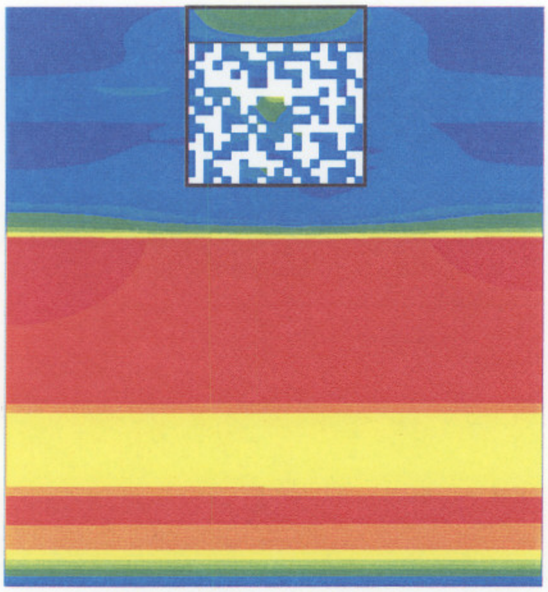
WSRC-TR-2000-00059

Recommendations for Phase II Vadose Zone Characterization and Monitoring at the E-Area Disposal "Slit" Trenches and Mega-Trench (U)



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Recommendations for Phase II Vadose Zone Characterization and Monitoring at the E-Area Disposal "Slit" Trenches and Mega-Trench (U)

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Executive Summary

A Radiological Performance Assessment Maintenance Plan (SDW,1997) was prepared in response to Recommendation 94-2 made by the Defense Nuclear Facility Board (DNFSB) and establishes a requirement for preparing and implementing the E-Area Monitoring Program (EMOP). Based on the results of a statistical analysis of the existing groundwater monitoring network at the Burial Ground and a review of alternative monitoring strategies, a vadose zone monitoring system (VZMS) was selected for the EMOP. The EMOP (SWD, 1998) was prepared in 1998 and describes a phased approach for implementation. The VZMS was designed to detect contamination before it reached the water table and includes collection of pore water samples from sediments above the water table and monitoring pore water pressure and water content of the unsaturated sediments that comprise the vadose zone. This information is then used to calculate the flux of contaminants for comparison with the requirements specified in the E-Area Performance Assessment

In 1999, Phase I of the EMOP was implemented by installation of advanced tensiometers, water content sensors, and vertical and angled lysimeters. In addition several cone penetrometer logs of resistivity and stress ratio were collected and shelby tube samples were collected for measurement of hydraulic properties. Results from Phase I of the EMOP show that the general strategy and techniques selected are adequate for monitoring moisture conditions and contaminant migration.

Data from Phase I of the EMOP was used to prepare a numerical model of moisture flow beneath a typical disposal trench. The moisture contents, pore pressure, and flow patterns predicted by the model were compared with field data and used to improve the components of Phase II of the EMOP. Based on these data and the numerical analysis of moisture movement at a typical disposal trench, the objectives of the Phase II EMOP characterization and monitoring are:

1) Collect additional data on moisture release properties to minimize uncertainty in flux calculations.
2) Use neutron probè to measure moisture profile and validate water content sensors.
3) Calibrate neutron probe with site specific calibration curve.
4) Locate tensiometers to provide data useful for calculation of hydraulic gradient.
5) Incorporate new data from EMOP in conceptual of moisture flow at disposal trenches to improve flux calculations.

Meeting these objectives will provide the information necessary to determine compliance with the requirements of the E-Area Performance Assessment and protect groundwater resources

Background

Low activity waste (<200mR/h @ 5cm) generated by operations at the Savannah River Site (SRS) are disposed of at the E-Area Low Level Radioactive Waste Disposal Facility (E-Area LLRWD). Job control waste and scrap metal are placed in metal containers and disposed of in the Low Activity Waste Vaults (LAWV). Job control waste consists of contaminated protective clothing, including plastic suits, shoe covers, lab coats and plastic sheeting. Contaminated tools, process equipment, and laboratory equipment are the primary sources of scrap metal disposed of in the LAWV. The decommissioning of closed facilities at the SRS occasionally generates low activity waste consisting of broken concrete, re-bar, lumber, and soil. This waste typically does not require containerization and is disposed of at the E-Area LLRWDF in "slit trenches" hereafter, referred to as disposal trenches. Figure 1 shows the location of the E-Area LLRWD, the disposal trenches.

SRS is currently developing the conceptual design for a "Mega-Trench" to replace the LAWV for disposal of containerized low activity waste. The proposed location for the Mega-Trench is shown on Figure 1. The Mega-trench will be an unlined trench with a contoured base to direct runoff to a sump in one end of the trench. Runoff collected in the sump will be analyzed and then disposed of as necessary.

A Radiological Performance Assessment Maintenance Plan (SDW,1997) was prepared in response to Recommendation 94-2 made by the Defense Nuclear Facility Board (DNFSB) and establishes a requirement for preparing and implementing the E-Area Monitoring Program (EMOP). The EMOP (SWD, 1998) was prepared in 1998 and describes a phased approach for implement a vadose zone monitoring system (VZMS). The VZMS was designed to detect contamination before it reached the water table and includes collection of pore water samples from sediments above the water table and monitoring pore water pressure and water content of the unsaturated sediments that comprise the vadose zone. This information is then used to calculate the flux of contaminants for comparison with the requirements specified in the E-Area Performance Assessment

In 1999, SRS implemented Phase I of the EMOP and began monitoring pore water in the unsaturated zone beneath one of the disposal trenches that had been completely filled and covered with soil. This document contains recommendations for Phase II of the EMOP to address characterization and monitoring needs at the disposal trenches and the location for the proposed Mega-Trench.

Phase I Results

Equipment used for Phase I monitoring consists of advanced tensiometers, water content reflectometers, standard lysimeters. During the installation of the monitoring equipment several "undisturbed" samples were collected and sent to a geotechnical laboratory to determine moisture release characteristics and saturated hydraulic conductivity of various sediment layers beneath the disposal trenches (Holmes-Burns, 1999).

The laboratory data on moisture release characteristics showed a large variation in material properties with soil type. Moisture release curve parameters for the Van Genuchten function (Van Genuchten, 1980) (1) were estimated from the laboratory data using nonlinear curve fitting software, RETC. Figure 2 and Table 1 shows the moisture release data from the laboratory and the estimated van Genuchten parameters. The Van Genuchten function is used with the van Genuchten-Mualem equation (Van Genuchten, 1980) (2) to determine relative hydraulic conductivity for flux calculations and moisture modeling.

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1+(\alpha h)^n\right]^{1-1/n}} \qquad (1)$$

θ = water content
θ_r = residual water content
θ_s = saturated water content
h = soil water pressure
α = curve shape parameter
n = curve shape parameter

$$K(S_e) = K_0 S_e^L \left\{1 - \left[1 - S_e^{n/(n-1)}\right]^{1-1/n}\right\}^2 \qquad (2)$$

K = hydraulic conductivity
S_e = relative saturation
L = pore tortuosity/connectivity parameter

Water content and pore pressure were measured at multiple depths and recorded on an hourly basis using advanced tensiometers, WCRs, and a Campbell datalogger at each of the three AT instrument bundles (ATs). Figures 3, 4, and 54 show the results from the ATs. Figure 3 shows the typical response for an AT instrument bundle. The moisture content is relatively constant at each depth, with the exception of 55 feet in AT5 which has some variation. This variation reaches it's maximum at the same water content, which happens to be approximately the water content at saturation and may be the result of a rise in the water table.

