72.75-73	tailings
438-74	123.5	145.1	134.3	74-74.25	sand, red
438-75	93.6	91.9	92.8	75-75.25	sand, red
438-76	29.6	32.9	31.3	76-76.25	sand, red
438-78	111.8	124.9	118.4	78-78.25	sand, red
439-82	1,993.9	2,321.0	2,157.5	82-82.25	tailings
439-83	2.7	3.9	3.3	83-83.25	silty sand, red
439-84	3.6	3.9	3.8	84-84.25	silty sand, red
439-87	24.0	23.7	23.9	87-87.25	silty sand, red
439-88	1.7	1.4	1.6	88-88.25	sand, red

pCi/g = picocuries per gram
ft/bgs = feet below ground surface

Assumptions

There are several assumptions made in using the subpile soil data in building the site conceptual model. These are listed below and discussed in the following text.

Samples used for subpile soil testing are representative of the soils located beneath the entire pile.
The constituents selected for analysis are appropriate for the site.
The extraction methods used for preparing subpile soils for analysis produce results that represent the leachable concentration of contaminants in soil.

Though the total number of samples and locations are limited, the spatial distribution of the 12 subpile sampling locations appears to provide a reasonable coverage of the pile footprint. It is unlikely that additional sampling would remove much uncertainty regarding representativeness or that this would likely affect the basic conceptual site model (Assumption 1). As can be seen from an examination of Figure 1 and Table 3, samples were collected over a large area of the pile and from beneath varying thicknesses of the pile. The current study examined samples from a variety of depths beneath the pile. Therefore, existing information should provide a good basis for developing a reasonable conceptual model regarding pile/subpile interactions.

Table 3. Summary of Previous Subpile Soil Analyses and Pore Fluid Samples[a]

Sample ID[b] (includes depth)	Lithology	NH_4 (mg/kg)	As (mg/kg)	Ba (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Se (mg/kg)	SO_4 (mg/kg)	U (mg/kg)	V (mg/kg)
Oak Ridge National Laboratory Subpile Results												
PB-1-94	Alluvium	Nd	3.1	75.8	15.4	Nd	Nd	20.5	0.62	Nd	52.3	1720
PB-1-101	Alluvium	Nd	5.5	187	10.7	Nd	Nd	0.98B	<0.2	Nd	5.4	31.2
PB-2-90	Alluvium	Nd	2.5	92.4	8.6	Nd	Nd	1.3B	0.3B	Nd	3.6	33.2
PB-2-100	Alluvium	Nd	5.5	195	10.3	Nd	Nd	1.3B	0.3B	Nd	8.3	22.3
SRK Subpile Results (partial constituent list)												
AR2-44-45	Clayey gravel	52.1	1.52	104	18.2	5700	241	0.14	0.33	Nd	6.46	11.9
AR3-67-70	Red-brn sand	161	1.57	141	7.74	9500	670	0.43	0.24	Nd	4.21	4.75
AR4-46-47	Red sand w/gravel	2467	15.6	63.7	33.5	9980	205	38.7	0.95	Nd	15.1	708
AR-4-46-50	Red sand w/gravel	Nd	1.81	85.5	8.36	9310	494	1.19	0.52	Nd	4.94	14.4
Shepherd Miller Subpile Results												
AR-10-86-87	Silty sand	133	2.9	Nd	Nd	4,480	1,070	11.5	<0.2	18,810	56.5	1,550
AR4-67-70	Silty sand	608	0.8	Nd	Nd	5,420	272.2	<0.2	<0.2	4,710	2	11.4
AR4-85-90	Silty sand	3.6	4	Nd	Nd	13,900	377	0.3	0.3	1,410	0.9	21.5
AR7—100	Silty sand	1.1	2.8	Nd	Nd	8,880	218	1.6	0.4	1,296	4.6	14.9
AR7-70-75	Silty sand	1.2	1	Nd	Nd	5,940	287	0.4	<0.2	855	4.2	19.3
AR9-85-90	Silty sand	181	1.9	Nd	Nd	8,690	926	1.8	0.6	2,922	1.7	19
AR1-29-30	Gravelly sand	4.7	1.1	Nd	Nd	8,790	541	<0.2	<0.2	1,809	59.4	28.5
Shepherd Miller Background Soil Analyses												
SMI-BH01-11-13.5	Gravelly sand	2.3	0.9	89.8	3.1	4670	301	<0.2	0.4	831	0.6	12.7
SMI-BH01-41-46	Gravelly sand	3.6	0.7	84.1	2.9	4430	303	0.4	0.4	768	0.4	7.8
SRK Average Tailings Slimes Results												
Avg. of 7	Slimes	715	42	816	226	8,892	395	4.45	6.1	Nd	135	953
SRK Average Pore Fluids (mg/L)												
Avg. of 6	Pore fluids	1,817	0.60	0.051	0.808	46	16	5.19	0.21	Nd	22	1.53

[a]Extraction methods not provided for Oak Ridge data; SRK and SMI extraction method is almost complete digestion (EPA 3050); analytical methods EPA 6010B and 6020.
[b]Last digits in sample identification indicate depth (ft) below ground surface.

Notes:
Nd = not determined; B = estimated value; NH_4 = ammonia; As = arsenic; Ba = barium; Cu = copper; Fe = iron; Mn = manganese; Mo = molybdenum; Se = selenium; SO_4 = sulfate; U = uranium; V = vanadium; mg/L = milligrams per liter

Ammonium concentrations are total ammonium as NH_4

Slime samples include locations AR4S-20-21, AR4S-21-25, AR4-30-35, AR8-21-22, AR8-22-25, AR8-25-35, AR8-40-45.
Pore fluid analyses include AR2S, AR8S, AR9S, AR11S, AR12S, AR13S.

As for assumption (2), constituents selected for analysis in the current study were based on review of extensive characterization results for tailings (SRK 2000) and review of ground water monitoring data. The constituents analyzed are those that are consistently elevated in tailings, tailings pore fluids, or ground water. Past studies have selected different analytes based on process knowledge or other considerations. Using results of all of these studies should yield a comprehensive understanding of subpile chemistry.

Assumption (3) most likely does not hold true for all of the data sets used in this document. The extraction method used for the most recent data collection effort may come closest to simulating leachable concentrations though it may be a more aggressive solvent than ambient ground water; using a fairly weak acid solution would not cause a dissolution of recalcitrant minerals such as apatite and quartz but probably would release all soluble and sorbed constituents. The method used by both SRK and SMI is an almost complete digestion using a strong acid and heat; these results probably overestimate the amount of contaminants that are available for leaching and are therefore conservative. There was no discussion of extraction method included in the ORNL report. Despite differences in extraction technique, results of different studies can be compared in a relative manner and are useful for identifying overall patterns in the data.

Calculation

Two grams of soil sample were extracted with a total of 200 mL of acid solution according to ESL Procedure CB(BT–1) (GJO 2002a). The resulting concentrations in micrograms per liter (µg/L, Table 1) of constituents measured in each decantate sample were then converted to units of milligrams per kilograms (mg/Kg) in order to estimate the amount of extractable contaminant per mass of subpile soil by the following equation:

$$\frac{200\text{ mL acid solution}}{2\text{ g soil}} \times \frac{\mu g\text{ contaminant}}{\text{L decantate}} \times \frac{L}{1{,}000\text{ mL}} \times \frac{mg}{1{,}000\ \mu g} \times \frac{1{,}000\ g}{Kg} = \text{mg/Kg}$$

For example, a concentration of 7.1 µg/L arsenic (As) was measured in the decantate for soil sample MOA 434–39. Converting this value to mg/Kg using the above equation results in 0.71 mg of As per Kg of subpile soil that is extractable using the acid solution (so the calculation is essentially the same as multiplying laboratory results [µg/L] by 0.1).

Soil concentration results along with depths and sample descriptions are provided in Table 4. Plots of concentration versus depth are shown on Figures 2 through 10 using results of the current study.

Discussion

Based on the plots in Figures 2 through 10 and data in Table 3, it is apparent that most of the analytes are elevated above background in the tailings and uppermost subpile samples. An exception to this is manganese, which is actually lower than background in locations 438 and 439, but increases to background levels with increasing depth. For all constituents but ammonium, selenium, and sulfate, concentrations decrease rapidly with increasing depth to concentrations within the range of background. The water table at location 437 is approximately.

Table 4. Converted 2002 Subpile Soil Study Data

Sample ID	NH_4 (mg/kg)	As (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Se (mg/kg)	SO_4 (mg/kg)	U (mg/kg)	V (mg/kg)	Depth (ft)	Dist. From Cont. (ft)	Description
MOA 434-39	3.46	0.71	516	221	0.66	0.011	235	2.72	2.08	39	-60	Silty sand, red
MOA 434-41	4.15	1.36	1660	282	0.3	<0.01	310	0.78	3.76	41	-65	Clayey silt, 5-ft below water
MOA 434-51	1.74	0.72	814	179	0.3	<0.01	77	0.41	3.25	51	-70	Sand, red, 15 ft below water
MOA 434-57	2.42	0.84	868	122	0.3	<0.01	159	0.45	3	57	-75	Sandy gravel, 21 ft below water
MOA 437-41	285	11.3	4820	538	1.66	0.18	1260	89.2	433	41	0	Tailings, at contact
MOA 437-43	40.9	1.98	265	262	0.87	0.056	270	6.98	41.6	43	-2	Sand/Silt, 2 ft below contact
MOA 437-46	8.62	1.72	187	356	0.61	0.027	256	1.31	26.7	46	-5	Sand/Silt, 5 ft below contact
MOA 437-51	3.16	0.81	135	225	0.46	0.048	191	1.46	15.1	51	-10	Sand, 10 ft below contact
MOA 437-82	3.13	2.3	323	270	0.84	0.015	381	1.85	21.3	82	-41	Silt, 50 ft below tailings, 6 ft above water
MOA 437-91	3.46	1.07	281	367	2.77	0.032	1090	1.73	5.08	91	-50	3 ft below water
MOA 437-110	2.86	0.55	635	131	0.68	0.06	574	1.41	1.38	110	-69	Sandy gravel, sample biased with fines, 54 ft below tailings, 12 ft below water
MOA 438-72	562	12.4	1650	33.2	46.4	0.21	143000	97.1	218	72	0	Tailings at contact
MOA 438-75	129	0.88	459	474	1.34	0.049	7590	3.4	10.8	75	-3	Sand, red, 2 ft below tailings
MOA 438-80	62.8	0.32	98.7	342	0.54	<0.01	481	0.83	3.09	80	-8	Sand, red 7 ft below tailings
MOA 438-90	55.6	0.56	715	468	1.16	<0.01	1680	1.35	3.9	90	-18	Sand, red, 12 ft below tailings, 6 ft above water
MOA 438-101	16.8	0.4	136	342	0.63	<0.01	621	0.66	1.34	101	-29	Sand, red, 23 ft below tailings, 5 ft below water
MOA 438-110	12.4	0.26	571	117	<0.3	0.12	530	0.81	3.59	110	-38	Sandy gravel, sample biased with fines, 14 ft below water
MOA 439-82	260	8.35	3750	25.8	54.7	0.11	151000	191	1230	82	0	Tailings at contact
MOA 439-83	291	0.85	2370	2440	<0.3	0.024	8220	1.82	3.64	83	-1	Silty sand, 1 ft below contact
MOA 439-87	201	0.9	1040	1440	<0.3	0.032	9330	2.38	9.33	87	-5	Silty sand, 5 ft below contact
MOA 439-90	85.3	0.35	137	852	<0.3	0.01	1310	0.9	2.54	90	-8	Sand, 8 ft below contact
MOA 439-95	153	0.87	297	284	<0.3	<0.01	1090	0.83	2.37	95	-13	Sand, 13 ft below contact
MOA 439-100	79.6	0.44	113	264	0.35	0.014	1120	0.7	2.15	100	-18	Sand, 18 ft below contact, 2 ft below water
MOA 439-116	10.6	0.88	851	108	0.33	0.047	1350	0.77	2.35	116	-34	Sand, gy-br, 34 ft below contact, 18 ft below water
MOA 439-121	6.69	0.47	975	95	0.5	0.033	1220	0.43	2.12	121	-39	Gravel, sample biased with fines, 39 ft below contact, 23 ft below water

