Appendix B-11

Environmental Monitoring Plan

ENVIRONMENTAL MONITORING PLAN

US ECOLOGY NEVADA

March 2010

Revised May 2011

SECTION 13

ENVIRONMENTAL MONITORING PLAN

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SECTION 13

ENVIRONMENTAL MONITORING PLAN

13.1.0 OVERVIEW OF ENVIRONMENTAL MONITORING DATA

The US Ecology Nevada environmental monitoring system includes data from three sources:

- 18 groundwater monitoring wells,
- Four pairs of leachate sumps, and
- A soil gas extraction well

The groundwater monitoring system uses eighteen wells in the Upper Water-Bearing Zone to monitor semi-annually for releases from landfill Trenches 11, 12 and the pre-RCRA Solid Waste Management Units (SWMUs) including Trenches 1 through 10. Water levels are measured in all wells at the time of each monitoring event to determine groundwater gradients. Samples are collected and analyzed for constituents as specified in the facility permit and as delineated below.

Leachate from Trench 11 and Trench 12 is sampled semi-annually from at least one sump in each Trench and analyzed for specified constituents. Leachate monitoring establishes a baseline of constituents present in leachate for comparison with groundwater monitoring data in the unlikely event of a release. In addition, leachate levels and pumping volumes are recorded and analyzed for compliance with permit conditions, and to assess the overall effectiveness of the leachate collection and detection sumps. Leachate data will also be used to assess the performance of alternative covers permitted for construction on Trench 11 and Trench 12.

Organic vapors have been detected in the vadose zone located under the facility, and a Soil Vapor Extraction (SVE) system has been installed to remove organic vapors. Extracted vapors are pumped through a carbon filter and monitored daily with a calibrated Photo ionization Detector (PID) that tests for volatile organic compounds (VOCs) exiting the filter system. In addition, weekly PID readings are recorded from a point between the wellhead and the carbon filter, and a summa canister sample is collected annually to quantify all constituents in the vadose zone. The performance of the SVE system is evaluated through monitoring of groundwater for selected VOCs.

13.2.0 GENERAL HYDROGEOLOGY INFORMATION

Numerous reports (Appendices A through F, References 1 through 5) contain information on site stratigraphy, physical and chemical properties of the vadose and upper saturated zones, and relationships with the confined gravel aquifer. The following sections briefly review regional and site geology and hydrology.

13.2.1 Regional and Site Geology

The US Ecology Nevada (USEN) Facility is located in the Amargosa Desert basin which was formed by normal block faulting, which displaced the surrounding strata upward with respect to the crustal block underlying the valley. This widespread structural process formed the characteristic topography of the entire Basin and Range province. Erosion of the uplifted areas, during and after their displacement, has filled the basin with a variety of sedimentary deposits. These deposits have reached a depth of 1000 feet in the center of the basin near Lathrop Wells.

The sediments of the valley floor are unconsolidated to partly indurated and Tertiary to Quaternary in age. Deposited as alluvial fans, debris flows, streambeds, dunes, and lake or marsh beds, they exhibit a very wide range of shapes and grain size distributions. The mineralogy of the sediments varies widely as well, reflecting the diversity of their source rocks.

Details on the nature of the unconsolidated strata beneath the facility have been determined from the various borings and well installations, which have been made since 1961. Extensive hydrogeologic investigations have been conducted at the site to determine the soil properties and hydrologic characteristics.

Stratigraphic information derived from the site characterization and monitoring well installation programs for the RCRA disposal facility describe a sequence of deposits consistent with alluvial fan and playa depositional processes. Deposits from the ground surface to a depth of approximately 300 feet beneath the RCRA facility are alluvial in nature. The alluvial sediments are predominantly gravelly sands with poorly sorted gravel or sand deposits which occur in discontinuous intervals. The gravelly sand extends deeper (approximately 350 feet below ground surface) at the southwestern area of the LLRW facility (Figure 3).

Generally, the next 50 to 150 feet of deposits beneath the RCRA facility consist of silt, clay and indurated deposits. The fine-grained sediments are typical of playa deposits and may change composition relatively quickly with depth.

The silt-clay deposits were also observed in borings 001 and 002. The upper surface of the silt-clay unit is relatively flat beneath the northern half of the RCRA facility and appears to deepen to the southwest beneath the LLRW facility.

Drilling investigations indicate that the upper saturated zone occurs near the contact of the silt-clay and indurated sediments with the overlying gravelly sands. The confined aquifer occurs in a sandy gravel formation underlying the silt-clay deposits.

This sandy gravel generally becomes coarser as it extends to depths exceeding 650 feet below ground level. The deeper gravels, cobbles, and boulders represent a higher energy, fluvial environment.

13.2.2 Regional Groundwater Flow Patterns

The surficial drainage area of the Amargosa Desert covers about 2600 square miles and is part of two regional groundwater systems (see Figure 13-3):

These two groundwater systems converge in the Amargosa Desert and probably continue to the south into Death Valley. Groundwater flow directions in the Amargosa Desert are generally to the southeast and southwest. Summaries of previous work on regional groundwater flow in this part of Nevada can be found in Elliott (1982) and Feeney, et al. (1987). Groundwater flow is controlled by alluvium, volcanic rock, and carbonate rocks. Thick volcanic sequences associated with calderas of the Nevada Test Site and areas to the west become less significant to the south, and thick carbonate rock sequences are assumed to be present beneath the Amargosa Desert (Feeney et al., 1987).

13.2.3 Site Hydrogeology

13.2.3.1 Saturated Zone

The degree of continuity of the hydrogeologic units beneath the site is illustrated in the cross-sections of Figures 13.5 and 13.6. At the 300-series well locations, saturation begins near the top of a 50-150 foot thick sequence of partially cemented to well-indurated clays, silts and sand. The depth to saturation from the ground surface ranges from near 285 feet on the north side of the site to > 360 feet at the southwest corner of the LLRW facility (see Appendix A). The interbedding of clays and cemented silts and sands at these depths serves to separate the upper saturated zone from the confined gravel aquifer beneath into discrete hydrogeologic units.