E-Area personnel periodically read the suction on the lysimeters that were installed in the AT instrument bundles. After the suction is read, additional vacuum is placed on the lysimeter using a hand pump. In most cases the rapid increase in suction that resulted from the additional vacuum placed on the lysimeter was detected by the ATs and produced downward spikes on the pore pressure graphs, Figures 3, 4, and 5. The suction in most monitoring intervals quickly returned to equilibrium. Pore water samples were periodically collected from lysimeters in the AT instrument bundles for analysis of tritium and other radionuclides (Holmes-Burns, 1999). The sampling events had the same effect on the ATs as did the previously described suction readings and are represented by colored circles on each of the pore pressure graphs. In July 1999 maintenance was performed on several instruments in the AT6 and AT7 bundles as evidenced by the significant increase in pore pressure at these times. Additional analysis of the pore pressure and water content trends recorded by the ATs should be performed to confirm proper operation of the ATs and separate responses due to sampling and maintenance of ATs from natural variations due to changing site conditions.

Table 1. Van Genuchten parameters for undisturbed samples

Sample ID	θr[a]	θs[a]	α[b]	n[b]
ST3: 11-13 feet	0.21	0.32	0.029	1.51
ST5; 20-21.9 feet	0.17	0.38	0.041	1.63
ST6; 23-25 feet	0.33	0.46	0.007	1.54
ST8; 41-43 feet	0.14	0.36	0.017	1.96
ST11; 64-65.2	0.13	0.39	0.018	1.74

[a] from laboratory, [b] estimate from RETC

Moisture Modeling

Basis

Field and laboratory data from 1999 was combined with literature data into a 2 dimensional flow model of a hypothetical disposal trench. FACT, a finite element code for modeling variably saturated flow and contaminant transport was used for the work. Lithologic core descriptions and cone penetrometer logs of resistivity and stress ratio were used to develop the conceptual hydrogeologic model. The model included 8 layers with different material properties to simulate the finer grain materials (layers 1-5) that overly coarser grained materials (Layers 6-8), Figure 6. The coarser grained materials were divided into 3 layers with a larger grained sand (layer 7) in the middle of the coarser grained materials. Five shelby tube samples were collected and analyzed to determine hydraulic properties. These samples correspond to Layers 2,4,5,6, and 8. Hydraulic properties for layers 1, 3, and 7 were estimated using the core descriptions and information from Schapp et al., 1998. Using the data collected in Phase I monitoring each layer was assumed to be anisotropic and homogeneous with a k_h:k_v of 30. Data collected during Phase II characterization and monitoring will be used to refine the assumption and incorporate more heterogeneity. The recharge was estimated to be 15 inches per year based on the work of Flach etal., 1999.

Results

Results from the steady state base conditions (no trench) used in the model show that without a disposal trench all flow is vertically downward as would be expected, Figure 7c. Suction pressure varies with depth and has rapid increase/decrease adjacent to the boundaries of layers with different material properties. The coarser grained sand from 45 to 55 feet is dryer and has lower suction pressure than the overlying and underlying finer grained sands and is shown by the yellow band in Figure 7b. This contrast in material properties produces increased saturation immediately above the coarse grained sand.

Waste disposal in a trench was simulated by randomly removing 50 percent of the finite element grid in the area of the trench, 20 feet wide and 15 feet deep, from the model for flow calculation. Five feet of backfill overlie the trench. Layering of the remaining materials within the trench was removed and the hydraulic properties were adjusted to simulate less compacted and more conductive material in the trench. The presence of waste and disturbed soil within the trench produced conditions that draw water into the sides of the trench and discharge it out the bottom, Figure 8. The increased flow out of the bottom of the trench caused flowlines to spread 5 to 10 feet outward from the bottom of the trench, Figure 8c. The spread of the flowlines indicates that samples collected from outside of the trench may contain water that has migrated through waste disposed near the end and sides of the trench. This flow pattern is the direct result of increased conductivity of the soil in the trench.

The model can best be improved by incorporating more heterogeneity within the identified layers. Three-dimensional models of cone penetrometer (CPT) data such as resistivity and stress ratio can be used to integrate heterogeneity if the relationship between CPT data and hydraulic properties is known. The refined model for the disposal trenches can be used to evaluate the effectiveness of the monitoring network, aid in flux calculations, and study alternative trench designs and operating scenarios.

Table 2. Observations from modeling results.

Observation	Impact on Monitoring Design	Correlation with Field Data
Large variability in moisture retention properties of sediments beneath disposal trenches	1. Must be careful placing suction lysimeters to maximize success of sampling events. 2. Need additional analysis of moisture retention properties to incorporate heterogeneity into model and flux calculations.	
Moisture contents vary greatly depending on sediment layer	1. Some layers will produce larger water samples than others. 2. Suction lysimeters should be installed in wetter layers. 3. Compare neutron probe with WCR in ATs to verify WCR 4. Consider using fewer WCRs at locations that have a neutron access port.	1. Simulated moisture content was higher than that measured in field using WCRs. 2. Updated model will improve correlation between model and field data and subsequently upgrade flux calculations. 3. Measure moisture profile using a neutron probe to verify general trends in model.
Rapid changes in saturation at boundaries between sediment layers.	1. Must be careful placing suction lysimeters to maximize success of sampling events. 2. Need additional site specific moisture retention data for all layers for use in flux calculation.	Currently, there is not sufficient field data to compare with simulated moisture profiles. New data will be used to evaluate and improve flux calculations.
Rapid changes in pressure head at boundaries between sediment layers.	1. Measurement of pore pressure at a single point within layers is not adequate to determine hydraulic gradient and contaminant flux. 2. Tensiometers should be installed at the top and bottom of primary layers involved in contaminant transport	Simulated pore pressures are lower than those observed in the field. This made lead to an overestimation of tritium flux resulting from artificially elevated hydraulic conductivity used in the flux calculations.
Flow lines for water entering the model outside the trench bend toward the trench.	The disposal trench will influence readings from shallow tensiometers adjacent to the trench.	Only one tensiometer is installed in the shallow sediments above the bottom of the trench.
Spreading of flow lines beneath disposal trench.	1. Suction lysimeters located close to the edge of disposal trenches can collect water that has migrated through the waste in the trench. 2. The 3 dimensional nature of water migration through the trench can produce unique contaminant profiles that are not completely explained by a nest of vertical lysimeters.	Vertical lysimeters outside the trench have elevated levels of tritium.

Characterization

In Phase I sediment samples were collected from several depths at a single location and analyzed to determine their hydraulic properties. Results from Phase I monitoring and moisture modeling revealed the presence of layered sequence of sediments and showed it's impact on moisture profiles and movement beneath a disposal trench. Similar information should be collected to study the variability of hydraulic properties within layers and determine it's effect on moisture movement. In order to study the lateral variability additional samples should be collected from different locations in the same layer and analyzed to determine hydraulic properties. Numerous studies have been conducted to relate sediment texture to hydraulic properties such as the parameters for the van Genuchten function for moisture retention. Schapp et al., 1998, presents typical moisture release parameters for 9 USDA Soil Classification System textures based on the analysis of 1209 samples and presents a model for predicting parameters for the van Genuchten functions.

During the installation of the Phase II lysimeters and advanced tensiometers sediment samples should be collected for grain size analysis (SSC), moisture release curve determination, saturated hydraulic conductivity, bulk density, and porosity. The results from these analyses can be used to corroborate the relationship in the Schapp et al model for use at the disposal trench and Mega-trench sites and determine the relationship between CPT logs and SSC sediment texture. Figure 9 is map showing the locations of the lysimeters and AT that should be installed around trench 2, 3, and 4. Sampling locations for the proposed Mega-Trench are shown on Figure 10. All of this data can be integrated in the model incorporate more heterogeneity and subsequently improve simulations.