Notes:

NH_4 = ammonia; As = arsenic; Fe = iron; Mn = manganese; Mo = molybdenum; Se = selenium; SO_4 = sulfate; U = uranium; V = vanadium; µg/L = micrograms per liter
mg/kg = milligrams per kilogram; ft = feet

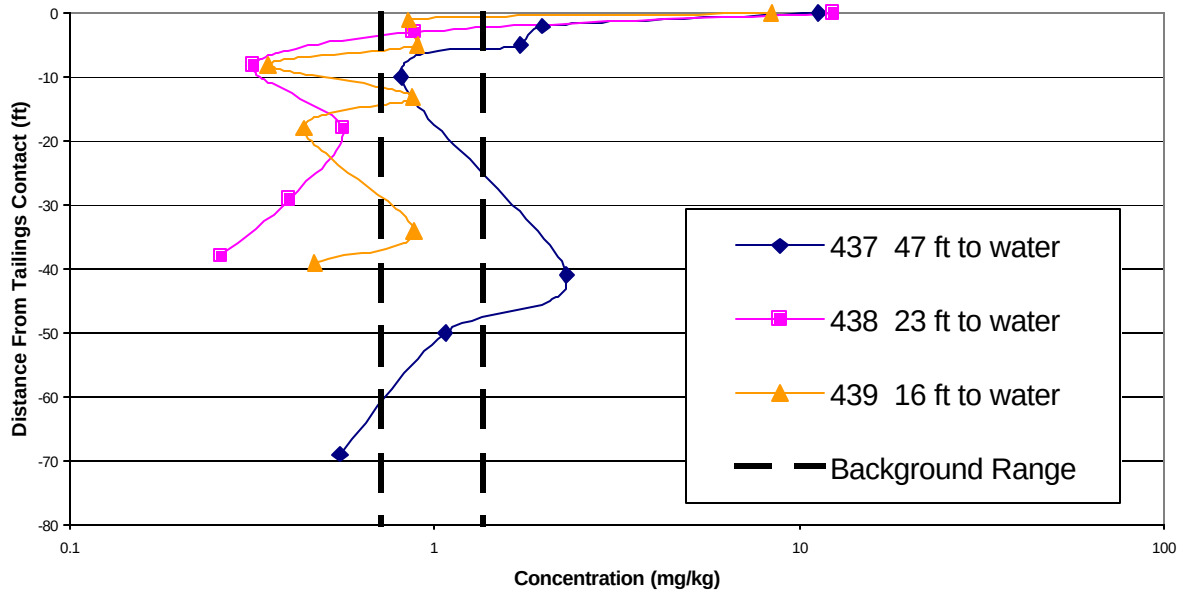


Figure 2. Arsenic Concentration Levels

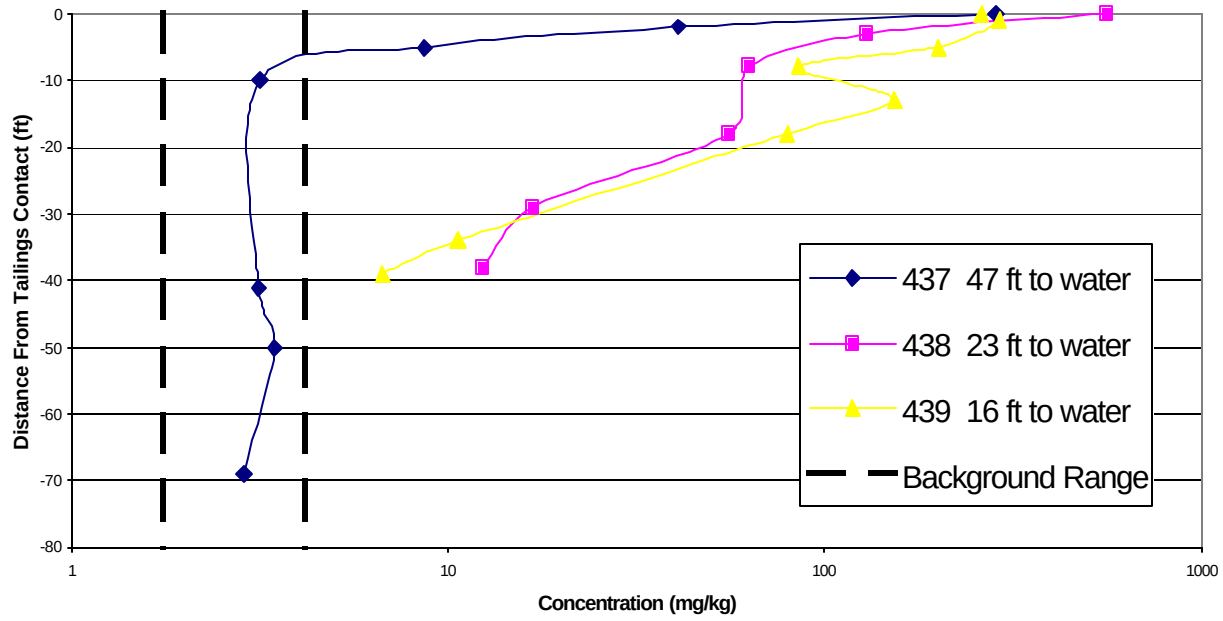


Figure 3. Ammonium Concentration Levels

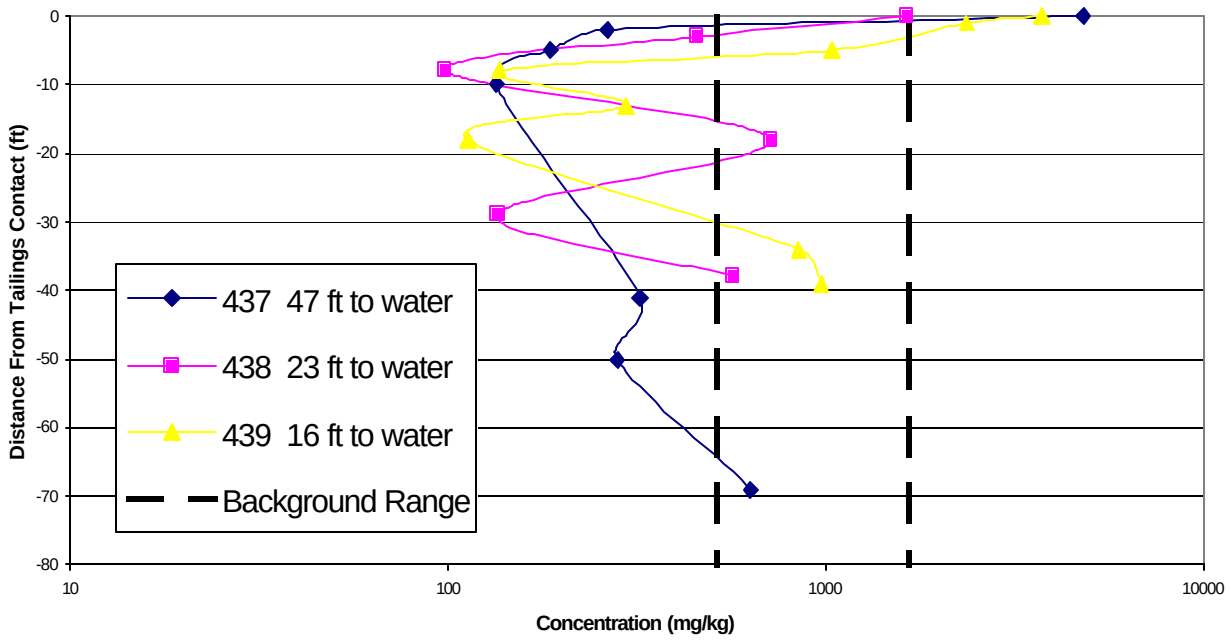


Figure 4. Iron Concentration Levels

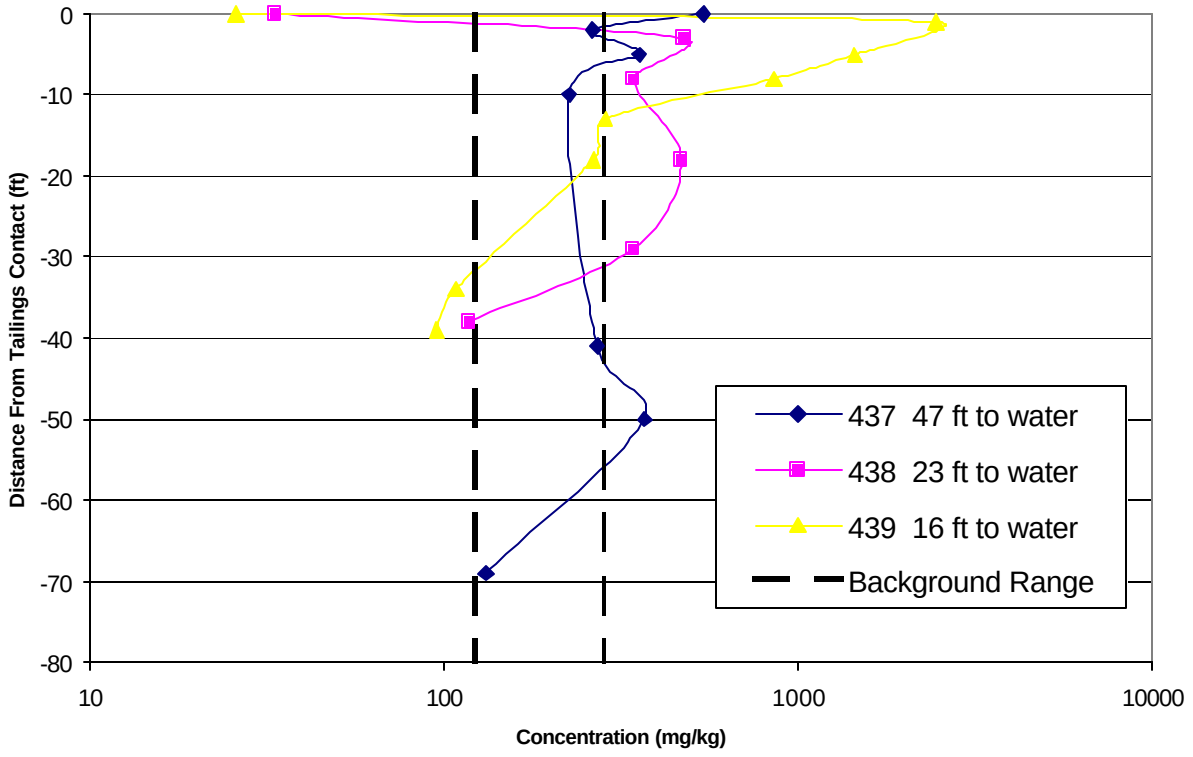


Figure 5. Manganese Concentration Levels

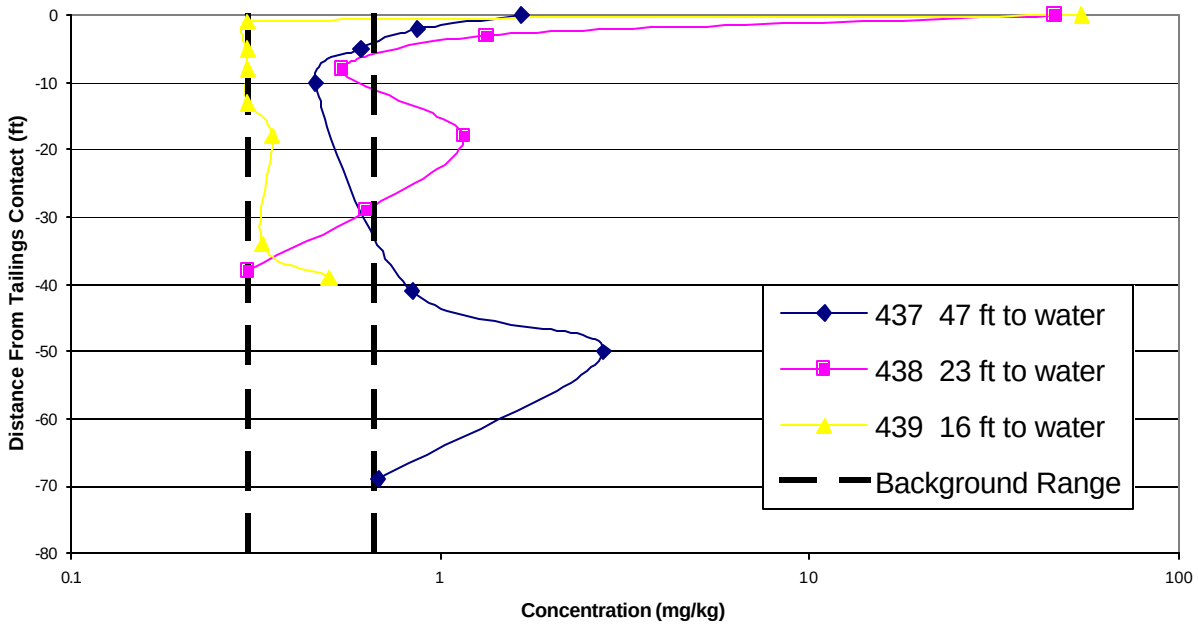


Figure 6. Molybdenum Concentration Levels

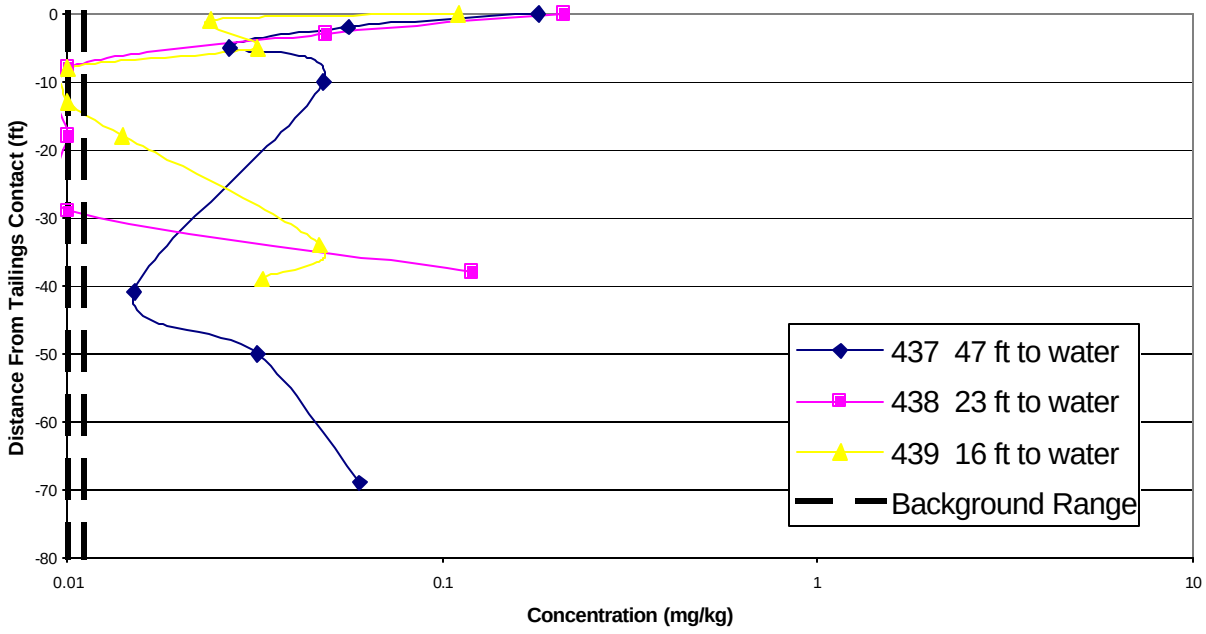


Figure 7. Selenium Concentration Levels

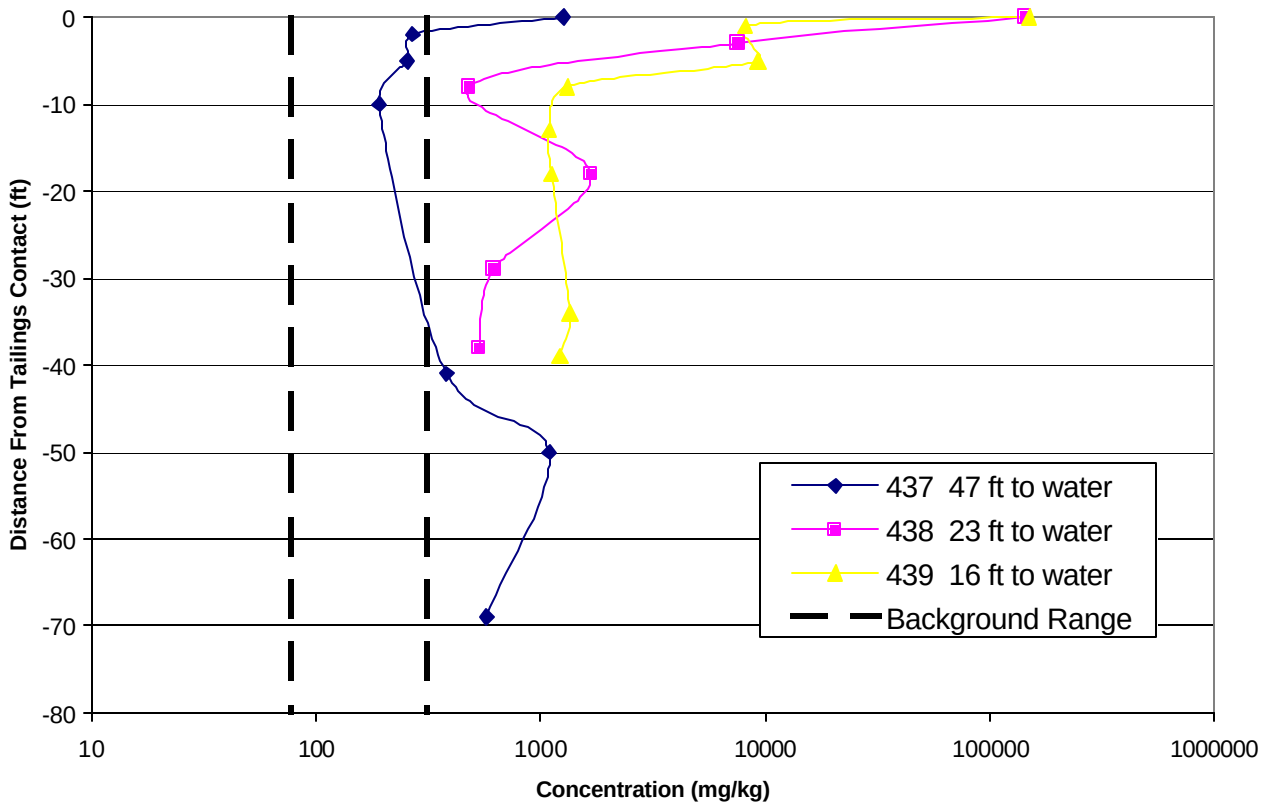


Figure 8. Sulfate Concentration Levels

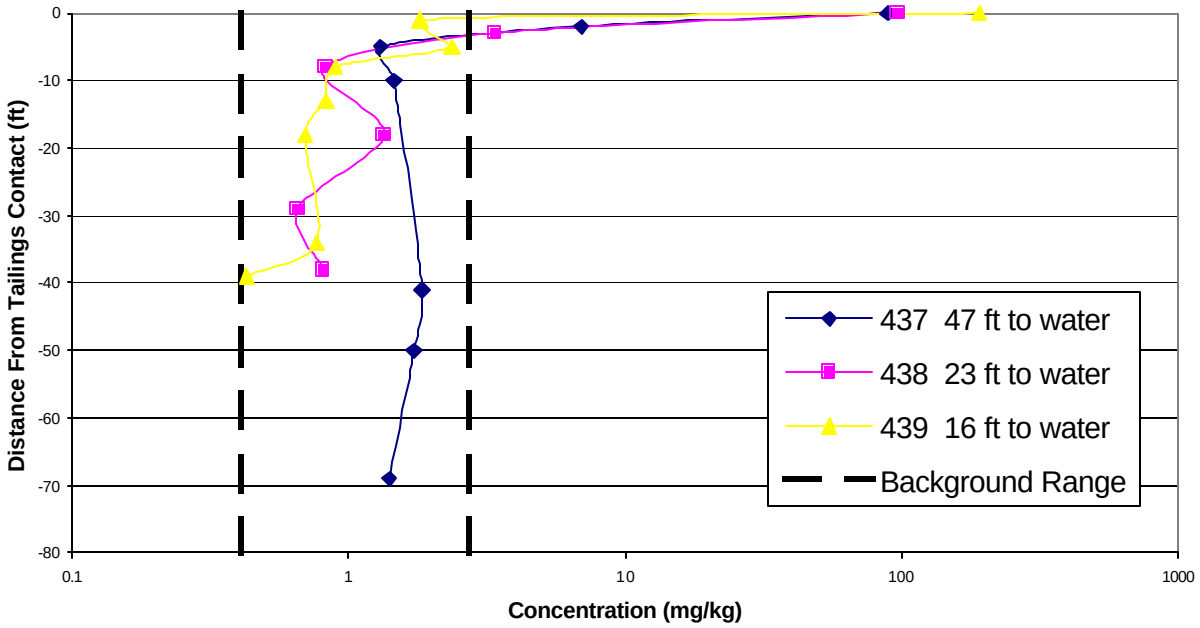


Figure 9. Uranium Concentration Levels

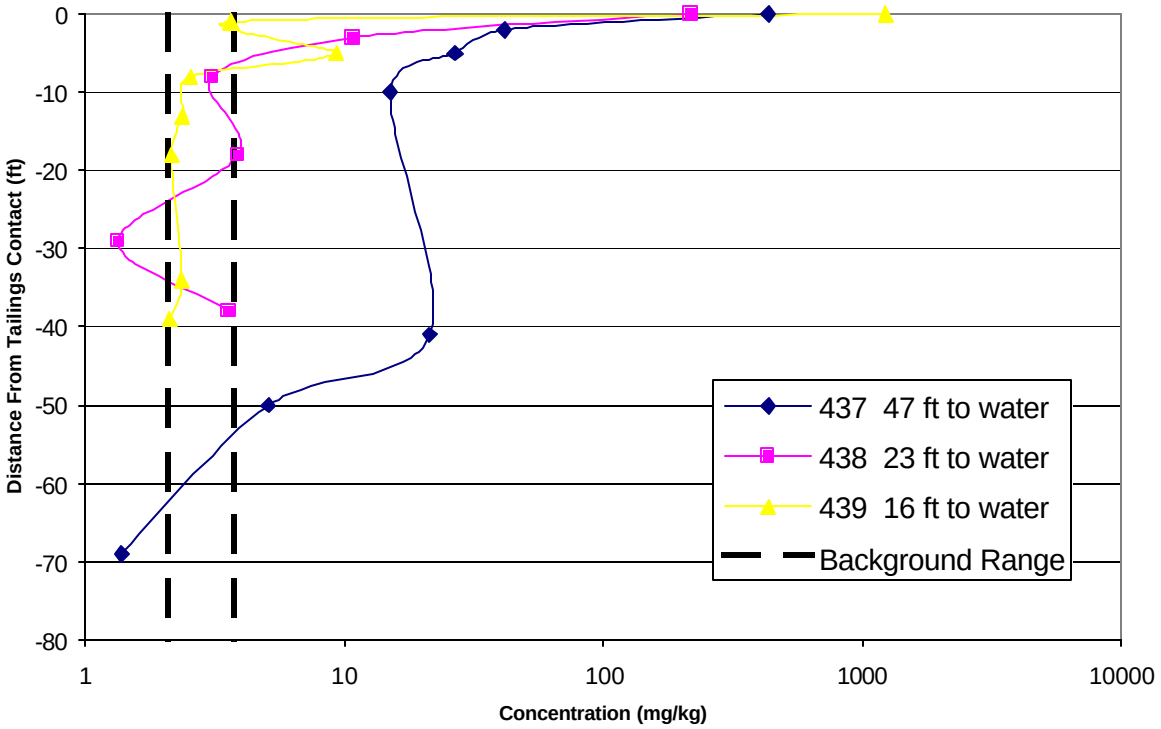


Figure 10. Vanadium Concentration Levels

47 ft below the tailings contact, whereas at locations 438 and 439 it is at 23 ft and 16 ft below the contact, respectively. This may explain why ammonium attenuates more rapidly with depth at location 437 compared to 438 and 439. Interaction with ground water at these latter two locations could mean that there is a continued flux of ammonium entering the system or a continual adsorption/desorption process occurring. However, although concentrations at locations 438 and 439 did not decrease to background, they did decrease to very low levels. The same is true for all three wells regarding sulfate.

Several constituents, including iron, fluctuate significantly with changing depth. Because this behavior is seen with iron, it suggests that some type of oxidation-reduction reactions may be responsible or it could be simple heterogeneity. However, it would be difficult to predict exactly what mechanism may be at work based on solids data only. Only very limited ground water data are available for the depths from which subpile soil samples were collected.

The radium-226 data show a similar, though even more dramatic decrease with depth in most locations (Table 2). At locations 437 and 439, radium concentrations decrease to levels below the surface standard of 5 picocuries per gram (pCi/g) within 6 ft of the base of the tailings. (Even though the standard is actually 5 pCi/g above background, OCS measurements are compared to the 5 pCi/g standard without background to account for measurement uncertainty.) Concentrations of radium-226 at location 438 also decrease within this depth range, though not to levels below the standard. At this location, concentrations remain above the UMTRA soil cleanup standard to depths of at least 5 ft.