The gravel aquifer is encountered beneath the fine-grained deposits at a depth of 380 feet or more. It consists of sandy gravel with some cobbles and boulders, and is > 250 feet thick at the southern boundary of the site. The piezometric level measured in this aquifer occurs near 315 feet below ground surface, indicating a confined condition. The groundwater gradient in both the upper saturated zone and confined gravel aquifer is to the south and southwest, following the trend of the Amargosa Valley. This gradient is consistent with regional data, as reported by Nichols (1987) and Kilroy (1991).

Appendix A is a site plan showing water table contours in 2009. Groundwater gradients increase to the south beneath the RCRA facility and are generally uniform to the southwest beneath the LLRW facility. All wells and borings drilled to sufficient depth have encountered a confined gravel aquifer. A piezometric contour map of the confined aquifer is provided as Appendix B. Groundwater flow in the confined aquifer is generally to the south-southwest.

Numerous studies have been conducted which estimate hydraulic conductivities and transmissivities for this facility. Appendix C provides the calculations used to determine an average hydraulic conductivity for the upper aquifer of 6.63 $\times 10^{-4}$ feet/sec. Hydraulic gradients based on March 1995 groundwater elevations range from 0.028 ft/ft on the eastern side of the facility to 0.058

ft/ft in the central to western portion. Groundwater velocity estimates using March 1995 information ranges from 5.3×10^{-5} ft/sec to 1.1×10^{-4} ft/sec (using an average effective porosity of 0.35, as calculated in Appendix C). The measured hydraulic conductivities are consistent with samples lithologies and are considered representative of the upper saturated zone. Lithologies vary both laterally and vertically; however, groundwater velocities will be predominantly near the low end of the range given, as a result of the high clay and silt contents of the upper saturated zone.

Pumping test data from earlier studies (References 1 and 5) indicate the confined gravel aquifer has a transmissivity ranging from about 1,900 to 3,000 gpd/ft. Assuming these values are representative of the screened intervals of the 600-series wells, and using gradients derived from Appendix B, a groundwater flow velocity of about 30-50 ft/year is considered typical of the confined aquifer (calculations are presented in Appendix C). The heterogeneity of the sediments in the confined aquifer suggests somewhat smaller or larger velocities may be possible on a local scale.

13.2.3.2 Vadose Zone

As discussed earlier, the thickness of the vadose zone beneath the USEN Facility varies from 285 feet to > 360 feet. The moisture contents of sediments in the vadose zone are, in general, < 10% by weight, as determined from core samples (Reference 1) and in-situ neutron probe measurements (Fischer, 1992). Fisher (1992) also concluded that the potential for contaminant transport by water flow through the vadose zone is minimal under conditions observed at the facility. The extreme dryness of subsurface sediments is further characterized by water potentials from -10 to -60 bars, measured at the U.S. Geological Survey (USGS) study site near the southwest corner of the LLRW facility (Nichols, 1987; Fischer, 1990 and 1992).

An environmental pathways analysis performed for the Beatty LLRW facility used physical property data of site sediments and assumed a conservative recharge rate of 0.5 mm/year. Calculated travel times for vadose zone water from trenches to the upper saturated zone ranged from 13,000 to 24,000 years.

13.3.0 GENERAL GROUNDWATER MONITORING REQUIREMENTS

13.3.1 Groundwater Monitoring Wells

The USEN groundwater monitoring program yields representative samples from upgradient and downgradient wells. The groundwater monitoring system consists of detection monitoring (point of compliance) wells and background wells screened in the upper aquifer. Table 13-1 lists the wells, the well application, and current condition.

Table 13-1 - Monitoring Well Designations		
Well Identification	**Designation**	**Aquifer**
001	Point of Compliance	Upper
002	Point of Compliance	Upper
308	Point of Compliance	Upper
309	Point of Compliance	Upper
310	Point of Compliance	Upper
311	Point of Compliance	Upper
313	Background	Upper
315A	Point of Compliance	Upper
316	Point of Compliance	Upper
317	Point of Compliance	Upper
318	Background	Upper
319	Background	Upper
320	Point of Compliance	Upper
322	Point of Compliance	Upper
324	Point of Compliance	Upper
325	Point of Compliance	Upper
326	Point of Compliance	Upper
327	Point of Compliance	Upper
600	Supplemental	Lower
601	Supplemental	Lower
603	Supplemental	Lower
604	Supplemental	Lower
605	Supplemental	Lower

Three (3) monitoring wells (MW-320, MW-322, and MW-324) were installed in 2008 along the western perimeter of the site downgradient of Trench 12.

13.3.2 Sampling and Analysis Plan

A sampling and analysis plan is included as Appendix D. This document describes in detail the procedures and techniques employed for sample collection, preservation and shipment. The plan also describes the procedures utilized for sample analysis and chain of custody control.

13.3.3 Statistical Procedures

The purpose of the USEN groundwater monitoring program is to determine if the facility has had a significant effect on groundwater quality. To determine if a statistically significant increase has occurred, groundwater data is initially compared with the groundwater quality standards in Table 13-2. These standards are based on an analysis of groundwater quality data from 2003 to 2009 comparing up gradient and down gradient wells. The statistical analysis method used by AquAeTer is outlined in Appendix 13-E.

13.4.0 DESCRIPTION OF DETECTION MONITORING PROGRAM

13.4.1 Analytical Parameters

The analytical parameters in the USEN detection monitoring program are listed in Table 3-2.

13.4.2 Frequency of Sampling and Statistical Evaluation

The Background Wells and Point of Compliance Wells in the upper aquifer are monitored quarterly for the constituents in Table 13-2 Statistical evaluations are made on groundwater analytical data from Point of Compliance Wells for each sampling event. The supplement wells will be maintain but not sampled. Justification for elimination of sampling the supplemental wells every five quarters is included in Appendix 13-G.