Sediment samples should be collected from boreholes for the vertical lysimeters and ATs for moisture content analysis to calibrate the Troxler 4300 neutron probe for use in Sch5 SS access tubes in SRS sediments. The samples should be collected and placed in leak proof 40 mL glass vials for analysis in the laboratory by ESSOP 2-118, Rev.1 Procedure for Preparing, Sampling, Weighing, and Data Analysis of Moisture Content Sediment Samples. The neutron probe should be used to measure moisture content in the field on the same day and at the same depth that the samples for moisture content analysis are collected. A calibration curve will then be developed using the procedures in the manual for operating the neutron probe. Results from the neutron probe calibration should also be used to verify operation of the WCRs installed with the ATs.

Monitoring

Disposal Trenches

Additional ATs, vertical lysimeters, and neutron access ports should be installed around disposal trenches 2,3, and 4, Figure 9 to supplement the monitoring equipment installed around and beneath disposal trench 1. Suction lysimeters should also be installed near contacts between coarser and finer grained layers for pore water sampling to increase likelihood that suction cups will be installed in moist sediments range and improve their ability to collect pore water samples. Advanced tensiometers and WCRs should be installed at the top and bottom of selected sediment layers to improve the calculation of hydraulic gradient and flux within the layer. Cone penetrometer logs and neutron probe data can be used to identify the specific depths for instrumentation.

A new technology for sampling tritium in the unsaturated zone should be tested at the disposal trench. The technology, known as the Cold Wringer system, is based on condensing moisture in the soil vapor and analyzing the condensate for tritium. To test the technology nested soil vapor extraction (SVE) wells should be installed next to an AT bundle using hollow stem augering and 1" PVC casing and slotted well screen. Soil vapor will be pumped from each SVE well and through a condenser until enough water has been collected for analysis. This technique will sample a larger volume of sediment than will a conventional suction lysimeter and as a result may be a more robust method for monitoring to identify if unacceptable levels of tritium are migrating from the disposal trenches. The specific field activities necessary to install all of the instruments are contained in the outline below.

Mega-Trench

Monitoring equipment for the Mega-Trench should be installed in 2 phases. The first phase would involve the installation of Advanced Tensiometer equipment bundles and neutron probe access ports prior to construction of the Mega-Trench. The specific depths for ATs will be identified using the same strategy discussed above for the disposal trenches. Consideration should be given to omitting the WCRs at the Mega-Trench in lieu of neutron access ports depending on the outcome of the validation of the existing WCRs at the disposal trenches.

Following construction of the Mega-Trench suction lysimeters should be installed at 2 depths beneath the sump to monitor infiltration. Sampling lines can be extended along the side of the trench to the surface during closure to allow sampling after the trench has been closed. Consideration should be given to installing additional suction lysimeters in the floor of the trench. These suction lysimeters could be progressively installed as the trench is filled to minimize interference with operations and reduce the potential for damage of the samplers. If the Cold Wringer sampling technique proves to be viable could be combined with the suction lysimeters to produce a more robust monitoring system for the Mega-Trench. Specific recommendations can be made after the design is finalized and preliminary plans for operation of the trench have been prepared. The specific field activities necessary to install all of the instruments are contained in the outline below.

A. Neutron Probe Access Port-Disposal Trench

- A.1. Neutron Probe access port, ~ 70 feet deep
  - A.1.1. Install using CPT
  - A.1.2. Constructed using Schd. 5 SS casing
  - A.1.3. Two locations, NP11, NP12
- A.2. One CPT for additional characterization, west of trench #4, CPTU-18

B. Lysimeters-and Cold Wringer System-Disposal Trench

- B.1. Lysimeters
  - B.1.1. Four locations, VL1, VL2, VL3, VL4
  - B.1.2. Four to five depths at each location, based on CPT data
  - B.1.3. Ceramic cup
  - B.1.4. Install using auger drilling
  - B.1.5. Continuous split spoon location at end of disposal trench #2, VL4
  - B.1.6. Grain size analysis, up to 10 samples, VL4
  - B.1.7. Moisture content analysis on 1-2 foot interval, VL4
- B.2. Cold Wringer System
  - B.2.1. Close to AT5 location
  - B.2.2. Install using auger drilling, 8" borehole
  - B.2.3. 1" PVC casing
  - B.2.4. Four depths
    - B.2.4.1. 20-25ft
    - B.2.4.2. 30-35ft
    - B.2.4.3. 40-45ft
    - B.2.4.4. 55-60ft
  - B.2.5. Slotted screen, 20 slot, 5 feet long
- B.3. Sump, 2 feet long

C. Neutron Probe Access Port-Mega Trench

- C.1. Neutron Probe access port, ~ 70 feet deep
  - C.1.1. Install using CPT
  - C.1.2. Constructed using Schd. 5 SS casing
- C.2. Installed at 4 AT locations

D. Lysimeters-Mega Trench
- D.1. 5 locations in sump
  - D.1.1. Two depths at each location
- D.2. Install using auger drilling
- D.3. Ceramic cup

E. AT installation Disposal Trench/Mega Trench
- E.1. Two at disposal trench, AT8, AT9
- E.2. Four at Mega-Trench
- E.3. Install using auger drilling
- E.4. Shelby tube
  - E.4.1. 6 each, at disposal trench (AT8, AT9)
  - E.4.2. 6 each at Mega Trench
    - E.4.2.1. 2 of 4 locations
  - E.4.3. Moisture release curves
  - E.4.4. Saturated hydraulic conductivity
- E.5. Split spoon
  - E.5.1. Continuous, except at shelby tube depths, AT8, AT9 and Mega Trench #2 and #4
  - E.5.2. Grain size analysis, up to 10 samples at each location
  - E.5.3. Moisture content analysis, 1-2 foot interval

Recommendations

Characterization and monitoring in Phase I of the EMOP provided valuable data on the hydraulic properties of the sediments at the disposal trenches, pore pressure and moisture content of different layers, and performance of the Advanced Tensiometer instrument bundles. Based on these data and the numerical analysis of moisture movement at a typical disposal trench, the objectives of the Phase II EMOP characterization and monitoring are:

1) Collect additional data on moisture release properties to minimize uncertainty in flux calculations.
2) Use neutron probe to measure moisture profile and validate water content sensors.
3) Calibrate neutron probe with site specific calibration curve.
4) Locate tensiometers to provide data useful for calculation of hydraulic gradient.
5) Incorporate new data from EMOP in conceptual of moisture flow at disposal trenches to improve flux calculations.

Meeting these objectives will provide the information necessary to determine compliance with the requirements of the E-Area Performance Assessment and protect groundwater resources. Tables 3 and 4 summarize the recommended field activities necessary to meet the previously stated objectives for Phase II of the EMOP.

Table 3. Summary of recommended sample collection/analysis and equipment installation for disposal trenches.

Type	Number	Use
Moisture release curves	12	Define hydraulic properties for flux calculations
Saturated Hydraulic Conductivity	12	
Sieve Analysis	36	Define hydraulic properties for flux calculations
Moisture Content Analysis	120	Calibrate neutron probe and verify operation of WCRs
Shelby Tube Sample	12	Samples for moisture release curves
Split Spoon Sampling Locations	3	
Cone Penetrometer Push	3	Identify intervals for installing lysimeters and ATs
Neutron Access Port	2	Measure moisture content profile for flux calculations and verify ATs
Vertical Lysimeter	20	Collect samples for radio isotope analysis
Advanced Tensiometer	2	Collection of pore water samples and monitoring of water content and pore pressure
Cluster of 4ea, 1" wells	1	Wells for testing innovative technology for sampling tritium in the vadose zone

Table 4. Summary of recommended sample collection/analysis and equipment installation for Mega-Trench.

