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As-Built Characterization and Monitoring System for the RH-LLW Disposal Facility

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ACRONYMS

ASTM	American Society for Testing and Materials
AT	advanced tensiometer
ATR	Advanced Test Reactor
HFEF	Hot Fuel Examination Facility
LCC	large concept cask
MFC	Materials and Fuels Complex
MFTC	modified facility transfer container
NRF	Naval Reactors Facility
PA	performance assessment
PVC	polyvinyl chloride
RH-LLW	remote-handled low-level waste
WCR	water content reflectometer

As-Built Characterization and Monitoring System for the RH-LLW Disposal Facility

1. BACKGROUND

A performance assessment (PA) for the Idaho National Laboratory Remote-Handled Low-Level Waste (RH-LLW) Disposal Facility is required to demonstrate that facility design will meet the performance objectives established for long-term protection of the public and environment following closure of the facility as outlined in U.S. Department of Energy (DOE) Order 435.1, "Radioactive Waste Management." Protectiveness of the facility in terms of the groundwater pathway is a function of the design features that control the hydrologic and geochemical conditions within and below the vault system. The facility design includes features to promote drainage of infiltrating water to limit accumulation of moisture next to the reinforced concrete disposal vaults and containerized waste. The PA groundwater pathway model accounts for a cement-impacted geochemical environment within and below the vault system to inhibit corrosion of stainless steel waste containers (i.e., waste liners), steel reinforcement in the concrete vault, and the effects on release and migration of non-anionic radionuclides. Upon closure of the facility, an engineered barrier (i.e., cover) will be placed over the facility to reduce infiltration through the waste zone, retarding the release and migration rate of radionuclides beneath the facility.

Crediting the long-term performance of the vault system requires characterization of the hydraulic and concrete performance over time. Verification of the vault performance requires monitoring for radiologic releases from the facility. The purpose of this document is to provide a description of the characterization and monitoring system installed in the vault yard to accomplish these two objectives. This document does not address the upgradient aquifer well (USGS-136) or the two downgradient aquifer wells (USGS-140 and USGS-141). Those wells are discussed in the monitoring plan (PLN-5501 2017).

2. VAULT SYSTEM DESCRIPTION

2.1 Facility Layout

The RH-LLW Disposal Facility will receive waste from the Advanced Test Reactor (ATR) Complex, Naval Reactors Facility (NRF), and the Materials and Fuels Complex (MFC). The RH-LLW Disposal Facility has been constructed approximately 0.3 miles southwest of the ATR Complex. Steel waste containers will be placed in precast concrete vaults constructed with hexagonal precast concrete bases with integral risers, upper riser sections, and precast concrete vault plugs (see Figure 1). Dimensions of the vault components for each waste container type are given in Tables 1 and 2 with the total vault height, including plugs, risers, and bases. The vaults are arranged by cask type and oriented in parallel rows (Figures 2 and 3). The Hot Fuel Examination Facility (HFEF) vaults are located at the west end of the NRF large concept cask (LCC) array, with this vault array positioned approximately 12.5 m (40-ft) east of the NuPac vault array. The 55-ton and modified facility transfer container (MFTC) vault arrays are located about 18.3 m (60-ft) south of the NuPac and LCC vault arrays, respectively.

The area containing the vaults was excavated (see Figure 4), leaving a minimum of 5 m of alluvium beneath the vaults (see Figure 2-13 of the PA for vertical cross-sections from the land surface to the aquifer showing the alluvium and underlying basalt-sediment sequences). The extent of soil disturbance beyond the vaults is approximately 21 to 24 m (70 to 80 ft), as indicated in Figure 5. The excavated area under the vaults was leveled using a thin pit run subbase and covered with a geotextile material to hold the subbase in place (see Figure 1). Over the subbase, a 47-cm (18–in.) thick drainage course was placed, with the drainage course extending 3 m (about 10 ft) beyond the horizontal extent of the vault bases (shown in Figure 5).

Table 1. Dimensions of waste containers.