Table 5 provides some common ranges of selected constituents found in Moab subpile soils for comparison with ranges found in Moab samples. Some constituents such as uranium are consistently higher in Moab subpile samples than naturally occurring concentrations and are

Table 5. Common Ranges of Selected Constituents in Soils and Soil Screening Levels

Constituent	Range for Moab Subpile Soils (mg/Kg)	Common Range in Soils (mg/Kg)	Soil Screening Level for Ground water; 1 DAF[3] (mg/Kg)	Soil Screening Level for Ground water; 20 DAF[3] (mg/Kg)
Arsenic	0.32 – 2.3	1-50[1]	0.0013	0.026
Barium	na	100-3,000[2]	110	2,100
Copper	na	2-100[1]	530	11,000
Iron	98.7 – 2,370	7,000-550,000[1]	na	na
Manganese	95 – 2,440	20-3,000[1]	330	6,700
Molybdenum	<0.3 – 2.77	1-5[2]	na	na
Selenium	<0.01 – 0.056	0.1-2[1]	0.95	19
Uranium	0.43 – 6.98	1 (avg.)[2]	na	na
Vanadium	1.34 – 41.6	20-500[2]	260	5,100

[1]McLean and Bledsoe 1992
[2]Levinson 1980
[3] EPA 2002
na = not available

most probably site-related. Other more common constituents such as iron and manganese are well within common ranges for soil and may or may not be attributable to processes at the site. Also provided in Table 5 are EPA Region III's soil screening levels for protection of ground water (EPA 2002). Two values are provided—one with a dilution attenuation factor (DAF) of 1, the other with a DAF of 20. These concentrations represent soil concentrations that would result in acceptable ground water concentrations with those respective DAFs. A DAF of 1 assumes no attenuation of contaminants occurs as ground water moves through the subsurface; this assumption is not realistic. EPA has selected a DAF of 20 as the "default" DAF to account for the variety of processes that affect contaminant movement in the subsurface. Site-specific data, if available, can be used to develop site-specific and contaminant-specific DAFs. Using default DAFs for comparison, only arsenic exceeds its DAF, which is very low due to arsenic's high toxicity.

Conclusions and Recommendations