Type	Number	Use
Moisture release curves	12	Define hydraulic properties for flux calculations
Saturated Hydraulic Conductivity	12	
Sieve Analysis	20	Define hydraulic properties for flux calculations
Moisture Content Analysis	60	Calibrate neutron probe and verify operation of WCRs
Shelby Tube Sample	12	Samples for moisture release curves
Split Spoon Sampling Locations	2	
Cone Penetrometer Push	4	Identify intervals for installing lysimeters and ATs
Neutron Access Port	4	Measure moisture content profile for flux calculations and verify ATs
Vertical Lysimeter	8	Collect samples for radio isotope analysis
Advanced Tensiometer	4	Collection of pore water samples and monitoring of water content and pore pressure

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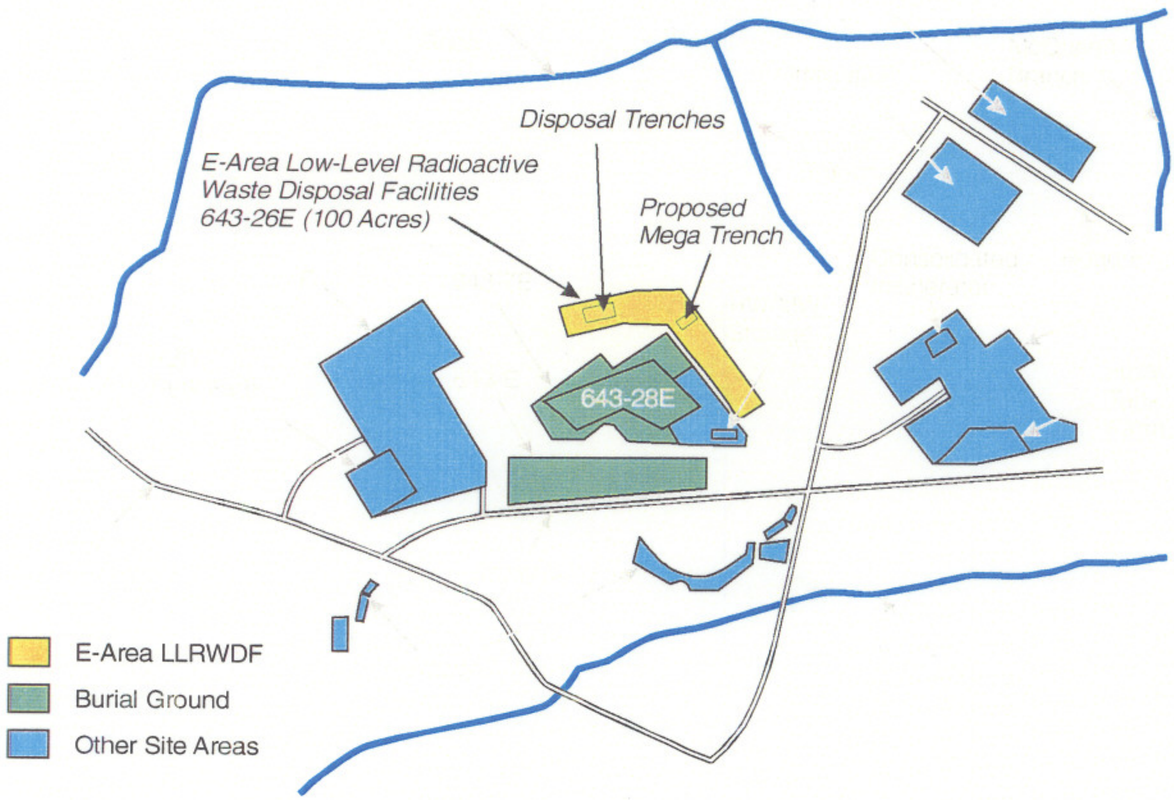

Figure 1. Location Map for E-Area Low Level Waste Disposal Facility.

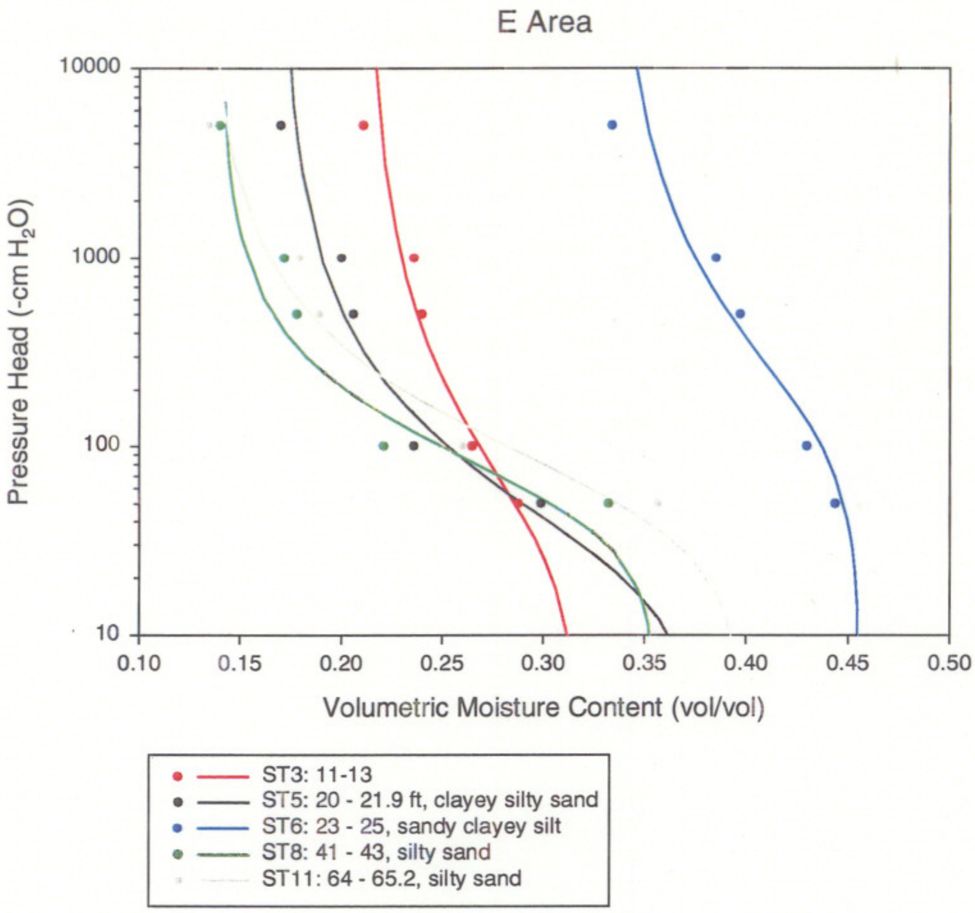

Figure 2. Laboratory measured moisture retention data and nonlinear least squares fit from RETC