Table 13-2 – Groundwater Protection Standards	
Ground Water Constituents	**Ground Water Protection Standard**
Arsenic	0.0152 mg/L
Barium	0.240 mg/L
Cadmium	0.0053 mg/L
Chromium	0.185 mg/L
Lead	0.0297 mg/L
Mercury	0.002 mg/L
Selenium	0.0039 mg/L
Silver	0.0627 mg/L
Sodium	324 mg/L
Cyanide	0.010 mg/L
Chloride	106 mg/L
Fluoride	5.5 mg/L
Nitrate-Nitrite as N	2 mg/L
Sulfate	274 mg/L
pH (std. units)	7 to 8.7
Specific Conductance	1,398 umhos
Total Organic Halides (TOX)	0.007 mg/L
Total Organic Carbon (TOC)	7.46 mg/L
Gross Alpha	22 pCi/L
Gross Beta	25 pCi/L
Radium 226/228*	5 pCi/L (Combination of Radium 226 & 228)
Tritium*	250 pCi/L
Endrin**	0.0002 mg/L
Lindane**	0.004 mg/L
Methoxychlor**	0.10 mg/L
Toxhaphene**	0.005 mg/L
2,4 – D**	0.1 mg/L
2,4,5 – TP Silvex**	0.01 mg/L

* From 2005 permit ** Established in 40 CFR §264.94

In addition to the constituents outlined in Table 13-2 groundwater will be analyzed to meet the requirements of 40 CFR §761.75 (b)(6)(iii).

13.4.3 Background Values

The upper aquifer "background" values for the parameters presented in Tables 13-2 were developed from the statistical analysis of groundwater samples collected from 2003 to 2009.

13.4.4 Determination of Groundwater Flow and Direction

Groundwater flow rate and direction in the upper saturated zone and the confined aquifer are determined and reported annually.

13.4.5 Other Source Demonstration

Once groundwater analysis results have been collected and subjected to a data quality review, the data is compared to the facility background value. To determine if a statistically significant increase has occurred, groundwater data is initially compared with the groundwater quality standards in Table 13.2. These standards are based on an analysis of groundwater quality data from 2003 to 2009 comparing up gradient and down gradient wells.

USEN also uses additional lines of evidence to evaluate whether liquids have been released from the landfill to groundwater. Leachate generation rates, leachate data, and landfill gas data are evaluated and compared with groundwater data to determine whether a source other than a currently-operating regulated unit caused the increase or that the increase resulted from error in sampling, analysis, evaluation, or natural variation in the groundwater. For example, constituents detected in leachate provide an indication of constituents that could be expected to be observed in groundwater if liquids were released from the site. USEN provides the results of this analysis in semi-annual reports to the NvDEP.

13.4.6 Detection Verification Procedure

Point of Compliance wells are evaluated statistically each time the wells are sampled. If a potential statistically significant increase (SSI) is identified, the results are verified during the next scheduled sampling event. Each semi-annual report includes analytical results for all environmental samples, and a discussion of any significant statistical increases.

13.4.7 Corrective Action Program

The facility submitted a Corrective Action Plan (CAP) in September 1998 and implemented a Corrective Measures Study (CMS) in March 1999. Prior investigations had determined that trace organic constituents detected in upper aquifer groundwater were attributable to gas migration from regulated units and solid waste management units. The selected remedy was extraction of waste constituents from the soil vapor in the overlying vadose zone. This work has now been competed with installation of a pilot SVE system. A final CMS report was submitted in April 2003. The CAP is included as Appendix E To evaluate the effectiveness of corrective measures, upper aquifer monitoring wells are sampled and analyzed semi-annually for the constituents in Table 13-3

Table 13-3 – Corrective Measures Evaluation

Ground Water Constituents	Ground Water Protection Standard (mg/L)
Carbon tetrachloride	0.005
Chloroform	0.005
Tetrachloroethene	0.005
Toluene	0.005
Trichloroethene	0.005
Trichloroflouromethane	0.005

13.5.0 LEACHATE MONITORING

On a quarterly basis samples will be collected and analyze from the Leachate Collection and Removal System (LCRS) and Leachate Detection and Removal System (LDRS) in both Trench 11 and Trench 12 (any leachate sump generating liquids will be sampled). Samples are analyzed for the parameters found in Table 13-4. The results of these analyses are submitted with the semi-annual report. .

Table 13-4 Leachate Sample Analysis

Arsenic	Endrin
Barium	Lindane
Cadmium	Methoxychlor
Chromium	Toxaphene
Lead	2,4-D
Mercury	2,4,5-TP Silvex
Selenium	
Silver	Chloroform
Cyanide	Tetrachloroethene
Fluoride	1,1,1- Trichloroethane
Sodium	Toluene
Sulfate	Acetone
Chloride	All chlorinated organics from EPA Method 8260
TOX	Total PCBs
TOC	
pH	Gross Alpha
Specific Conductance	Gross Beta
Nitrate-Nitrite as N	Radium 226/228
	Tritium

13.6.0 SOIL GAS MONITORING

Extracted soil gas is pumped through a carbon filter and monitored daily with a calibrated Photo ionization Detector (PID) that tests for volatile organic compounds (VOCs) exiting the filter system. In addition, weekly PID readings are recorded from a point between the wellhead and the carbon filter, and a summa canister sample is collected annually to quantify all constituents in the vadose zone. (See table 3-5.)

13.7.0 REPORTING REQUIREMENTS

This section describes the general record keeping and reporting requirements for the Facility's environmental monitoring program.