Subpile soil samples are elevated in most site-related constituents above concentrations detected in background samples, indicating there is some tailings pile contamination that has migrated below the pile. However, with increasing depth, most constituents decrease to background levels at depths of less than 10 ft below the pile. For two of the three subpile boreholes included in the current study, radium decreased to background within a 6 ft distance. These results suggest that only limited subpile soil cleanup would be required if the mill tailings pile were to be removed for disposal at another location. Only arsenic exceeded its soil screening level for protection of ground water. However, arsenic is detected only sporadically in ground water with the highest concentrations in samples from the wood chip area located east of the tailings pile. This suggests that subpile soils are not significantly affecting ground water quality with regard to arsenic. It appears that if soils were cleaned up to meet radium-226 cleanup standards, soils would be protective of ground water for other nonradiological constituents. Although the characterization data are considered sufficient for developing the conceptual site model, it may not be sufficient for estimating quantity of contaminated soil to be removed if the pile is relocated. Therefore, the extent of radium-226 contamination may need to be reassessed at a later date depending on project direction. If the decision is made to cap the pile in place, study results suggest that

subpile soils will have little impact on ground water quality. However, the high contaminant concentrations obtained from leaching the tailings may indicate that rewetting and draining of the pile itself has the potential to negatively impact ground water quality.

Computer Source

All calculations were made in an Excel spreadsheet.

Appendix A

Lithologic Logs

MONITORING WELL COMPLETION LOG MOA01-0434

PROJECT MOAB
LOCATION Moab, UT
SITE MOAB
WELL NUMBER 0434

NORTH COORD. (FT) 6667455.31
EAST COORD. (FT) 2186665.40
HOLE DEPTH (FT) 85.30
WELL DEPTH (FT) 85.30

DATE DRILLED 07/11/2002 to 07/12/2002
SURFACE ELEV. (FT NGVD) 3990.60
TOP OF CASING (FT) 3990.21
MEAS. PT. ELEV. (FT) 3990.21
SLOT SIZE (IN) 0.020
BIT SIZE(S) (IN) 6.0

WELL INSTALLATION		INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	0.39	to	75.0
WELL SCREEN:	2 in. Slotted PVC	75.0	to	85.0
SUMP/END CAP:	2 in. PVC Sch 40	85.0	to	85.3
SURFACE SEAL:	Cement	0.0	to	3.0
GROUT:	Bentonite Grout	3.0	to	65.5
SEAL:	Bentonite Chips	65.5	to	71.0
UPPER PACK:	20-40 Silica Sand	71.0	to	73.0
LOWER PACK:	10-20 Silica Sand	73.0	to	85.3

DRILLING METHOD SONIC
SAMPLING METHOD SAMPLE TUBE
DATE DEVELOPED 07/12/2002
WATER LEVEL (FT BTOC) 33.65 on 07/12/2002
LOGGED BY Goodknight, C.
REMARKS Centralizer placed @ 84.5 - 85.0 ft.