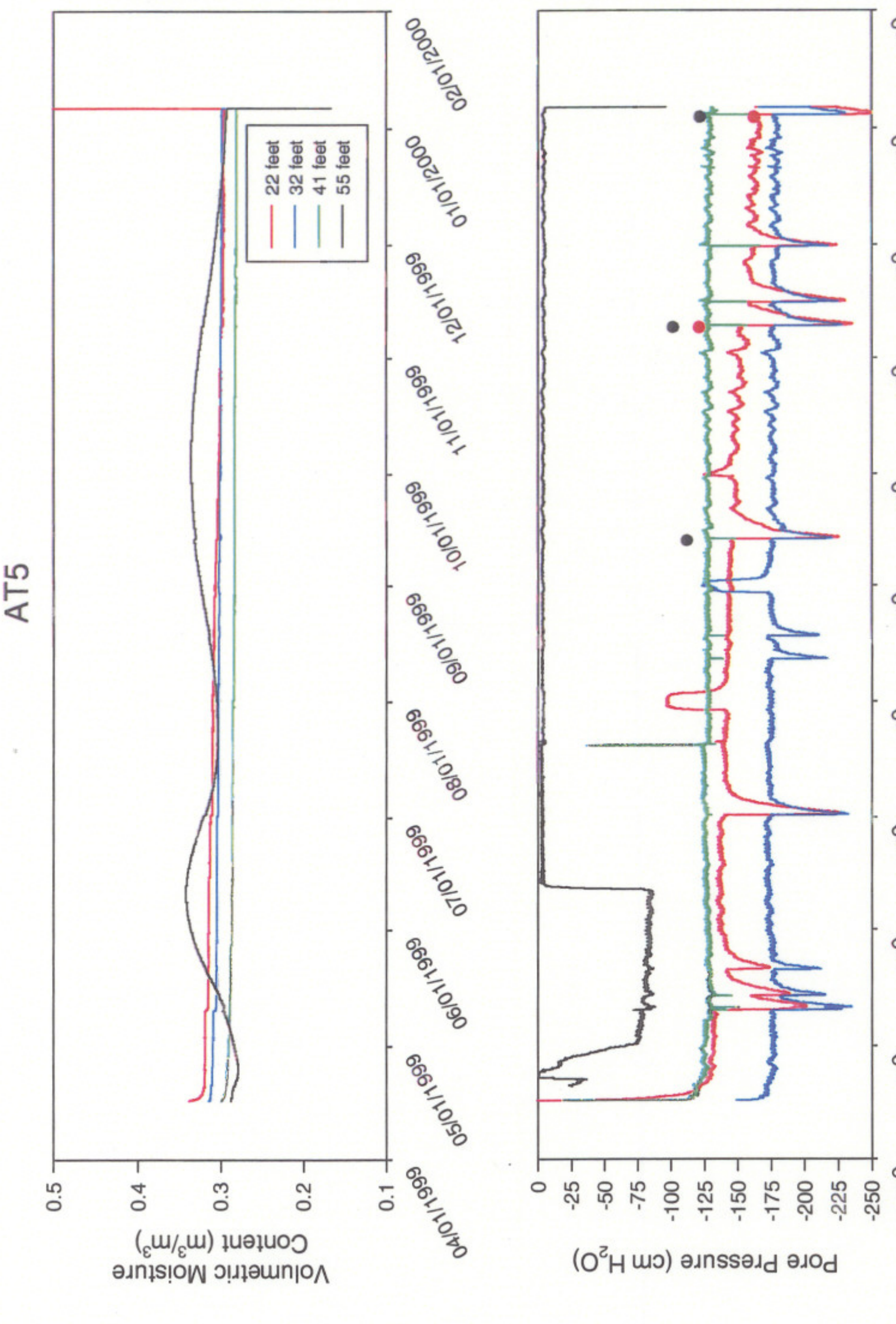

Figure 3. Volumetric moisture content and pore pressure trends for Advanced Tensiometer AT5

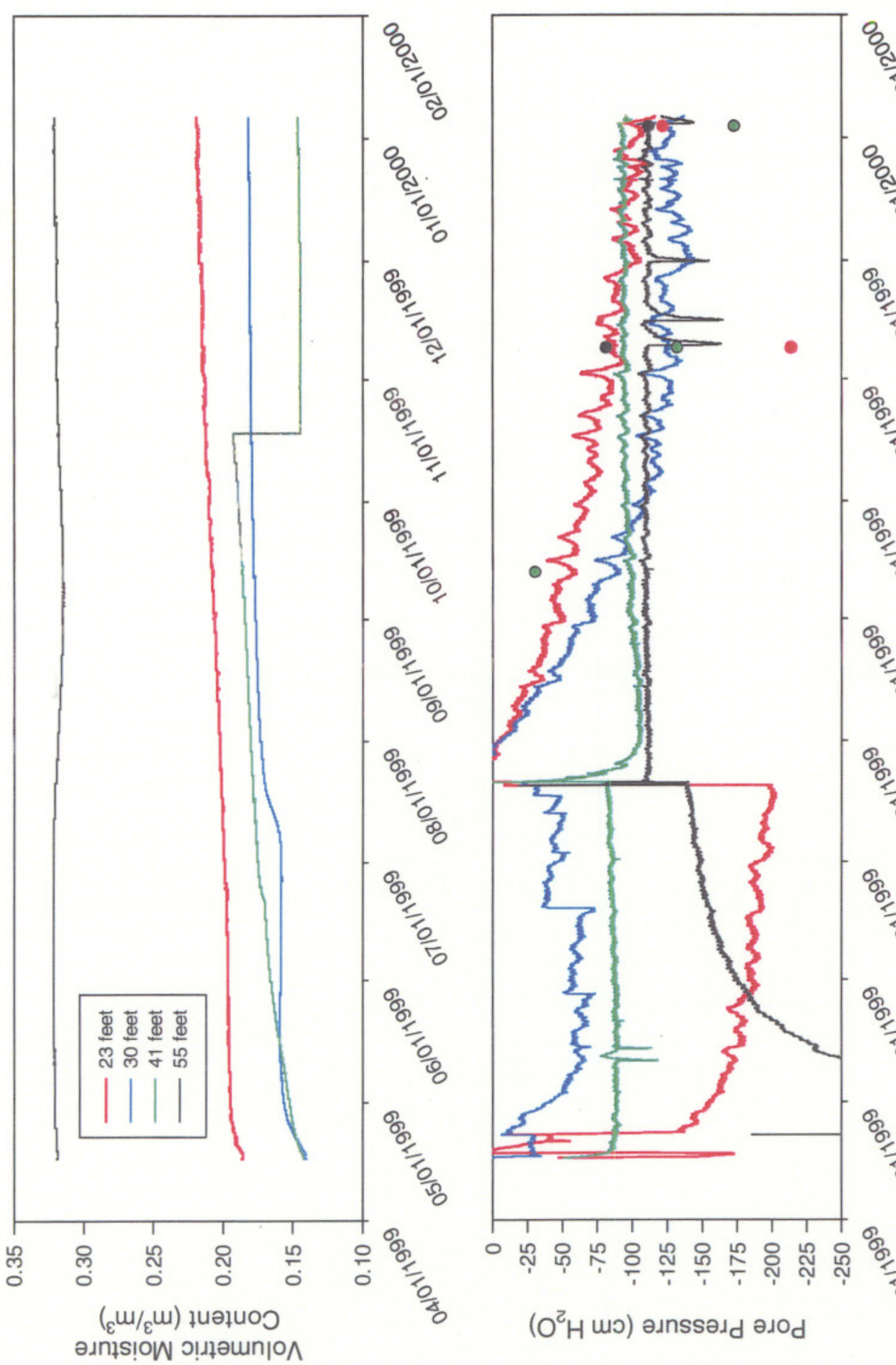

Figure 4. Volumetric moisture content and pore pressure trends for Advanced Tensiometer AT6