Waste Generation Facility	Container Type	Waste Type	Waste Container Size: Outer Diameter (cm)	Waste Container Size: Height (cm)	Total Number of Containers	Number of Container Layers	Stacked Container Height (cm)
ATR	NuPac	Resins	191	203	120	2	406
NRF	LCC	Resins/Activated Metals	152	432	192	1	432
NRF	55-Ton Scrap	Resins/Activated Metals	122	267	164	2	534
MFC	MFTC	Activated Metals/Debris	74	445	272	1	445
ATR	HFEF-5	Activated Metals	33	191	56	2	381
MFC	HFEF-5	Activated Metals/Debris	33	191	115	2	381

Table 2. Dimensions of individual concrete vaults.

Waste Generation Facility	Container Type	Waste Type	Number of Index Positions (Number Containers/Layer)	Vault Dimensions: Inner Diameter (ID) (cm)	Inner Vault Height (cm)	Base Thickness (cm)	Plug Height (cm)	Total Vault Height (cm)
ATR	NuPac	Resins	1	213	442	46	152	640
NRF	LCC	Resins/Activated Metals	1	168	442	46	152	640
NRF	55-Ton	Resins/Activated Metals	1	137	564	46	152	762
MFC	MFTC	Activated Metals/Debris	3	76	442[b]	46	152	640
ATR	HFEF-5	Activated Metals	6	38	442	46	152	640
MFC	HFEF-5	Activated Metals/Debris	6	38	442	46	152	640
PA Confirmation Vaults[a]	NA	NA	1	137	564	46	152	762

a. PA Confirmation Vaults are two 55-ton vaults separated from the other arrays for the purpose of studying concrete longevity.

b. The inner vault height for the MFC vaults is measured from the hexagonal base to the top of the inner partition concrete. For other vaults, it is measured from the hexagonal base plate to the top of the tongue flat surface on the upper riser. This adds an additional 3 in. to the inner height necessary to accommodate the waste canister height.