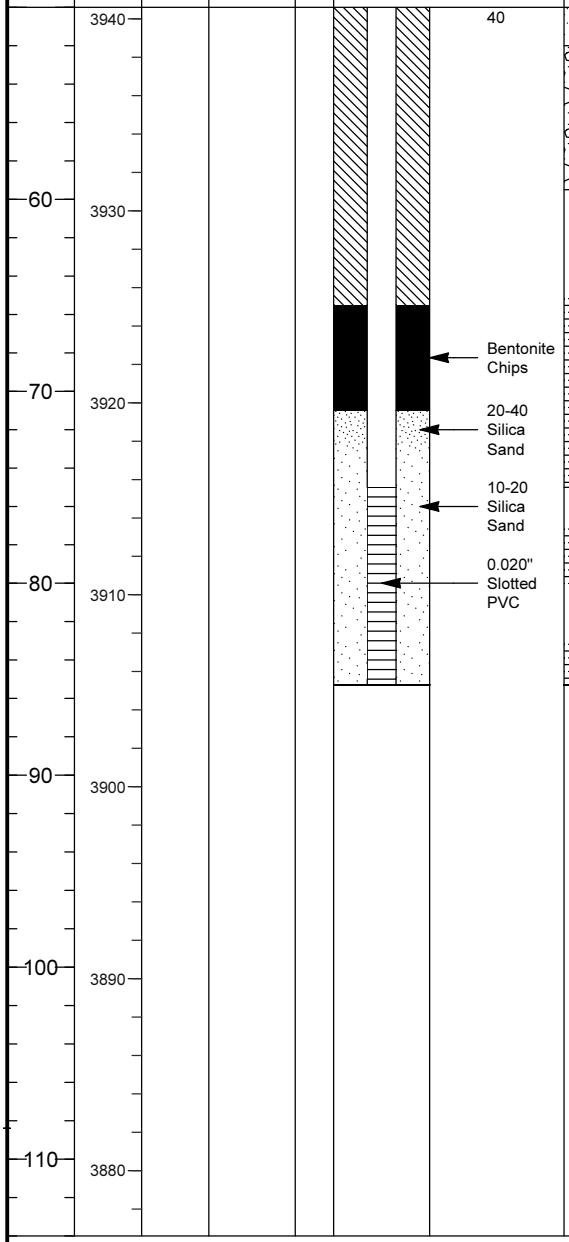
DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	3990				Cement		0-14.0 ft. SILTY SAND(SM); sand and silt, very fine grained, reddish yellow (5YR 6/6), loose, dry.
10	3980						@14.0 ft. some mottling, slightly compacted. 14.0-30.0 ft. SILT (ML); reddish yellow (5YR 6/6) to red (2.5YR 5/6), some very fine grained sand, loose, dry.
20	3970				PVC Sch 40		22.0-27.0 ft. silt slightly compacted. 27.0-29.0 ft. silt is red (2.5YR 5/6), noncalcareous, well compacted.
30	3960				Bentonite Grout		29.0-30.0 ft. silt is yellow (10YR 7/6) and white, calcareous, represents a soil development zone. 30.0-40.0 ft. SILTY SAND (SM); very fine grained sand with silt, <5% rock fragments and pebbles, red (2.5YR 5/6), dry above 34.0 ft. Rock fragments (~10%) at 33.0 ft.
40	3950				PVC Sch		38.0-40.0 ft. damp to wet. @ 40.0 ft. is a large rock fragment (fine grained sandstone). 40.0-41.0 ft. CLAYEY SILT (ML); mottled, brown (10YR 4/3) and red (2.5 YR 4/6), moist. 41.0-46.0 CLAYEY SAND (SC); very fine grained, and clayey silt (ML), brown (10YR 4/3), slight plasticity, saturated. 46.0-52.0 ft. SAND (SP); fine grained, reddish brown (5YR 4/4). @47.0 ft. color changes to dark yellowish brown (10YR 4/4), trace of small pebbles.

MONITORING WELL COMPLETION LOG MOA01-0434

PROJECT MOAB **WELL NUMBER** 0434

SITE MOAB **DATES DRILLED** 07/11/2002 to 07/12/2002

Continued from Previous Page



52.0-59.5 ft. SANDY GRAVEL (GP); hard, mainly metamorphic and crystalline lithologies with 30-50% pebbles/cobbles (up to 3.0 to 4.0" in diameter), fine to medium grained sand matrix, yellowish brown (10YR 5/4), wet. Material deposited by the ancestral Colorado River.

59.5-65.0 ft. SANDSTONE: weathered, fine-grained, noncalcareous, brownish yellow (10YR 6/6).
60-65.0 ft. (only about 1.0 ft. recovery) fine to very fine grained, light brown (5YR 5/6), obvious bedding mostly parallel and flat, but some crossbeds, noncalcareous, Fe oxides along fractures. Probably lower part of Wingate Sandstone.
65.0-75.0 ft. No Recovery, but likely alternating beds of very fine grained sandstone and siltstone/shale. Est. top of Chinle Formation @65.0 ft.

75.0-80.0 ft. SILTSTONE and SANDSTONE; alternating beds of fine to very fine grained sandstone, light brownish gray (5YR 6/1) and siltstone, soft, pale brown (5YR 5/2). Some high angle fractures. Both lithologies are noncalcareous. About 50% recovery.
80.0-85.0 ft. alternating beds of siltstone, dark yellowish orange (10YR 6/6) and pale yellowish brown (10YR 6/2) and soft, friable siltstone, pale reddish brown (10R 5/4). Both rock types are noncalcareous. About 50% recovery.

Total Depth 85.3 ft.

Note: From the interpretation of geologic formations in this borehole, it is necessary that a normal fault trending east, down to the south, is present between the borehole and outcrops of Chinle Formation present north of the old highway.

MONITORING WELL COMPLETION LOG MOA01-0437

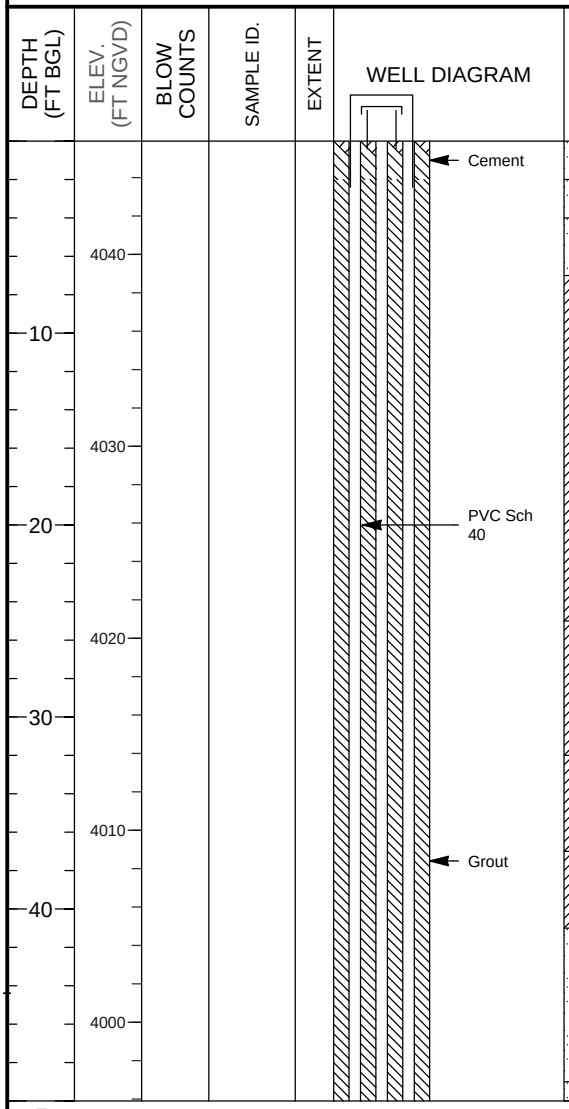
PROJECT MOAB
LOCATION Moab, UT
SITE MOAB
WELL NUMBER 0437

NORTH COORD. (FT) 6665399.33
EAST COORD. (FT) 2183802.67
HOLE DEPTH (FT) 250.00
WELL DEPTH (FT) 100.30

DATE DRILLED 08/22/2002 to 08/25/2002
SURFACE ELEV. (FT NGVD) 4045.90
TOP OF CASING (FT) 4048.25
MEAS. PT. ELEV. (FT) 4048.25
SLOT SIZE (IN) 0.010
BIT SIZE(S) (IN) 8.0

WELL INSTALLATION		INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.35	to	90.0
WELL SCREEN:	2 in. 0.01 Slotted PVC	90.0	to	100.0
SUMP/END CAP:	2 in. PVC Sch 40	100.0	to	100.3
SURFACE SEAL:	Cement	0.0	to	2.0
GROUT:	Bentonite Grout	2.0	to	73.0
SEAL:	Bentonite Chips	73.0	to	83.0
UPPER PACK:	20-40 Silica Sand	83.0	to	85.0
LOWER PACK:	10-20 Silica Sand	85.0	to	102.0

DRILLING METHOD SONIC
SAMPLING METHOD SAMPLE TUBE
DATE DEVELOPED 09/12/2002
WATER LEVEL (FT BTOC) 90.11 on 09/12/2002
LOGGED BY Goodknight, C.
REMARKS No centralizers.