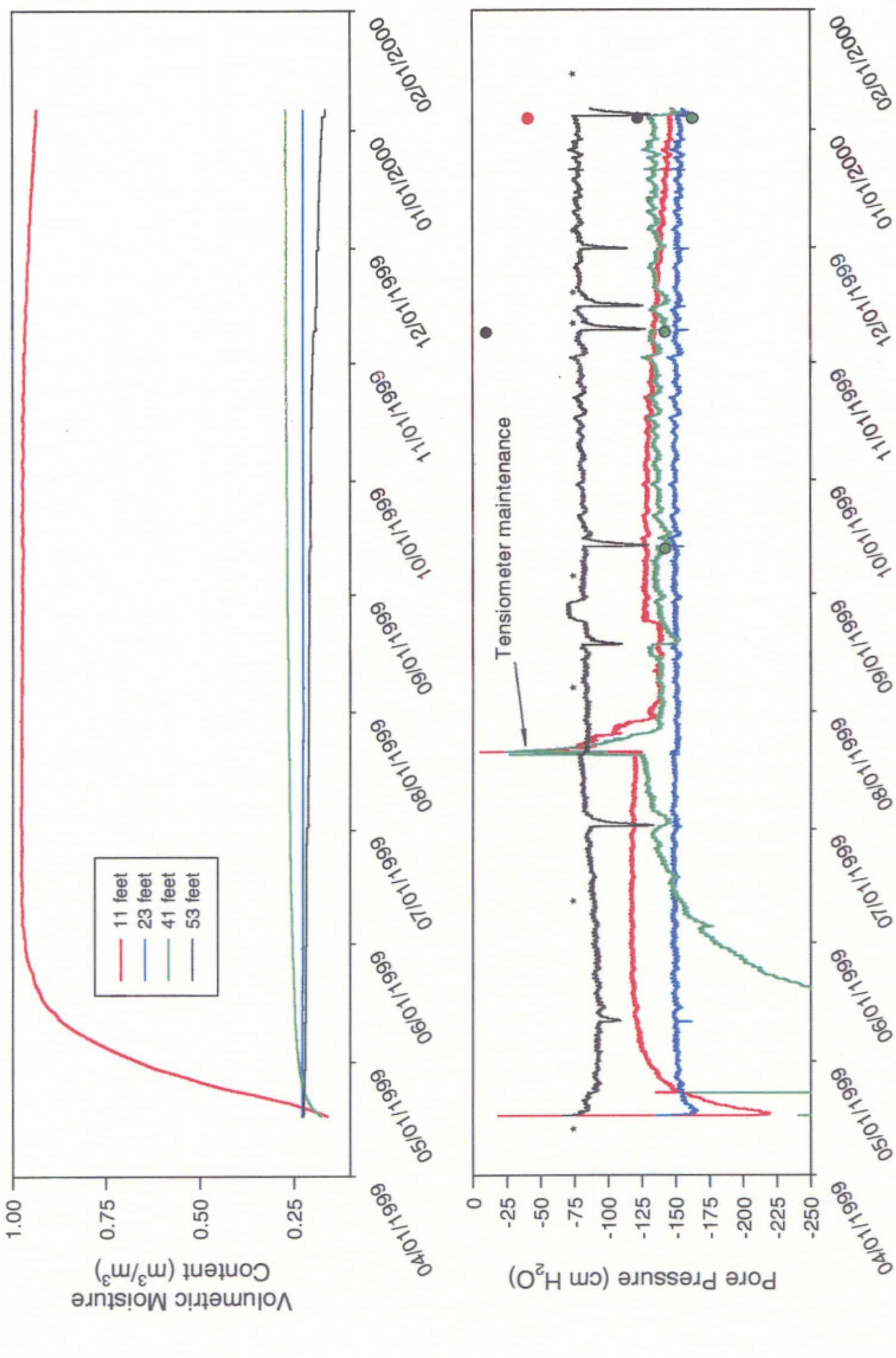

Figure 5. Volumetric moisture content and pore pressure trends for Advanced Tensiometer AT7

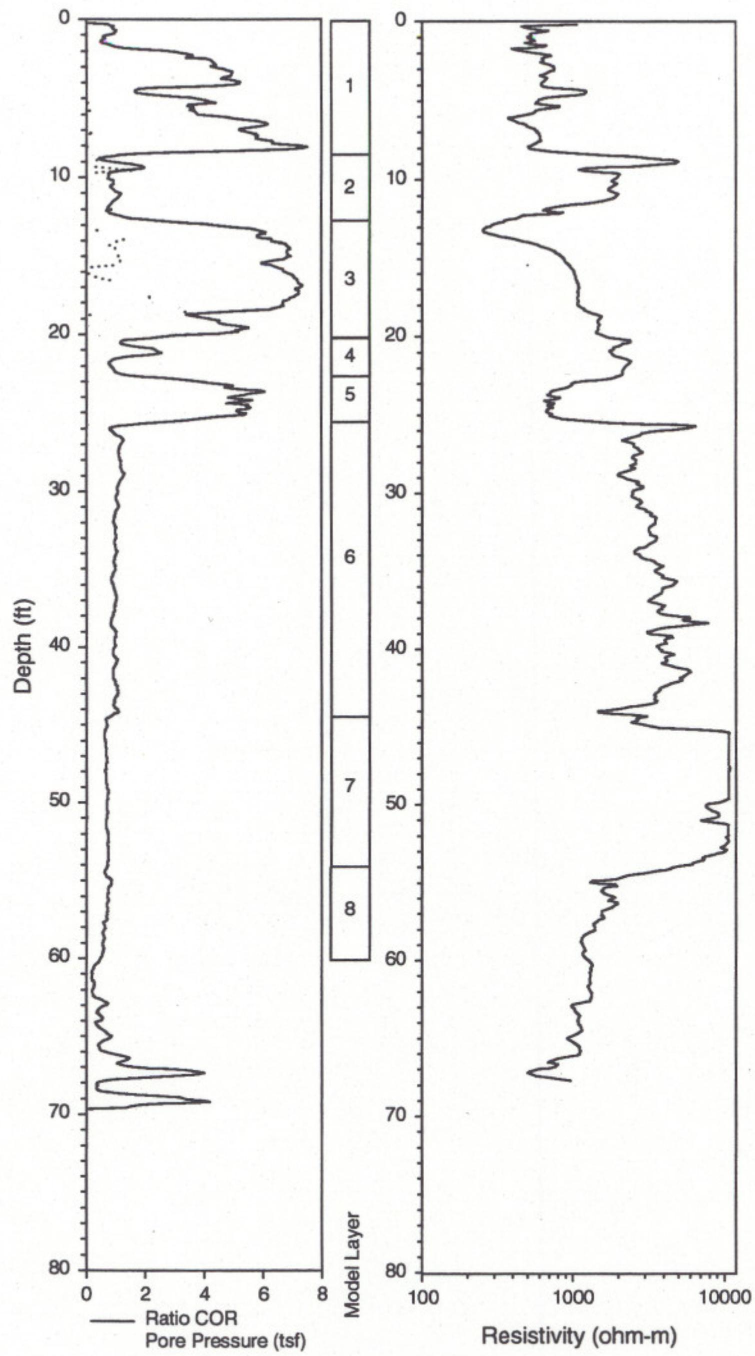

Figure 6. Cone penetrometer log for EAVZCPT3 and sediment layers identified for moisture modeling