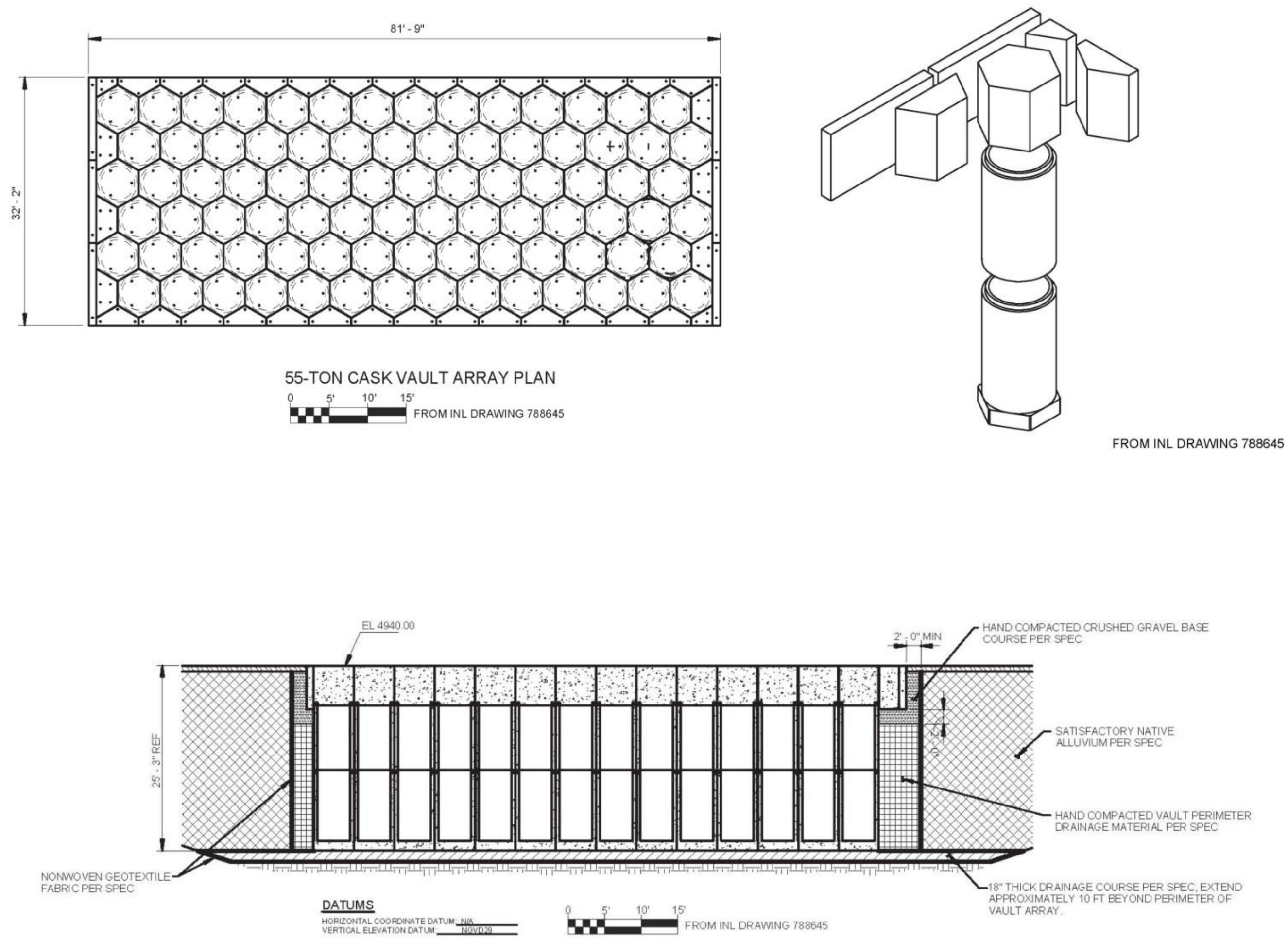


Figure 1. Cross-section through a vault array showing vault bases, riser sections, plugs, drainage course material, vault perimeter drainage material adjacent to the vaults, alluvial fill material throughout the remainder of the excavation area (from Drawings 788645). All vault arrays are constructed similarly.