13.7.1 Records

The facility maintains the following information on-site:

- Field records concerning environmental measurements, sampling events, and related information
- All lab analyses of samples collected from all sources.
- Copies of semi-annual reports

	Table 3-5 **Soil Vapor Extraction Annual Summa Canister Analysis** Compounds Analyzed	
Hexane	Chloroform	Chlorobenzene
o-Xylene	Dichloromethane (Methylene chloride)	Chloroethane (Ethyl chloride)
Trichlorofluoromethane	1,1,2,2-Tetrachloroethane	cis-1,2-Dichloroethene
Ethylbenzene	1,1,2-Trichloroethane	cis-1,3-Dichloropropene
1,2-Dichloropropane	1,2,4-Trichlorobenzene	Dichlorodifluoromethane
Benzene	1,2,4-Trimethylbenzene (Pseudocum)	Dichlorotetrafluoroethane
m&p-Xylene	1,2-Dibromoethane (EDB)	Hexachlorobutadiene
Chloromethane (Methyl chloride)	1,2-Dichlorobenzene	Styrene
1,1,1-Trichloroethane	1,2-Dichloroethane (EDC)	Tetrachloroethene (PCE)
Carbon tetrachloride	1,3,5-Trimethylbenzene/4-Ethyltoluene	trans-1,2-Dichloroethene
1,1-Dichloroethane	1,3-Dichlorobenzene	trans-1,3-Dichloropropene
Trichloroethene (TCE)	1,4-Dichlorobenzene	Vinyl chloride
1,1-Dichlorethene	Benzyl chloride	
Trichlorofluoroethane	Bromomethane (Methyl bromide)	

13.7.2 Environmental Report Content

USEN submits narrative reports for each sampling event 90 days after the analytical information is received and verified. Reports include descriptions of the groundwater flow conditions and groundwater quality conditions, as described below.

- Executive Summary – brief summary of the report, emphasizing key results and conclusions.
- Alternative Source Notification (if required)
- Groundwater Quality Conditions – groundwater sample data and data evaluation
  - Summary of Detection Monitoring Results, including identification of statistically significant increases.
  - Background data evaluation;
- Leachate data, including leachate removal rates, comparison with Action Leakage Rate, leachate levels, and leachate analytical data.
- Soil gas monitoring data
- Groundwater gradients
- Tables, Figures and Appendices, including field and analytical data for the sampling events and corrective measures.

13.8.0 REFERENCES

Currie L.A., 1968. Limits for qualitative detection and quantitative determination: application to radiochemistry. Analytical Chemistry, 40, 586-593.

Elliot, B. 1982. An investigation of selected quality parameters in the Amargosa drainage basin. Desert Research Inst. Publ. 45039, DOE/NV/10162-18, 20 pp.

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Fischer, J.M., 1992. Sediment properties and water movement through shallow unsaturated alluvium at an arid site for disposal of low level radioactive waste near Beatty, Nye County, Nevada. U.S. Geological Survey, Water Resources Invest. Report, 92-4032.

Gibbons, R.D., 1987. Statistical models for the analysis of volatile organic compounds in waste disposal sites. Ground Water, Vol. 25, No. 5, pp. 572-580.

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Hubaux, A., Vos, G., (1970). Decision and detection limits for linear calibration curves. Analytical Chemistry, 42, 849-855.

Kilroy, K.C., 1991. Groundwater conditions in Amargosa Desert, Nevada-California, 1952- 87. U.S. Geological Survey. Water Resources Invest. Report, 89-4101.

McKinley, P.W., Long, M.P., and Benson, L.V., 1991. Chemical analyses of water from selected wells and springs in the Yucca Mountain area, Nevada and southeastern California. U.S. Geological Survey. Open-File Report 90-355.

Nichols, W,D., 1987. Geohydrology of the unsaturated zone at the burial site for low level radioactive waste near Beatty, Nye County, Nevada. U.S. Geological Survey. Water- Supply Paper 2312.

Daniel B. Stephens and Associates, Jan. 1989, Laboratory Analyses of Soil Hydraulic Properties for the Beatty, Nevada Project.

USEPA, 1992. Draft Addendum to Interim Final Guidance – Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities.

13.8.1 <u>Additional References</u>

The following list of references corresponds to reports previously submitted to the Nevada Division of Environmental Management.

Reference 1 Exploratory Boring and Monitoring Well Installation Program, US Ecology, RCRA Facility, Beatty, Nevada; The MARK Group, 2 Volumes, April, 1989.

Reference 2 Drilling, Sampling and Installation of Two Monitoring Wells at the US Ecology, Inc., Beatty, Nevada Facility Rad Site; Geraghty & Miller, Inc., Dec., 1990. (This report was included in the RCRA Facility Investigation (RFI) report submitted on April, 1992)

Reference 3 Drilling and Installation of Six Monitoring Wells at the US Ecology, Inc., Beatty, Nevada Facility Chemical Site; Geraghty & Miller, Inc., May, 1991 (included in RFI report).

Reference 4 Completion Report Vadose Zone Monitoring Well 500 and 501 Beatty, Nevada, IT Corp., July, 1991 (included in RFI report).

Reference 5 Beatty, Nevada Aquifer Test Review; J.L. Grant & Associates, 1990

Reference 6 Statistical Analyses of Groundwater Data at Background Well 313, AquAeTer, 1999