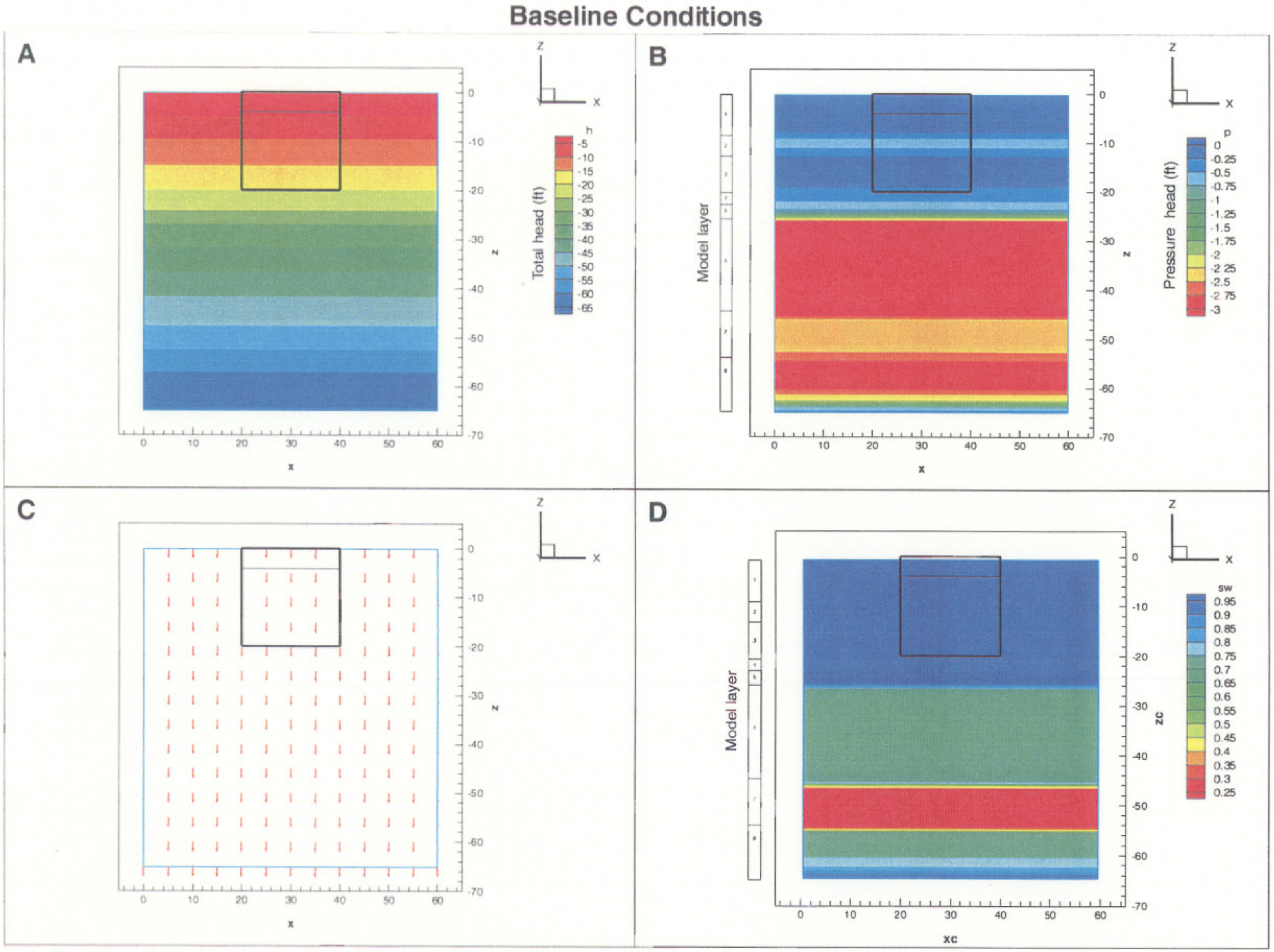

Figure 7. Simulated flow field for moisture migration, Base case (no trench), (a) total head, (b) pore pressure, (c) flow patterns, (d) saturation

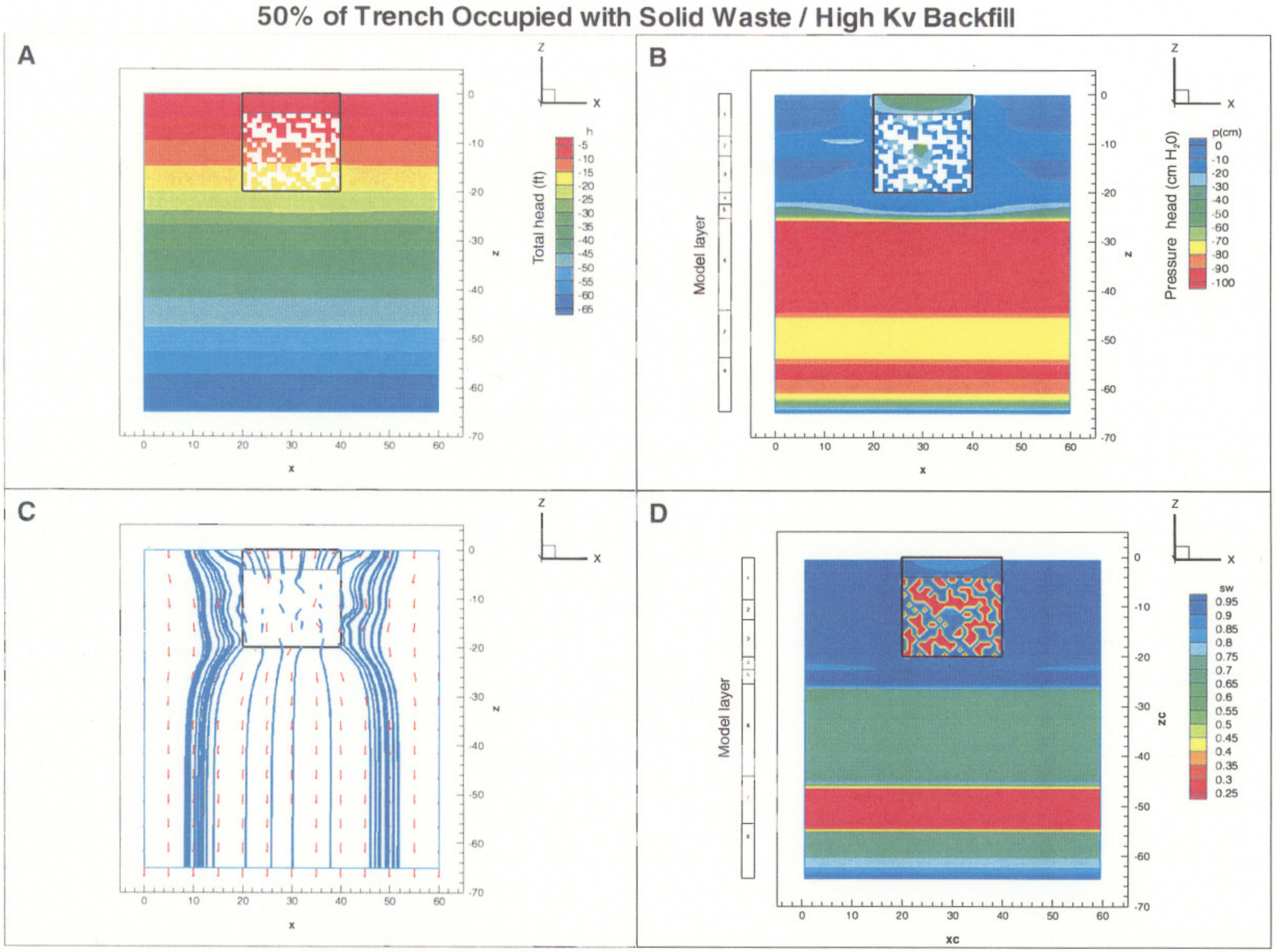

Figure 8. Simulated flow field for moisture migration beneath a disposal trench, (a) total head, (b) pore pressure, (c) flow patterns, (d) saturation