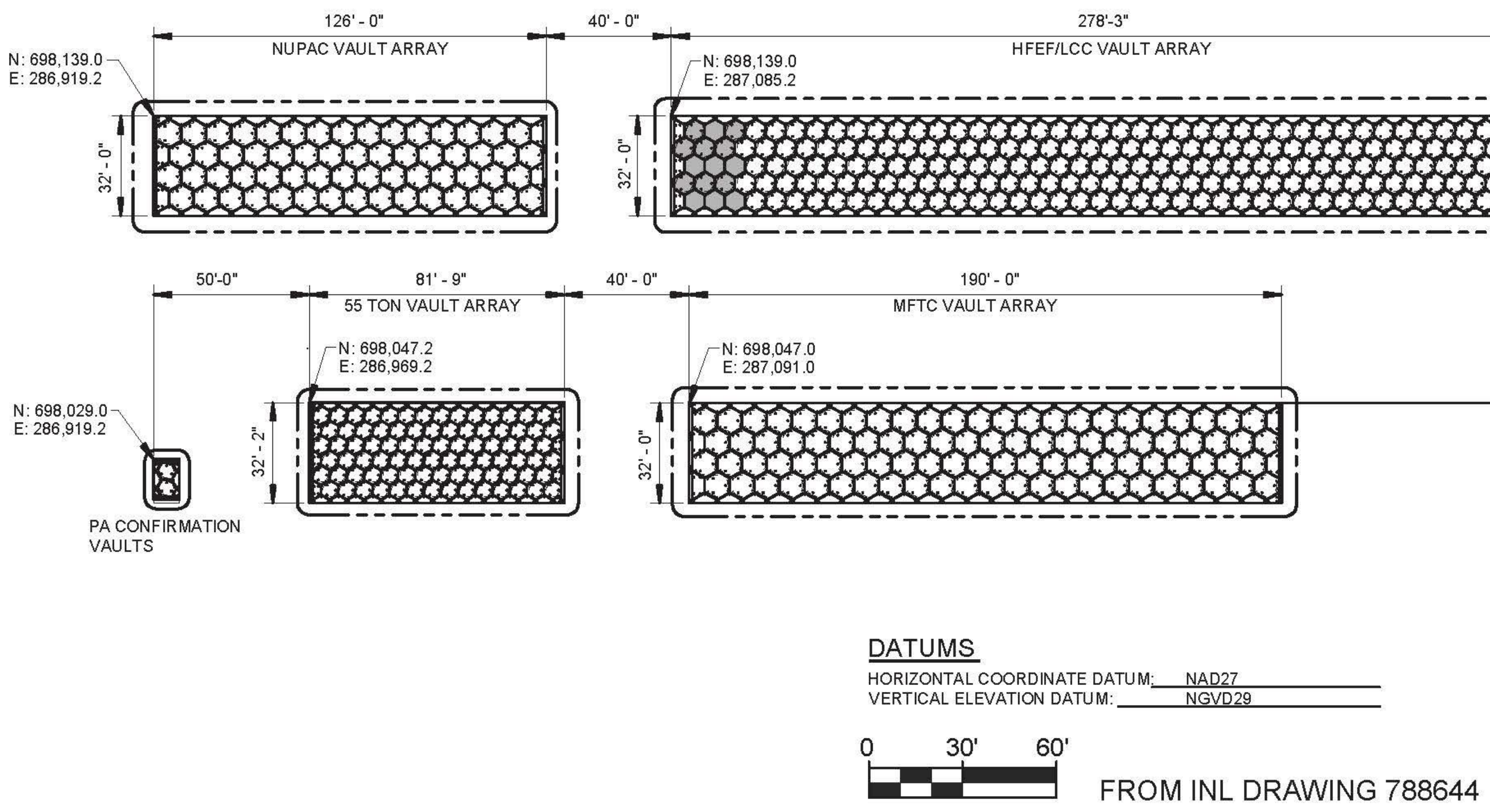


Figure 2. Horizontal layout of the vault arrays (from Drawing 788644). The PA Confirmation Vaults are the two vaults in the southwest corner denoted by C-14.