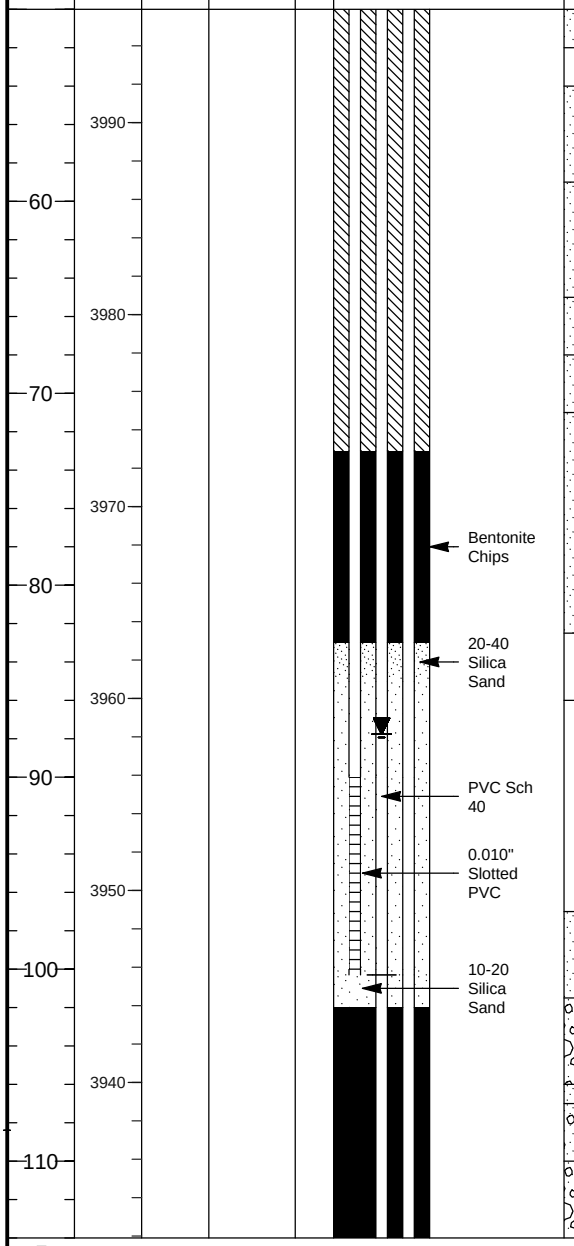


MONITORING WELL COMPLETION LOG MOA01-0437

PROJECT MOAB **WELL NUMBER** 0437

SITE MOAB **DATES DRILLED** 08/22/2002 to 08/25/2002

Continued from Previous Page



49.0-52.0 ft. SAND (SP); mostly very fine grained sand, loose, no rock fragments, red (2.5YR 5/6), highly calcareous, trace of mica.

52.0-54.0 ft. No recovery.

54.0-59.0 ft. SANDY SILT (SM); very fine grained sand, mottled, compacted, red (2.5YR 4/6), trace of mica, highly calcareous.

59.0-65.0 ft. SAND (SP); very fine grained, loose, dry, red (2.5YR 5/6), calcareous.

65.0-68.0 ft. SANDY SILT (SM); very fine gained sand, mottled with small gray-green clasts, compacted, red (2.5YR 4/6), trace of mica, becoming damp at 65 ft., highly calcareous. From 66.0-67.0 ft., no recovery.

68.0-71.0 ft. SAND (SP); very fine grained, loose, dry.

71.0-82.5 ft. SANDY SILT (SM); mottled, compacted, alternating with sand, very fine grained, loose, dry to damp, trace of mica, red (2.5YR 4/6), highly calcareous, trace of weathered rock fragments.

82.5-86.0 ft. SILT (ML); some very fine grained sand, compacted to loose, mottled, reddish brown (2.5YR 4/4), highly calcareous. Damp at ~84.0 ft.

86.0-97.0 ft. SILT (ML); red (2.5YR 4/6), trace of mica, highly calcareous, slightly plastic. Wet at 86.0 ft.

91.5-97.0 ft. dark grayish green brown (10YR 4/2), with limonitic mottling, trace of mica, highly calcareous, slightly plastic. Amount of fine grained sand increases with depth.

97.0-101.5 ft. SAND (SP); fine grained, subangular grains, brown (7.5YR 4/3), calcareous.

101.5-106 ft. SANDY GRAVEL (GP); matrix is fine grained sand (~60%), brown (7.5YR 4/2), pebble gravel up to 1" diameter from 101.5-104.0 ft., calcareous. Pebble gravel increases in size up to 2" diameter below 104.0 ft. Deposited by the ancestral Colorado River.

106.0-107.0 ft. SAND (SP); fine grained.

107.0-110.0 ft. GRAVELLY SAND (SP); mostly fine grained sand with ~10% gravel and cobbles (up to 3.0" in diameter), brown (7.5YR 4/2), calcareous.

110.0-155.0 ft. SANDY GRAVEL (GP); matrix is fine grained sand (30-50%), gravel pebbles/cobbles up to 3.0" in diameter. Some

MONITORING WELL COMPLETION LOG MOA01-0437

PROJECT MOAB **WELL NUMBER** 0437

SITE MOAB **DATES DRILLED** 08/22/2002 to 08/25/2002

Continued from Previous Page

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							limonitic stain at 113.0 ft.
120	3930						@118.0 gravel becomes coarser (up to and > 4.0" in diameter). Cobbles and pebbles are rounded, of Colorado River origin, and are composed mostly of Precambrian metamorphic rocks, igneous rocks, and a few are sandstone. Matrix is mostly fine grained sand, brown (7.5YR 4/2), and calcareous.
	3920						126.0-134.0 ft. pebbles/cobbles are smaller - mainly less than 2.0" in diameter.
130							
	3910						134.0-147.0 ft. pebbles/cobbles are larger (up to and > 4.0" in diameter). Matrix mostly fine grained sand and calcareous.
140					Bentonite Chips		
	3900						147.0-149.0 ft. sandy gravel is very saturated and matrix is finer grained with some clay/silt. 149.0-155.0 ft. large cobbles (up to 4.0" in diameter are common). Matrix mostly fine grained sand, calcareous.
150							
	3890						155.0-158.0 ft. SAND (SP); mostly fine grained, "salt and pepper sand", trace of pebbles, wet, dark grayish brown (10YR 4/2), slightly calcareous.
160							158.0-167.0 ft. SANDY GRAVEL (GP); matrix is fine grained sand; gravel - pebbles and cobbles (up to ~3.0" in diameter).
	3880						167.0-169.0 ft. CLAYEY GRAVEL (GC); gravel has more silty/clayey matrix.
170							169.0-177.0 ft. SAND (SP); red (2.5YR 4/6), with small pebbles and red siltstone fragments. 170.0-173.0 ft. contains "salt and pepper" sand, dark grayish brown (10YR 4/2), calcareous. 173.0-177.0 ft. contains ~10% small pebbles (up to 1.0" in diameter), calcareous.
	3870				Bentonite Chips		

MONITORING WELL COMPLETION LOG MOA01-0437

PROJECT MOAB **WELL NUMBER** 0437

SITE MOAB **DATES DRILLED** 08/22/2002 to 08/25/2002

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DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
180							177.0-179.0 ft. SANDSTONE; arkosic fragment, red (2.5YR 4/6), slightly calcareous.
							179.0-184.0 ft. SILTY SAND (SM); with 10% small pebbles, highly calcareous, red (2.5YR 4/6), some small weathered rock fragments. @183.0 ft. - weathered mauve-purple siltstone fragments.
	3860						184.0-186.0 ft. SILTY GRAVEL (GM); ~10% rounded pebbles (up to 2.0" in diameter), red (2.5YR 4/6) to reddish brown (5YR 4/4), calcareous.
							186.0-190.0 ft. SAND (SP); fine grained sand , red (2.5YR 4/6). 10-15% gravel (pebbles up to 2.0" in diameter, wet.
190							190.0-207.0 ft. SANDY GRAVEL (GP); sand in matrix is mainly fine to very fine grained, brown (7.5YR 4/2), calcareous, pebbles (up to 3.0" in diameter), wet.
	3850						
200							
							203.0-207.0 ft. matrix becomes more reddish, red (2.5YR 4/6), calcareous, trace of weathered sandstone fragments. @203.5 ft a flat , thin , 2.0" piece of oil shale, dark gray, of Green River Formation, Mahogany Ledge.
	3840						207.0-210.0 ft. GRAVELLY SAND (SP); very fine to fine grained sand, "salt and pepper", brown (10YR 4/3), ~10% pebbles (up to 2.0" in diameter), calcareous.
210					← Bentonite Chips		210.0-216.0 ft. SANDY GRAVEL (GP); sand in matrix is mainly fine grained, brown (7.5YR 4/3), calcareous. Pebbles ~30% and up to 3.0" in diameter.
	3830						216.0-219.0 ft. SAND (SP); mostly fine gained, "salt and pepper", trace of pebbles, brown (7.5YR 5/2), calcareous.
220							219.0-220.0 ft. SANDY GRAVEL (GP); 30% pebbles and cobbles, fine grained sand matrix.
							220.0-224.0 ft. SAND (SP); fine grained, "salt and pepper", trace of pebbles, brown (7.5YR 5/2), calcareous.
	3820						224.0-229.0 ft. GRAVELLY SAND (SP); fine grained, 10-15% pebbles and cobbles (up to 2.0" in diameter), brown (7.5YR 4/2), calcareous.
230							229.0-231.0 ft. SANDY GRAVEL (GP); fine grained sand matrix, dark reddish gray (5YR 4/2), calcareous.
							231.0-235.0 ft. SAND (SP); mostly fine grained, brown (7.5YR 4/2), calcareous, trace of pebbles (up to 2.0" in diameter).
	3810						235.0-250.0 ft. SANDY GRAVEL (GP); mostly fine grained sand matrix, brown (7.5YR 4/2), cobbles (up to 4.0" in diameter).
240							

MONITORING WELL COMPLETION LOG MOA01-0437

PROJECT MOAB **WELL NUMBER** 0437

SITE MOAB **DATES DRILLED** 08/22/2002 to 08/25/2002

Continued from Previous Page

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
250	3800				Piezometer VW (0452) OH (0458) Slough		246.0-250.0 ft. gravel (cobbles) become more coarse (up to 5.0" in diameter), some weathered rock fragments near TD.
							Total Depth 250.0 ft.
							NOTE: @248.5 ft. Installed location #452, vibrating wire piezometer (Geokon 4500s-100 PSI), and location #458, 1.0" diameter open hole PVC piezometer. Vibrating wire piezometer was taped to outside of 1.0" diameter PVC.
260	3790						
270	3780						
280	3770						
290	3760						
300	3750						

MONITORING WELL COMPLETION LOG MOA01-0438

PROJECT MOAB
LOCATION Moab, UT
SITE MOAB
WELL NUMBER 0438

NORTH COORD. (FT) 6665241.03
EAST COORD. (FT) 2185009.53
HOLE DEPTH (FT) 120.00
WELL DEPTH (FT) 119.30

DATE DRILLED 08/20/2002 to 08/21/2002
SURFACE ELEV. (FT NGVD) 4052.00
TOP OF CASING (FT) 4054.22
MEAS. PT. ELEV. (FT) 4054.22
SLOT SIZE (IN) 0.010
BIT SIZE(S) (IN) 8.0

WELL INSTALLATION		INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.22	to	109.0
WELL SCREEN:	2 in. 0.01 Slotted PVC	109.0	to	119.0
SUMP/END CAP:	2 in. PVC Sch 40	119.0	to	119.3
SURFACE SEAL:				
GROUT:	Bentonite Grout	0.0	to	91.0
SEAL:	Bentonite Chips	91.0	to	100.5
UPPER PACK:	20-40 Silica Sand	100.5	to	103.5
LOWER PACK:	10-20 Silica Sand	103.5	to	120.0