FIGURE 13-1

REGIONAL GROUNDWATER FLOW PATTERNS IN THE AMARGOSA DESERT AND VICINITY

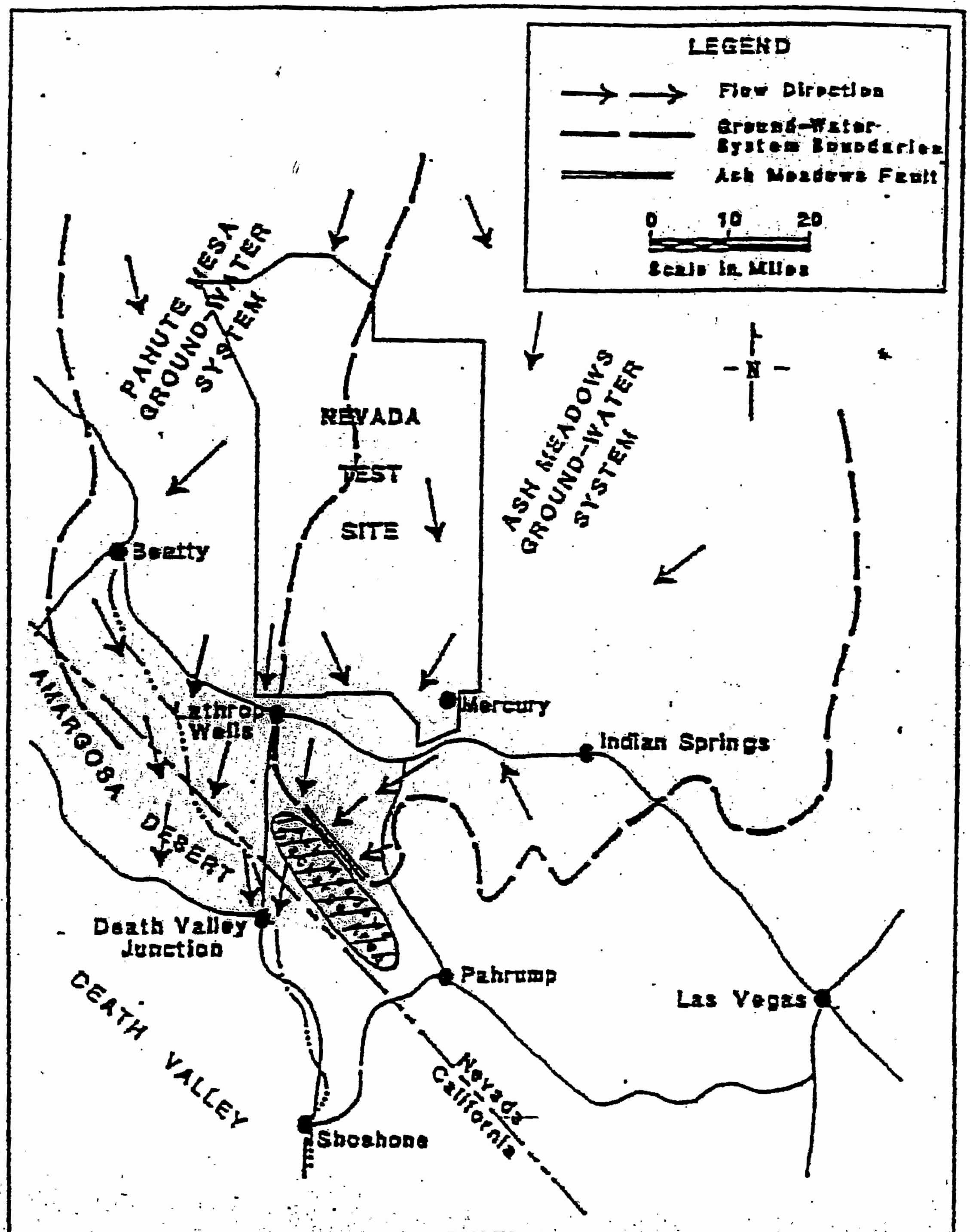
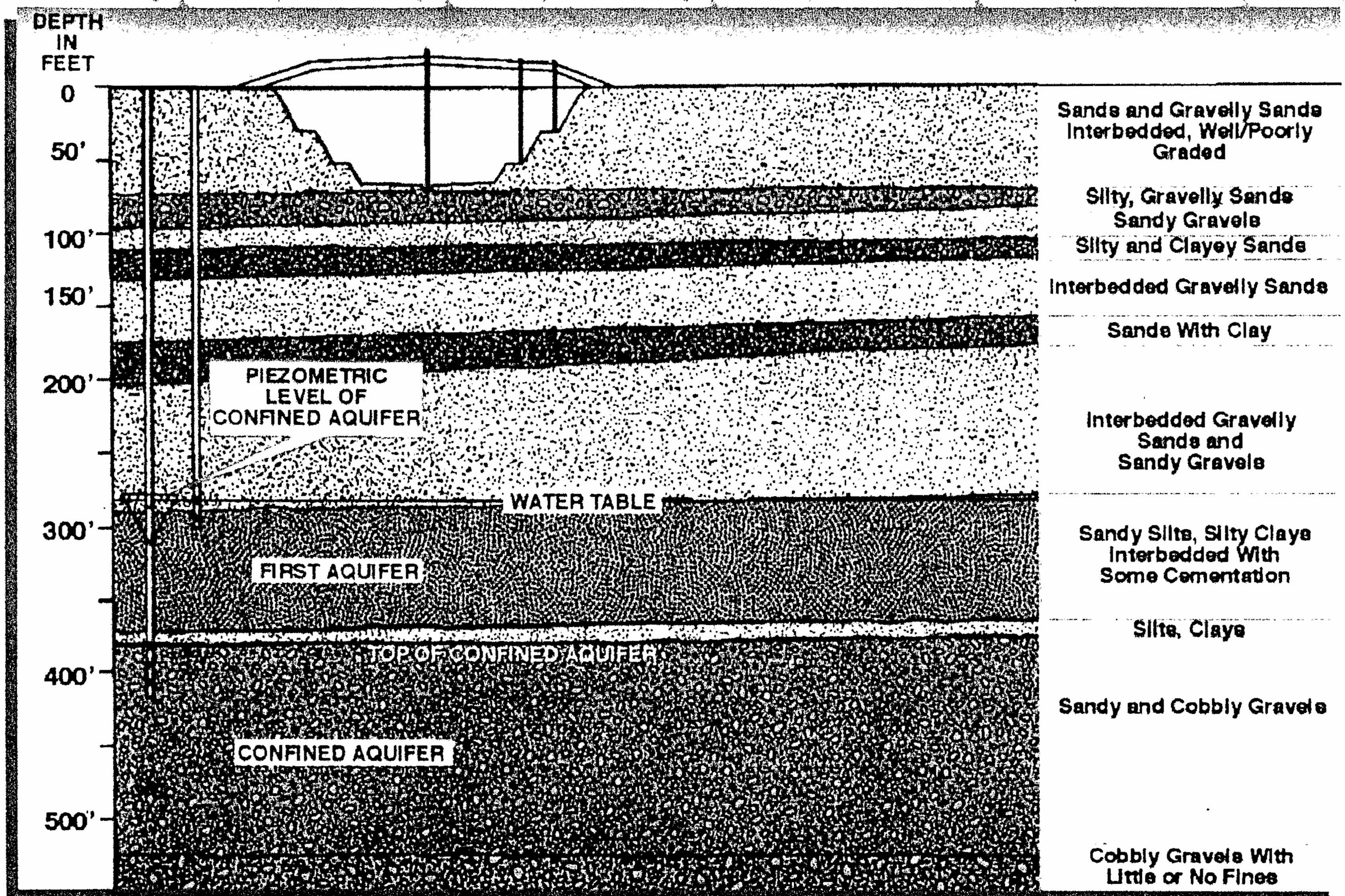