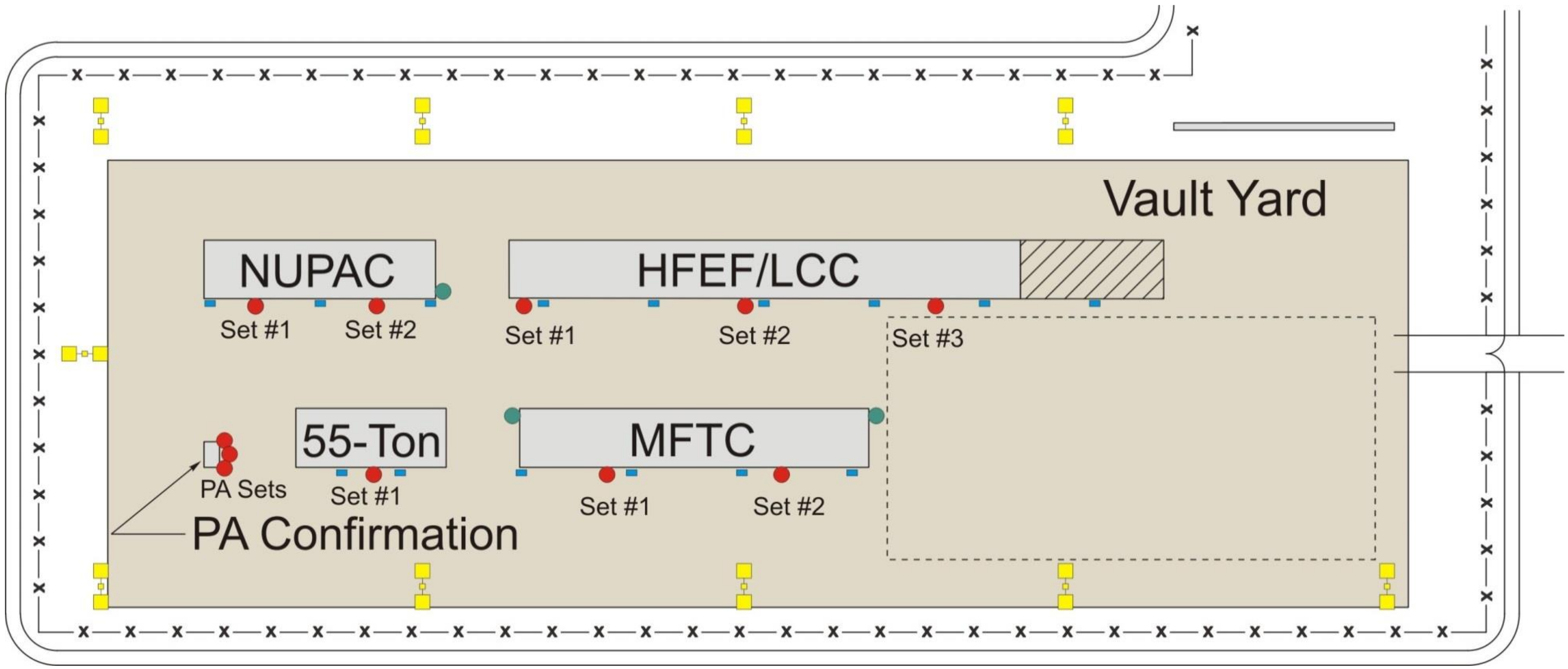


Figure 3. Approximate locations of the PA confirmation vaults and NuPac, 55-Ton, HFEF/LCC, and M-FTC vault arrays. Red circles indicate locations of instrumented tubes and drilled boreholes. Green circles indicate locations of 175-ft sedimentary interbed wells. Blue squares indicate approximate locations of power pedestals. Yellow squares indicate lighting locations.