DRILLING METHOD SONIC
SAMPLING METHOD SAMPLE TUBE
DATE DEVELOPED 09/16/2002
WATER LEVEL (FT BTOC) 97.47 on 09/16/2002
LOGGED BY Karp, K.
REMARKS Centralizers @ 9.0, 69, and 119.0 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	4050						0-3.0 ft. SAND (SP); mostly fine grained (2.5YR 4/6), red, some pebbles, angular. From 1.0-3.0 ft., mottled fill material, gray (5Y 6/1), dry.
							3.0-5.0 ft. CLAYEY SILT (ML); tailings, very fine grained sand to clayey silt, reddish brown (5YR 4/3), to dark gray (5Y 4/1), dry.
10	4040						5.0-18.0 ft. CLAYEY SILT TO SILTY CLAY (CL); some plasticity, dark grayish brown (10YR 4/2), wet.
20	4030				PVC Sch 40		18.0-21.0 ft. SAND (SP); very fine sand, yellowish brown (10YR 5/6), moist. No recovery from 20.0-21.0 ft.
							21.0-22.0 ft. SILTY CLAY (CL); dark grayish brown (10YR 4/2), wet.
							22.0-26.0 ft. SAND (SP); very fine sand, yellowish brown (10YR 5/6) to 23.0 ft., moist to dry.
							23.0-26.0 ft. color change to grayish brown (10YR 5/2), moist to dry.
30	4020						26.0-38.0 ft. CLAYEY SILT (ML); reddish brown (5YR 4/3) slightly plastic, wet @27.0 ft.
40	4010						38.0-44.0 ft. SILTY CLAY (CL); black organic streaks at 40.0 ft., more dense.
					Grout		44.0-48.0 ft. No recovery.
							48.0-52.0 ft. CLAYEY SILT (ML); wet to saturated slimes, reddish

MONITORING WELL COMPLETION LOG MOA01-0438

PROJECT MOAB **WELL NUMBER** 0438

SITE MOAB **DATES DRILLED** 08/20/2002 to 08/21/2002

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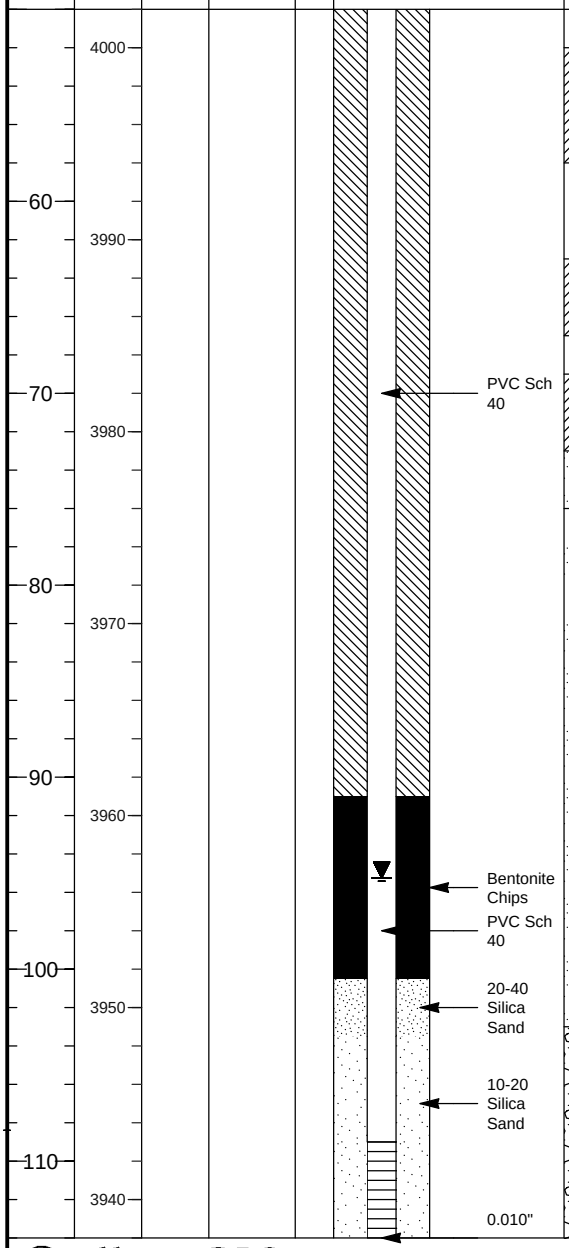

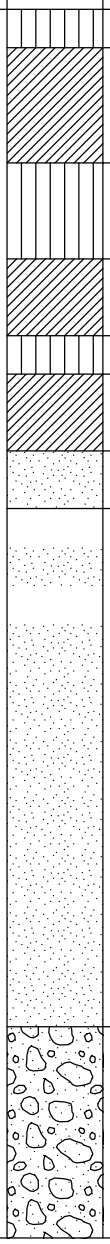

LITHOLOGIC DESCRIPTION

brown (5YR 4/4).

52.0-58.0 ft. SILTY CLAY (CL); wet, reddish brown (5YR 4/4) with black organic streaks to 54.0 ft..
54.0-58.0 ft. dense, some plasticity and color change to grayish brown (10YR 5/2).

58.0-63.0 ft. CLAYEY SILT (ML); wet to saturated slimes, dense, grayish brown (10YR 5/2).

63.0-67.0 ft. SILTY CLAY (CL); wet, dense, grayish brown (10YR 5/2).

67.0-69.0 ft. CLAYEY SILT (ML); wet, grayish brown (10YR 5/2).

69.0-73.0 ft. SILTY CLAY (CL); wet to moist, very dense. Pinkish gray (5YR 6/2) to gray (5YR 6/1). Some plasticity; bottom of tailings at 73.0 ft.

73.0-103 ft. SAND (SP); very fine grained, red (2.5YR 4/6). Sub pile sediments, calcareous, dry, some pebbles up to 1" diameter.

76.0-78.0 ft. No recovery - some slough @78.0 ft.

80.0-82.0 ft. No recovery - slough.

@85.0 ft. wet, large cobble ~6" diameter.

@95.0 ft saturated.

103.0-120.0 ft. SANDY GRAVEL (GM); poorly sorted sand matrix, reddish brown (5YR 4/4 - wet color), crystalline pebbles up to 1.0" in diameter. Colorado River deposits.

109.0-120.0 ft. gravel is coarser than above, color change to dark brown (7.5YR 4/2 - wet color), cobbles (up to 3.0" in diameter).

MONITORING WELL COMPLETION LOG MOA01-0438

PROJECT MOAB **WELL NUMBER** 0438

SITE MOAB **DATES DRILLED** 08/20/2002 to 08/21/2002

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DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
120	3930				Slotted PVC		Total Depth 120.0 ft.
130	3920						
140	3910						
150	3900						
160	3890						
170	3880						

MONITORING WELL COMPLETION LOG MOA01-0439

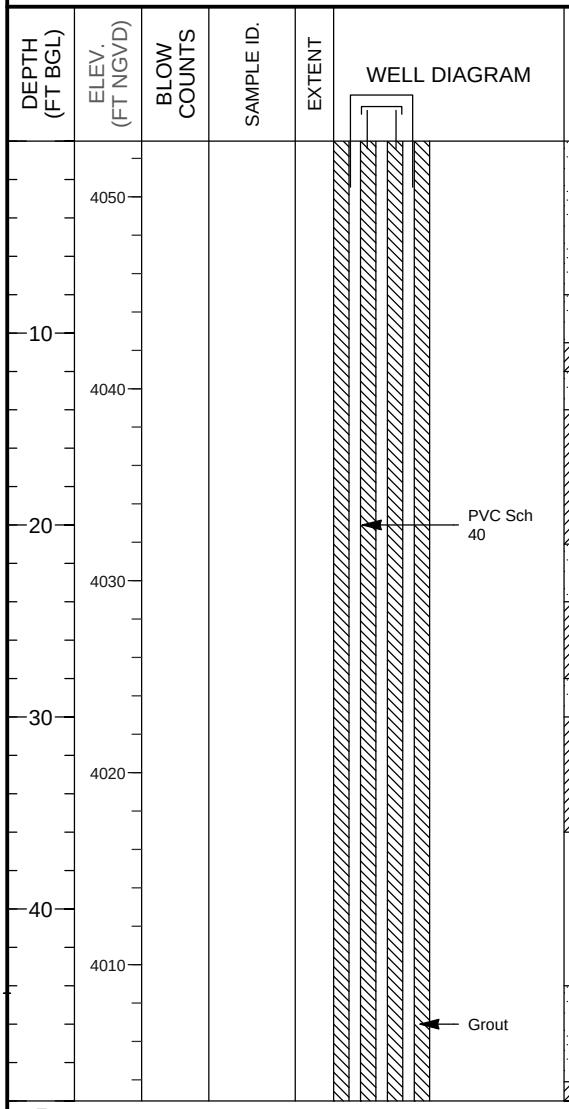
PROJECT MOAB
LOCATION Moab, UT
SITE MOAB
WELL NUMBER 0439

NORTH COORD. (FT) 6664189.32
EAST COORD. (FT) 2184731.49
HOLE DEPTH (FT) 304.00
WELL DEPTH (FT) 120.30

DATE DRILLED 08/07/2002 to 08/13/2002
SURFACE ELEV. (FT NGVD) 4052.90
TOP OF CASING (FT) 4055.27
MEAS. PT. ELEV. (FT) 4055.27
SLOT SIZE (IN) 0.020
BIT SIZE(S) (IN) 8.0

WELL INSTALLATION		INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.37	to	110.0
WELL SCREEN:	2 in. 0.02 Slotted PVC	110.0	to	120.0
SUMP/END CAP:	2 in. PVC Sch 40	120.0	to	120.3
SURFACE SEAL:				
GROUT:	Bentonite Grout	0.0	to	92.0
SEAL:	Bentonite Chips	92.0	to	102.5
UPPER PACK:	20-40 Silica Sand	102.5	to	105.2
LOWER PACK:	10-20 Silica Sand	105.2	to	122.0

DRILLING METHOD SONIC
SAMPLING METHOD SAMPLE TUBE
DATE DEVELOPED 09/18/2002
WATER LEVEL (FT BTOC) 99.82 on 09/18/2002
LOGGED BY Goodknight, C., Kautsky, M.
REMARKS Centralizer @ 120.0 ft..