Figure 1. Regional groundwater flow patterns in the Amargosa Desert and vicinity (from Elliott, 1982).

FIGURE 13-2

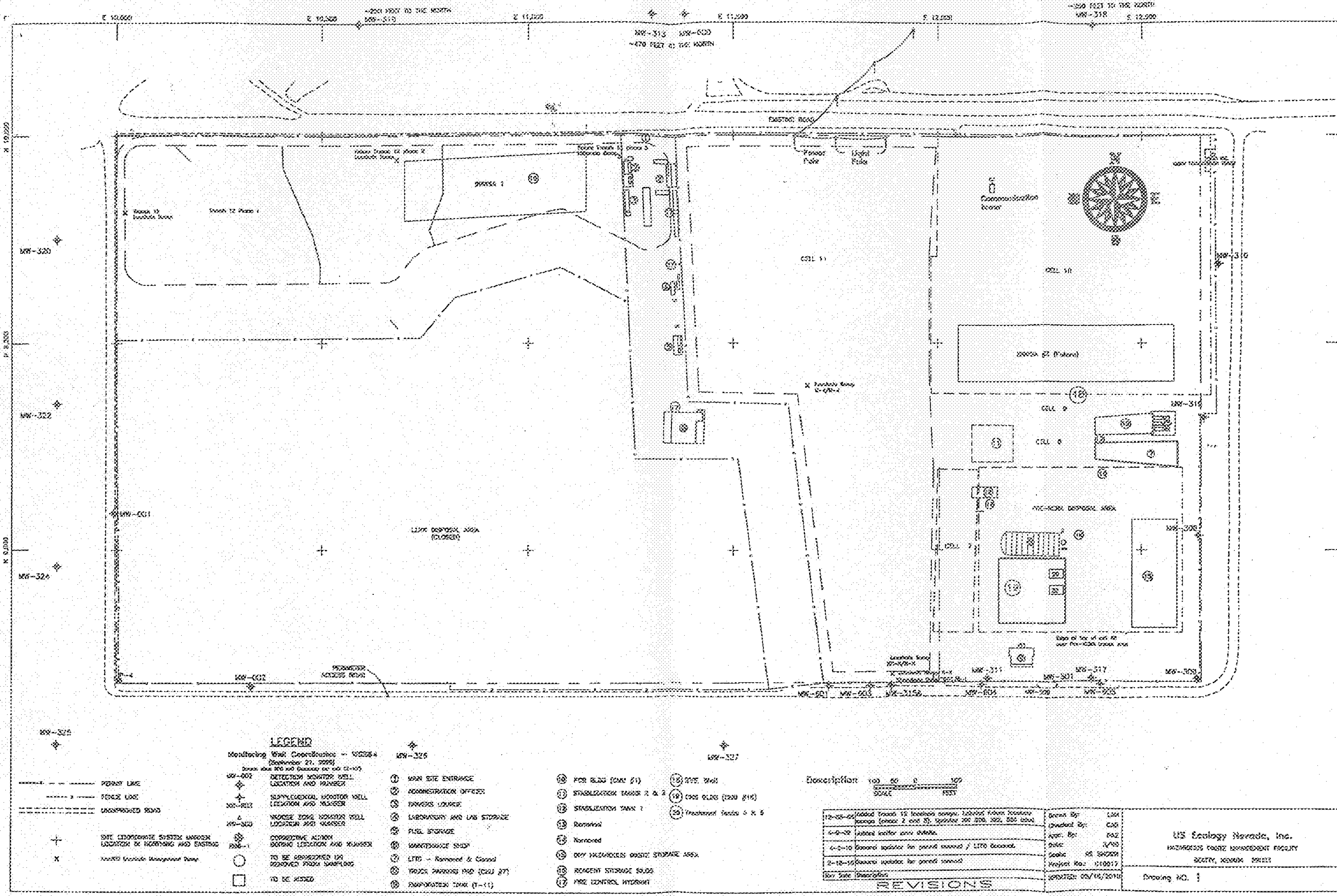
SITE STRATIGRAPHIC PROFILES

Conceptual Subsurface Profile



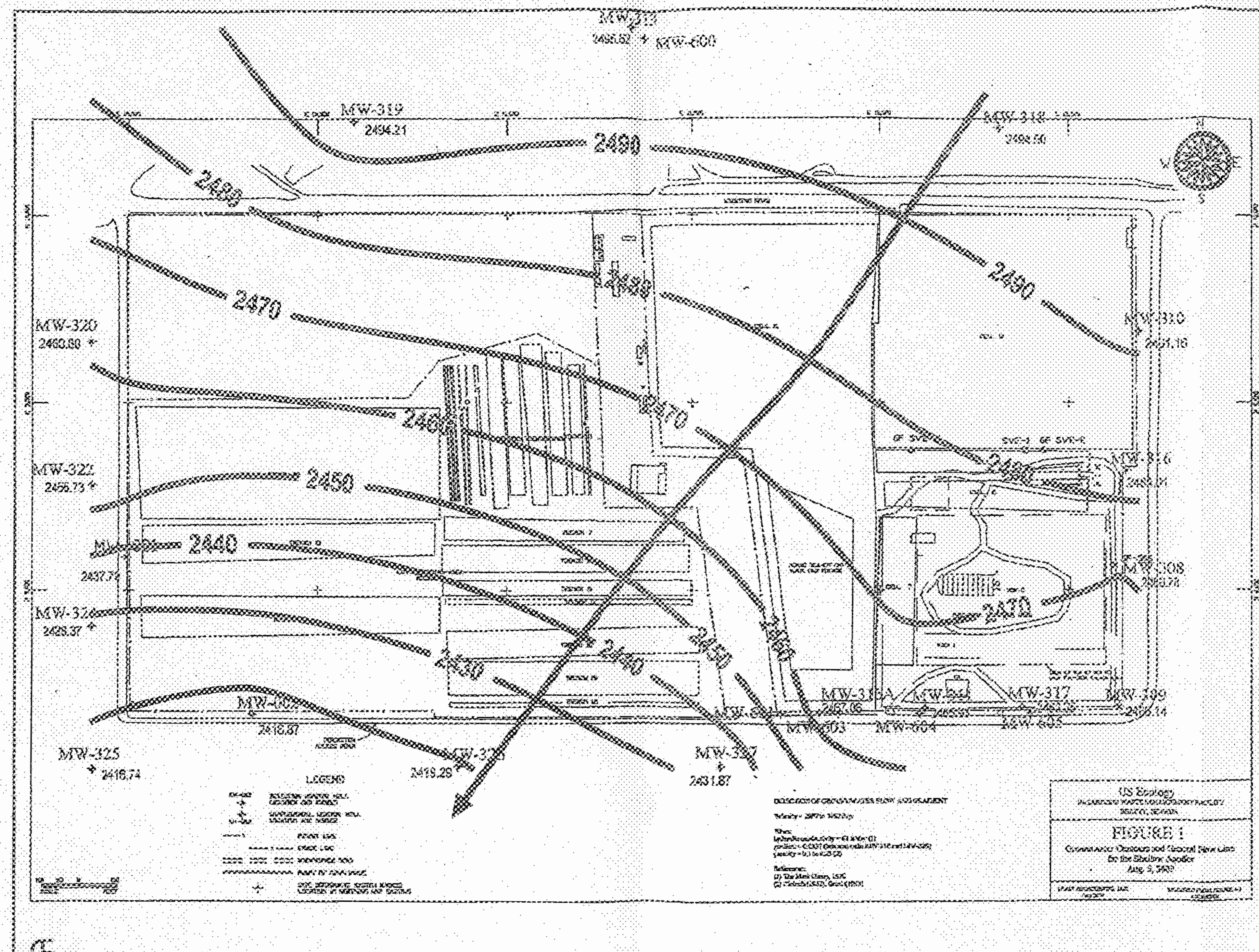
Appendix 13 A

Upper Aquifer Contour Map


LEGEND
PERMIT LINE
FENCE LINE
UNIMPROVED ROAD
MAIN SITE ENTRANCE
ADMINISTRATION OFFICES
DRIVERS LOUNGE
LABORATORY AND LAB STORAGE
FUEL STORAGE
MAINTENANCE SHOP
LTTD – Removed & Closed
TRUCK PARKING PAD (CELL 27)
EVAPORATION TANK (T-11)
STABILIZATION TANKS 2 & 3
STABILIZATION TANK 1
Removed
DRY HAZARDOUS WASTE STORAGE AREA
REAGENT STORAGE SILOS
FIRE CONTROL HYDRANT
TO BE ABANDONED OR REMOVED FROM SAMPLING
CELL 11
CELL 10
CELL 9
CELL 8
CELL 7
LLRW DISPOSAL AREA (CLOSED)
PERIMETER ACCESS ROAD
EXISTING ROAD
Communication Tower
Description
SCALE
FEET
REVISIONS
US Ecology Nevada, Inc.
HAZARDOUS WASTE MANAGEMENT FACILITY
Drawing NO. 1