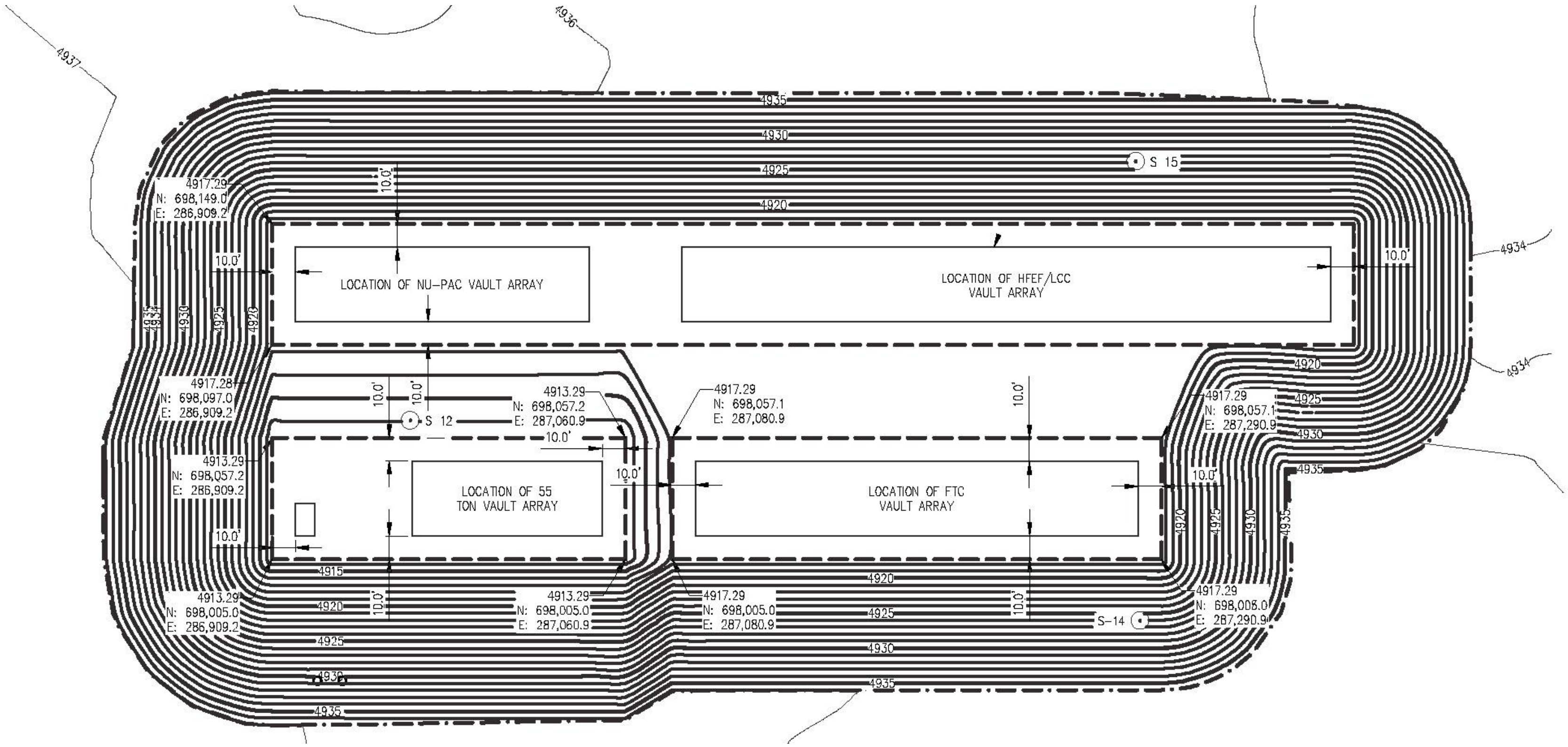


Figure 4. Excavation plan for the vault arrays showing the lateral extent of the excavation area (from Drawing 778766).

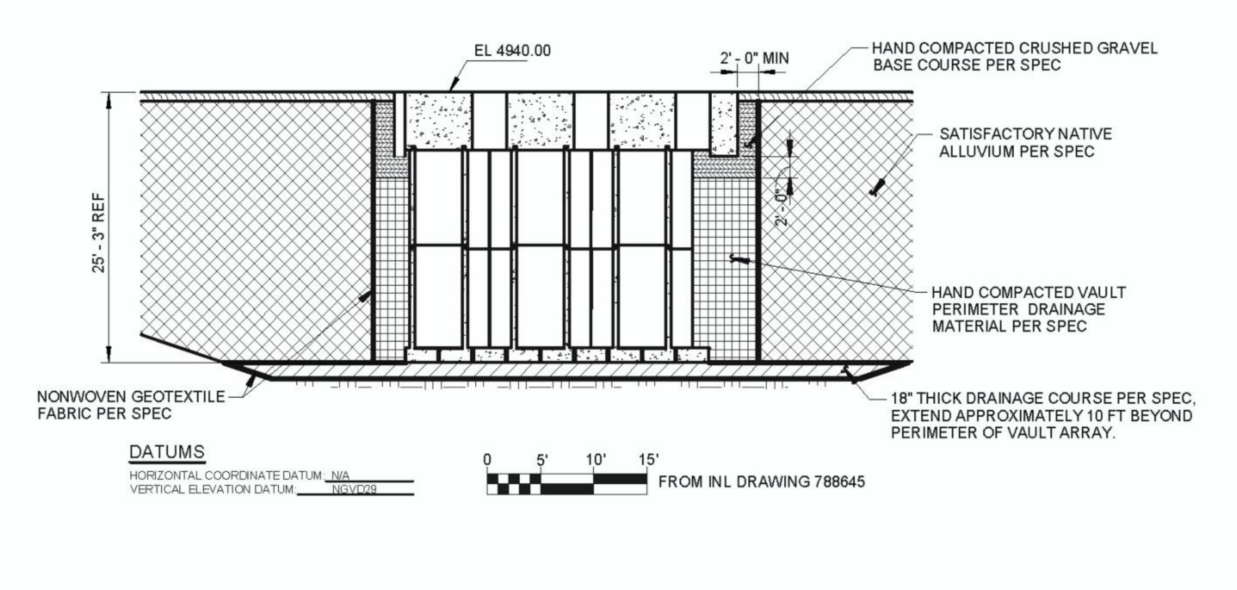


Figure 5. Vault installation showing alluvium backfill, hand compacted crushed gravel base course under the perimeter and edge blocks, perimeter drainage material adjacent to the vaults, pea gravel infill between the vaults, and lower drainage course beneath the vaults. The lower drainage course overlies the native undisturbed alluvium that extends to the upper basalt contact. Also note the geotextile fabric that separates the perimeter drainage material, the alluvium backfill, and the lower drainage course from the native alluvium.