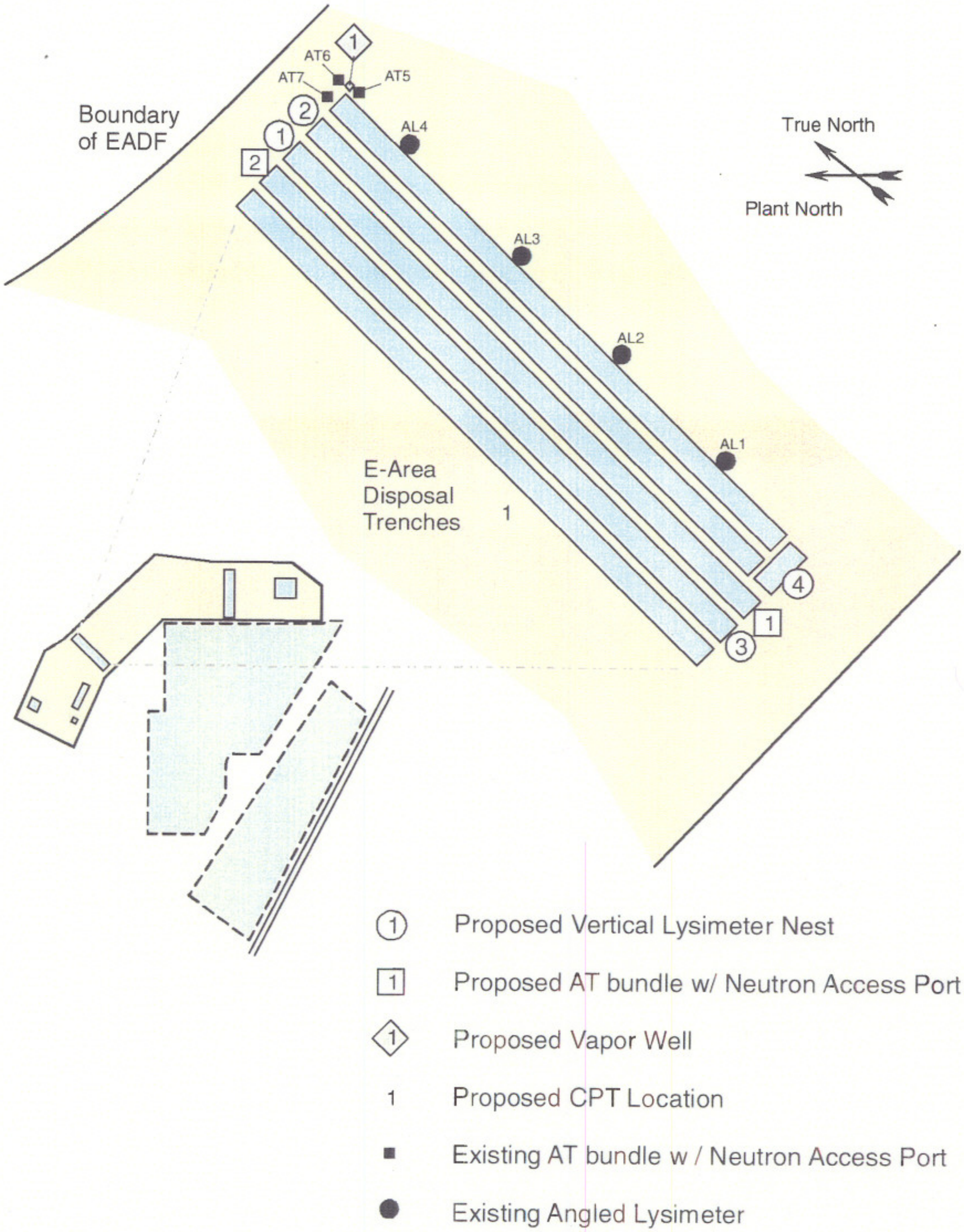

Figure 9. Map of proposed locations for characterization and monitoring at the Disposal Trenches.

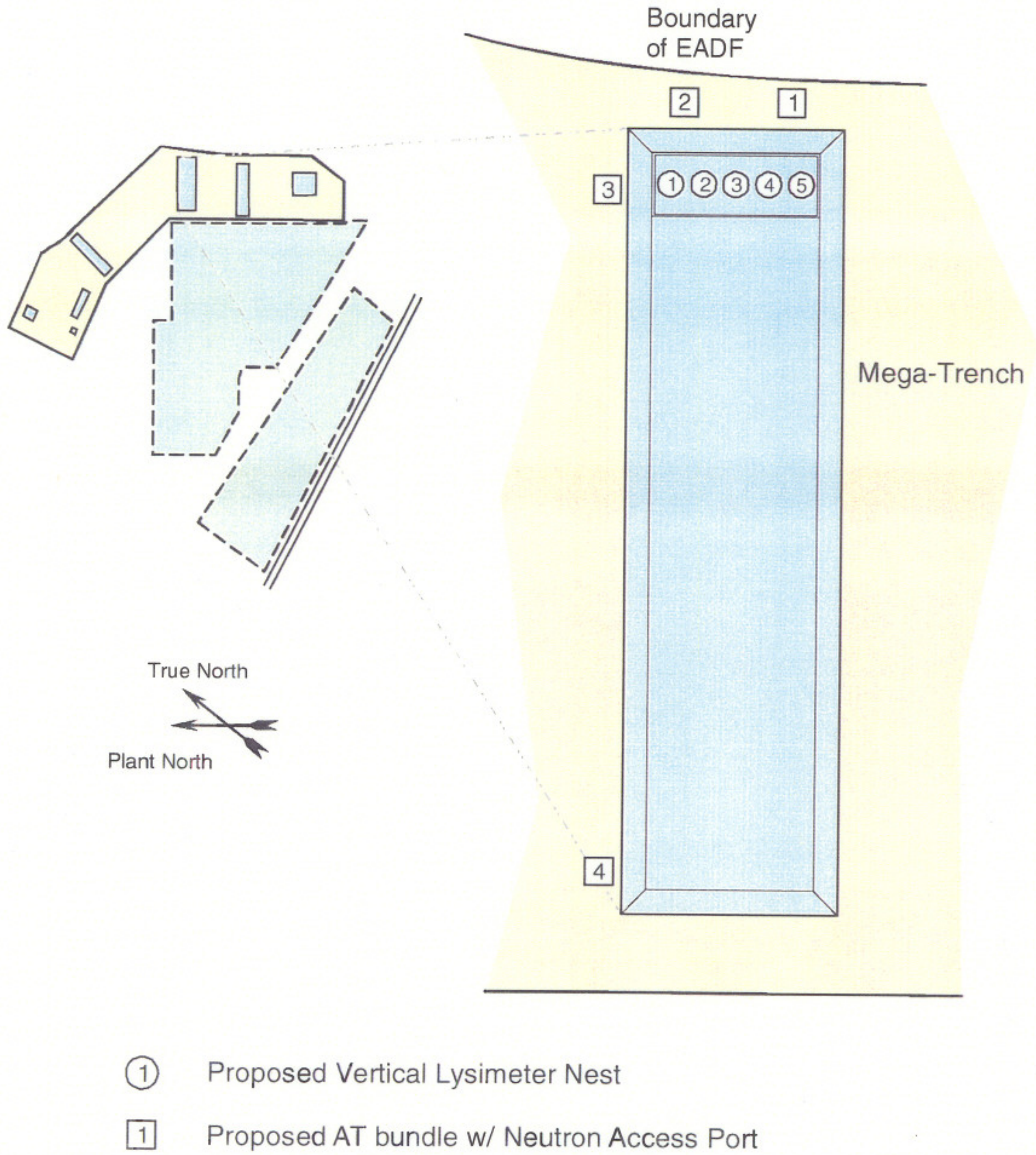

Figure 10. Map of proposed locations for initial characterization and monitoring at the Mega-Trench.

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