Appendix 13 B

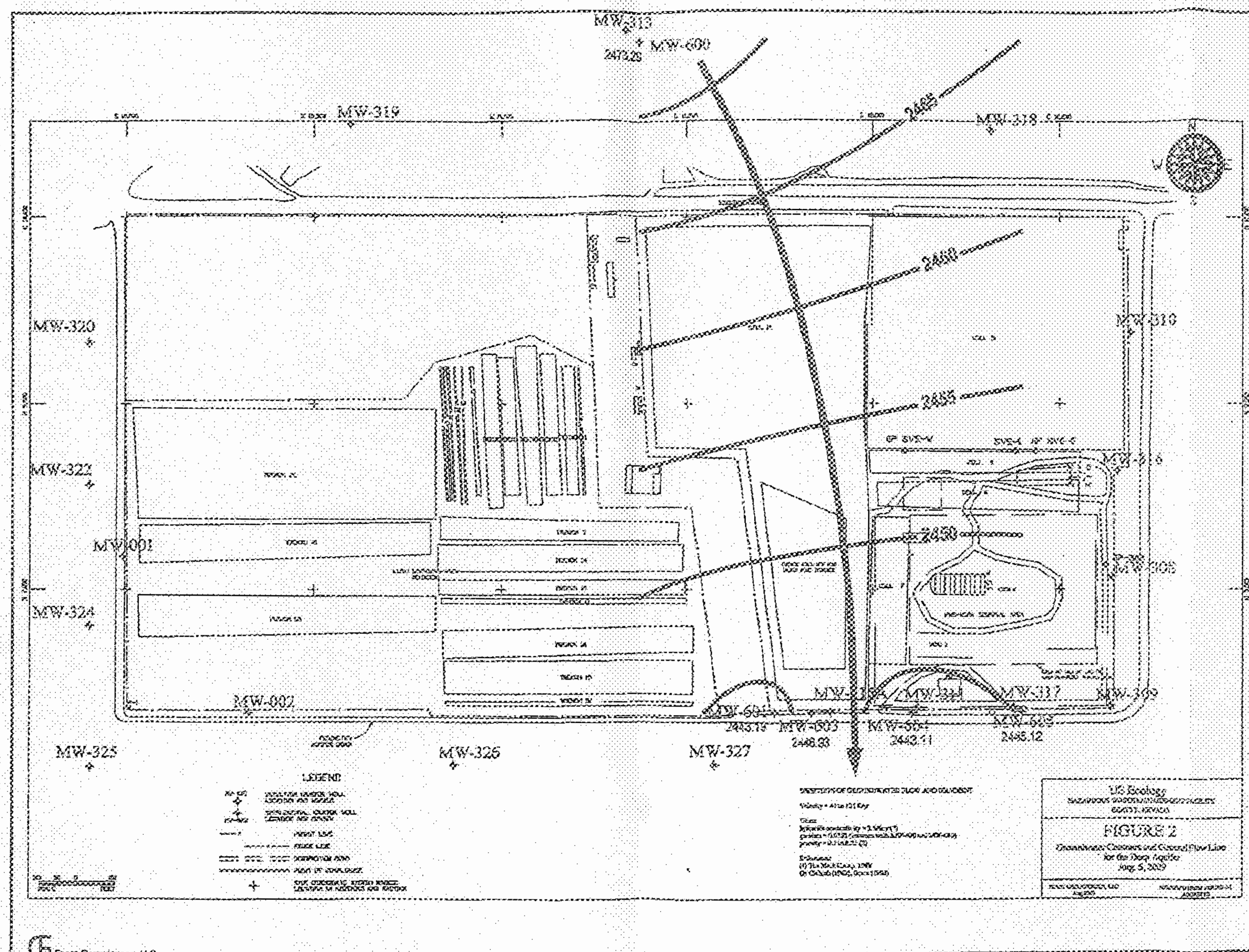
Confined Aquifer Potentiometric Contour Map



MW-319
2494.21
MW-320
2460.80
MW-322
2456.73
2437.72
MW-324
2428.37
MW-325
2418.74
2418.87
MW-326
MW-310
2491.16
MW-316
MW-308
MW-317
MW-309
MW-603
MW-604
MW-327
2431.87
MW-600
2490
2480
2470
2460
2450
2440
2430
LEGEND
US Ecology
FIGURE 1

Appendix 13 C

Hydraulic Conductivity and Porosity Calculations



MW-313
2473.25
MW-600
MW-319
MW-318
2465
2460
2455
2450
MW-310
MW-316
MW-308
MW-320
MW-322
MW-001
MW-324
MW-002
MW-325
MW-326
MW-327
MW-601
2443.19
MW-603
2446.83
MW-604
2443.11
MW-317
MW-309
2445.12
LEGEND
US Ecology
FIGURE 2
Aug. 5, 2009

Calculations of
Hydraulic Conductivities
Upper Aquifer

1. Reference : Law Engineering, 1981

   Transmissivity (T) = 7,000 gpd/ft
   Average Saturated Thickness (h) = 11 feet (Mark Group, 1989)
   Hydraulic Conductivity (K) = T/h
   K= 7,000/11 = 636 gallons per day (gpd)/ ft^2

   Converting to feet/ sec
   gpd/ ft^2 X 1.55 X 10^{-6} = ft/sec (Freeze & Cherry)
   636 gpd/ ft^2 X 1.55 X 10^{-6} = 9.86 X 10^{-4} ft/sec

2. Reference: Mark Group, 1989
   K= 184 gpd/ ft^2

   Converting to feet/ sec
   184 gpd/ ft^2 X 1.55 X 10^{-6} = 2.85 X 10^{-4} ft/sec

3. Reference: Mark Group, 1989
   K= 455 gpd/ ft^2

   Converting to feet/ sec
   455 gpd/ ft^2 X 1.55 X 10^{-6} = 7.05 X 10^{-4} ft/sec

4. Reference: Emcon, 1973
   K= 500 gpd/ ft^2

   Converting to feet/ sec
   500 gpd/ ft^2 X 1.55 X 10^{-6} = 7.75 X 10^{-4} ft/sec

5. Reference: Grant, 1990
   T= 4,000 gpd/ft
   Average Saturated Thickness (h) = 11 feet (Mark Group, 1989)
   Hydraulic Conductivity (K) = T/h
   K= 4,000/11 = 363.6 gallons per day (gpd)/ ft^2

   Converting to feet/ sec
   363.6 gpd/ ft^2 X 1.55 X 10^{-6} = 5.64 X 10^{-4} ft/sec

Average K = 9.86×10^{-4} ft/sec
2.85×10^{-4} ft/sec
7.05×10^{-4} ft/sec
7.75×10^{-4} ft/sec
$\underline{5.64 \times 10^{-4}\ \text{ft/sec}}$

32.15×10^{-4} ft/sec/ 5 = 6.63×10^{-4} ft/sec

Porosity Calculations

Reference: Freeze & Cherry

$N = 1 - Pb/Ps$

Using the samples taken from the 400, 402c and 403 borings

From boring 400 at a depth of 273 feet $Pb = 1.45$ $Ps = 2.22$ so
$N = 1 - (1.45/2.22) = 0.35$

From boring 402 c at a depth of 271 feet $Pb = 1.62$ $Ps = 2.38$ so
$N = 1 - (1.62/2.38) = 0.31$

From boring 403 at a depth of 279 feet $Pb = 1.38$ $Ps = 2.31$ so
$N = 1 - (1.38/2.31) = 0.4$

The average porosity is then computed to be 0.35