During vault construction, the vault bases and integral riser sections were placed on the drainage course, the vault top riser section was added, and volume between the individual vaults was filled with pea gravel. Vault plugs were placed on the vault risers, forming the upper surface hexagonal pattern shown in Figure 1. Concrete blocks were placed around the perimeter of the vault arrays for stability.

The excavation depth and vault height combine to leave the vault plugs above the natural surrounding grade (elevation). This leaves the vault plugs above the frost-line (approximate depth 1.4 m [about 4 to 5 ft) and places the vault risers and bases entirely below the frost line. This arrangement allows the road apron to serve as a protective flood-control berm that will prevent ingress of surface water, with the exception of direct precipitation on the vault yard surface.

2.2 Hydraulic Drainage System and Upper Vadose Zone

One of the stated purposes of the characterization system is to quantitatively determine the hydraulic performance of the vault system. The hydraulic performance of the vault system is of interest because it determines the amount of water and water-vault contact time. It is determined by the fill materials used adjacent to the vaults, between the vaults, and for the drainage course under the vaults as illustrated in Figure 5, with the materials being described as follows from land surface downward:

1. Surface road base is placed in compacted lifts at the upper most vault surface so the top is even with the top of the concrete plugs. This material is the same as the crushed gravel base course material and is installed a minimum of 12-in. thick (SPC-1860, “General Site Construction Specification”).

2. Crushed gravel base course material beneath and adjacent to the vault perimeter blocks (see inset in the upper left of Figure 1). This material is adjacent to the vault perimeter blocks and tops of the upper vault riser sections. It extends vertically from beneath the surface road base to 2-ft below the base of the perimeter blocks. Per SPC-1910, "Construction Specification – Vault Installation for the RH LLW Disposal Project," this material is a naturally or artificially graded mixture of 3/4-in. maximum size natural or crushed gravel, crushed stone, and natural or crushed sand. It meets the requirements of the Idaho Transportation Department Standard Specifications for Highway Construction, Subsection 703.04, Type B material (see Table 3) (SPC-1910) (see Table 3).

3. Vault perimeter drainage material placed below the crushed gravel base course material adjacent to the vault base sections and upper vault risers along each vault array perimeter. This material extends 2-ft beyond the vault perimeter blocks, which are 1 to 3-ft wide. Therefore, the vault perimeter drainage material column is 3 to 5-ft wide and approximately 13 to 17-ft high, depending on the specific vault array height (see Table 2). Per SPC-1910, this material is a narrowly graded mixture of crushed stone or crushed or uncrushed gravel; American Society for Testing and Materials (ASTM) D 448; coarse-aggregate grading Size 67; with 100% passing a 1-1/2-in. sieve and 0 to 5% passing a No. 8 sieve (see Table 3) (SPC-1910).

4. Pea gravel is placed between each of the vaults to fill the inter-vault void space. The hexagonal bases and plugs were sized to minimize the space between the vault risers where they meet. Pea gravel is placed in areas where the risers do not touch to within approximately 7-in. below the top of the upper riser sections. Per SPC-1910, this material is a naturally or artificially graded mixture of natural or crushed gravel or stone with a nominal size of 1/2-in. and a coefficient of uniformity less than 2 (SPC-1910) (see Table 3).

5. Drainage course material is placed in a 47-cm (18-in.) thick layer beneath each of the vault arrays and extends 10-ft beyond the outer extent of the hexagonal bases along each vault array perimeter. Per SPC-1910, this material is a narrowly graded mixture of crushed stone or crushed or uncrushed gravel, ASTM D 448 coarse-aggregate grading Size 67, with 100% passing a 1-1/2–in. sieve and 0 to 5% passing a No. 8 sieve (see Table 3) (SPC-1910).

6. Non-woven geotextile material placed beneath the drainage course material and between the alluvial fill material and vault perimeter drainage material column. It is a non-woven, needle-punched geotextile that is manufactured for separation applications and complies with American Association of State Highway and Transportation Officials M 288 and the following measured per-test methods referenced (SPC-1910):
    - Grab tensile strength: 180 lbf; ASTM D 4632
    - Elongation at break: 50%; ASTM D 4632
    - Tear strength: 75 lbf; ASTM D 4533
    - California bearing ratio puncture strength: 460 lbf; ASTM D 6241
    - Apparent opening size: No. 70 sieve maximum; ASTM D 4751
    - Permittivity: 1.5 per second minimum; ASTM D 4491
    - UV stability: 70% after 500 hours of exposure; ASTM D 4355.