MONITORING WELL COMPLETION LOG MOA01-0439

PROJECT MOAB **WELL NUMBER** 0439

SITE MOAB **DATES DRILLED** 08/07/2002 to 08/13/2002

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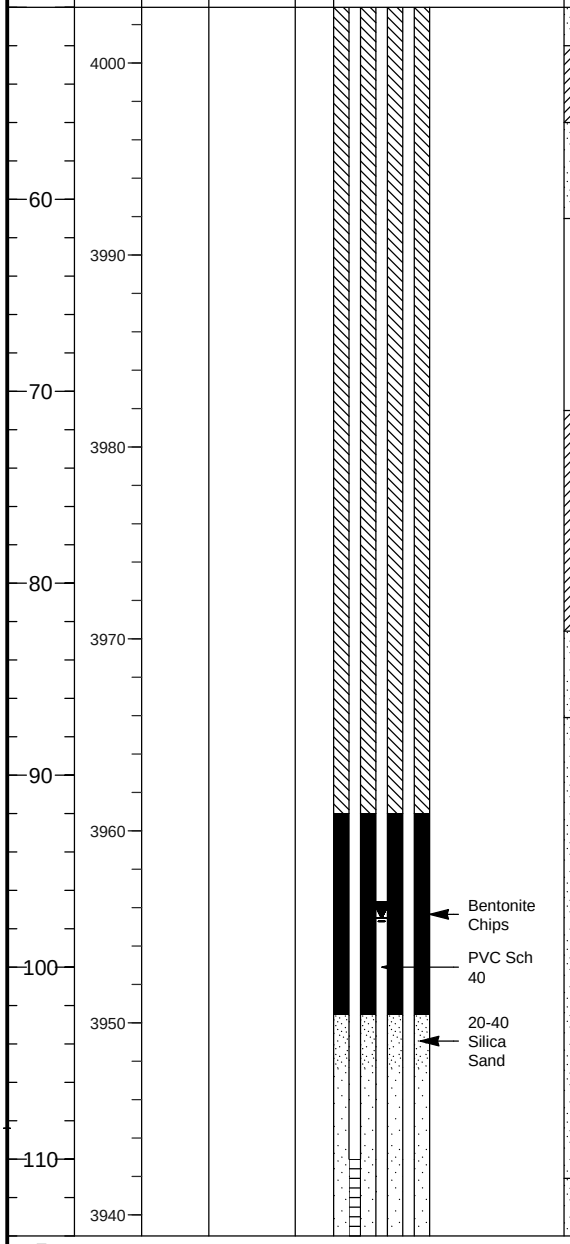

GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	49.0-50.0 ft. SILTY CLAY (CL); moderate plasticity.
	50.0-52.0 ft. SILTY SAND (SM); very fine grained.
	52.0-56.0 ft. SILTY CLAY (CL); moderately plastic, reddish gray (5YR 5/2), highly calcareous, holds moisture well.
	56.0-61.0 ft. SILTY SAND (SM); slightly plastic, reddish brown (5YR 5/3), highly calcareous, very wet.
	61.0-71.0 ft. CLAYEY SILT (ML); slimes, slightly plastic, grayish brown (10YR 5/2), highly calcareous.
	71.-82.5 ft. SILTY CLAY (CL); limonitic surface at 71.0 ft., light yellowish brown (2.5Y 6/4), moderately plastic to highly plastic, dense, brown (7.5YR 5/3) to gray (7.5YR 6/1), brown and yellowish brown material is calcareous and gray material is noncalcareous, slimes. Mostly noncalcareous and gray below 76.0 ft.
	82.5-87.0 ft. SILTY SAND (SM); very fine grained, highly calcareous, red (2.5YR 4/6), ~5% small rock fragments dry. Probably prepared base for tailings pile down to 87.0 ft.
	87.0-111.0 ft. SAND (SP): highly calcareous, mostly very fine grained, red (2.5YR 4/6), mostly windblown material (loess). Damp below 94.0 ft., moist by 98.0 ft. 101.0-111.0 ft. No recovery. Believed to still be in loess (fine sand), that is nearly saturated. Sample recovered on 8/9/2002, but somewhat disturbed.
	111.0-117.5 ft. SAND (SP); mostly very fine grained with some silt, dark grayish brown (10YR 4/2), calcareous, damp/moist.

MONITORING WELL COMPLETION LOG MOA01-0439

PROJECT MOAB **WELL NUMBER** 0439

SITE MOAB **DATES DRILLED** 08/07/2002 to 08/13/2002

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DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
120	3930				0.020" Slotted PVC; 10-20 Silica Sand		117.5-180.0 ft. SANDY GRAVEL (GP-GW); pebbles and cobbles (up to 5.0" diameter), matrix of fine grained sand, brown (7.5YR 4/2), ~50% sand, wet. Deposited by the ancestral Colorado River.
130	3920						131.0-132.0 ft. gravel is finer grained with pebbles only up to 1.0" in diameter.
140	3910						140.0-142.0 ft. matrix is coarser grained - mostly fine to medium grained sand.
150	3900						@155.0 ft. coarse cobble gravel.
160	3890				Bentonite Chips		
170	3880						170.0-176.0 ft. cobbles increasing in size and amount, most matrix material being lost - ~60% recovery.

MONITORING WELL COMPLETION LOG MOA01-0439

PROJECT MOAB **WELL NUMBER** 0439
SITE MOAB **DATES DRILLED** 08/07/2002 to 08/13/2002

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DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
180							178.0-180.0 ft. increasing amount of fine to medium grained sand matrix (~50-60%).
	3870						180.0-184.0 ft. SAND (SP); light red gray (2.5YR 7/1), medium grained, wet, subangular grains with black mica chips.
							184.0-200.0 ft. SANDY GRAVEL (GP); light red gray (2.5YR 7/1), cobble size rock fragments, rounded, comprise ~50% of mass, remaining 50% is fine to medium grained sand.
190							
	3860						
200							200.0-202.0 ft. SAND (SP); fine to medium grained sand.
	3850						202.0-206.0 ft. GRAVELLY SAND (SP); fine to medium grained sand with ~30% 1.0" diameter gravel (subrounded).
					Bentonite Chips		206.0-209.0 ft. SANDY GRAVEL (GP); gravel clasts (up to 3.0" in diameter) mixed with ~30% sand.
210							209.0-210.0 ft. SANDY CLAY (CL); dark gray (5YR 4/1), medium stiff.
							210.0-212.0 ft. SANDY GRAVEL (GP); mixed with ~20% sand.
	3840						212.0-219.0 ft. GRAVELLY SAND (SP); mixed with 30% gravel, subrounded to 2.0" diameter.
220							219.0-227.5 ft. SAND (SP); medium grained sand , no gravel, subrounded, red-gray (2.5YR 5/1).
	3830						
							227.5-228.0 ft. SANDY CLAY (CL); dark gray (5YR 4/1).
230							228.0-244.5 ft. SAND (SP); fine to medium grained sand, subrounded, no gravel. 230.0-240.0 ft. few gravel fragments, rounded (< 1%), loose. Flowing sand.
	3820						
240							

MONITORING WELL COMPLETION LOG MOA01-0439

PROJECT MOAB **WELL NUMBER** 0439

SITE MOAB **DATES DRILLED** 08/07/2002 to 08/13/2002

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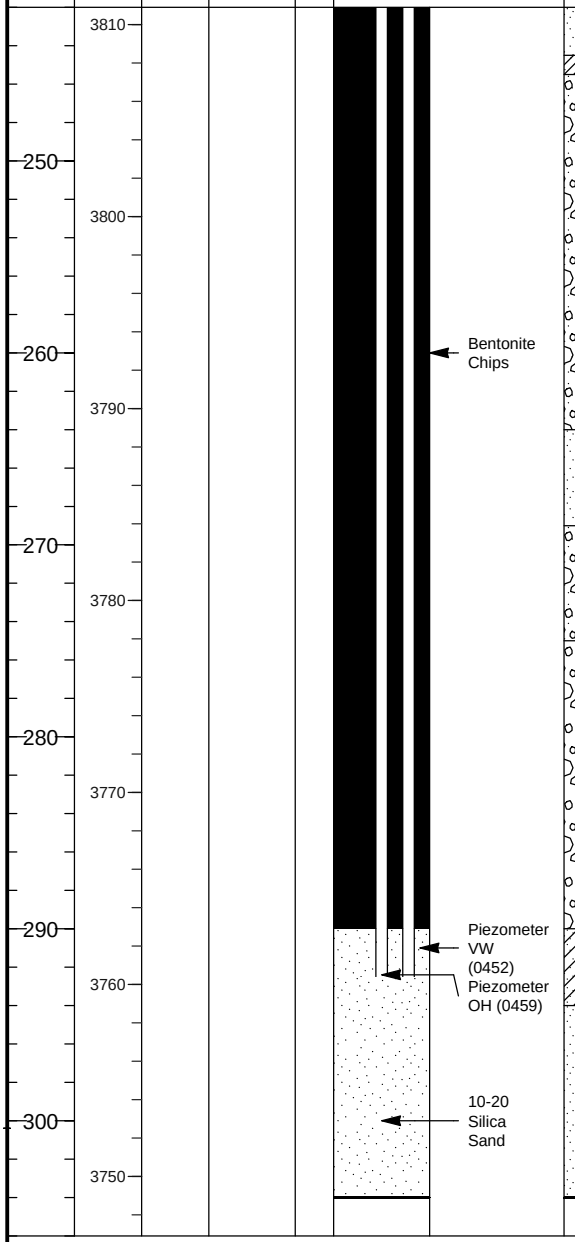

244.5-245.5 ft. SANDY CLAY (CL); dark gray (5YR 4/1), fine grained sand.

245.5-264.0 ft. SANDY GRAVEL (GP); reddish gray (2.5YR 5/1), ~30% sand, 70% gravel, rounded (average 1.0" in diameter).

262.0-263.0 ft. contains ~10% clay in matrix.

264.0-269.0 ft. SAND (SP); fine to medium grained sand, clean, no gravel.

269.0-275.0 ft. SANDY GRAVEL (GP); ~40% sand and 60% gravel (average 1.0" in diameter).

275.0-290.0 ft. CLAYEY SANDY GRAVEL (GP); reddish brown (5YR 5/3, 5/4, 4/3, and 4/4). Mottled, clay mixed with some sand and gravel, with individual clasts (up to 5.0" in diameter), with ~10% clay matrix.

290.0-294.0 ft. CLAYEY SAND (SC); poor recovery, red brown siltstone clasts in clayey sand matrix.

294.0-304.0 ft. SAND (SP); fine to medium grained sand.

NOTE: @292.85 ft. Installed location #451, vibrating wire piezometer (Geokon 4500s-100 PSI), and location #459, 1.0" diameter open hole PVC piezometer. Vibrating wire piezometer was taped to outside of 1.0" diameter PVC.

Total Depth 304.0 ft.