7. Native alluvial sands, gravels, and silty clays left in place extend vertically downward from the base of the drainage course material to the upper basalt contact. During the geotechnical investigation of the RH-LLW Disposal Facility location (American Geotechnics 2011), 12 borings were advanced to practical refusal on basalt rock or resistant earth material through the surficial sediment. While drilling, the following three strata were identified:

- Stratum I alluvium consists of silt with sand (ML), extending from the existing (i.e., initial pre-construction excavation) ground surface to depths ranging from about 1 to 5 ft below the existing grade.
- Stratum II alluvium, located below the Stratum I alluvium, at depths ranging from about 26 to 58 ft below the existing grade was classified as poorly graded sand with gravel, poorly graded gravel with sand, clayey gravel with sand, well graded gravel with sand, well graded gravel with silt and sand, silty, clayey sand, silty sand, and poorly graded sand with clay.
- Stratum III alluvium, classified as lean clay with sand, was encountered below the Stratum II alluvium and varied in thickness from a few inches to about 5 ft.

The Stratum II alluvium predominately underlies the drainage course material, with pockets of Stratum III alluvium found near the PA Confirmation Vaults at the base of the drainage course material.

8. Alluvial fill material is placed adjacent to the vault perimeter drainage material column extending between each of the vault arrays. This material was obtained from the Stratum II alluvium. It is well sorted and free of debris, waste, frozen materials, vegetation, and other deleterious matter. It does not fall in the unsatisfactory soil classifications of clayey gravel with sand, lean clay with sand, silt with sand as defined according to ASTM D 2487, or in combinations of these groups (SPC-1910).
9. Bulk of the vadose zone beneath the surficial alluvium. The vadose zone below the surficial alluvium is comprised of a thick sequence of basalt flows separated by thinner sedimentary interbeds. The surficial alluvium is approximately 15-m (50-ft) thick in the vault area and the aquifer is approximately 146 m (480 ft) below land surface.

Vault system materials placed within 5-ft of the vault components were hand compacted and materials further from the vaults were machine compacted. SPC-1910 required the materials used in the vault system to be placed in lifts not more than 8 in. in loose depth for material compacted by heavy compaction equipment and not more than 6 in. in loose depth for material compacted by hand-operated tampers. The installation specification also required the materials with the exception of the drainage course material and perimeter drainage course material to be compacted to no less than 95% of the maximum dry unit weight according to ASTM D 698. Those materials do not contain sufficient fines to allow achieving 95% maximum dry unit weight.

3. CHARACTERIZATION AND MONITORING SYSTEM

The characterization and monitoring system was designed and installed to obtain data necessary to quantify hydraulic performance of the vault system and to enable early detection of potential radiologic releases from the facility. This section provides a description of the system.

3.1 System Overview

The subsurface characterization and monitoring system consists of a combination of instrumented tubes and boreholes, instrumentation, data collection/communication system hardware, and temporary power supplies configured to allow collection of water samples and moisture characteristic data. The subsystems are described as follows:

- Instrumented tubes. Instrumented tubes are located next to the vault perimeter blocks at several horizontal locations along the vault arrays. Instrumented tubes will be used to collect hydrologic data at multiple elevations in the vault perimeter drainage material and drainage course material and also allow collection of water samples.

- Forty-five foot drilled boreholes. The 45-ft depth measured from the top of the vault plugs corresponds roughly to the top of the Stratum III alluvium. These “shallow boreholes” will be used to collect water samples and hydrologic data in the alluvium above the first basalt layer.
- Sedimentary interbed wells. These boreholes were completed near the top of a 20-ft thick sedimentary interbed located at a depth of approximately 165 to 175 ft below the top of the vault plugs (USGS 2012, USGS 2014, INL 2017b). These boreholes will be used to allow collection of water samples and hydrologic data in the sedimentary interbed located at that depth.

Specific configurations and instrumentation installed in the instrumented tubes, boreholes, and wells are detailed in Section 3.2.

Data could be collected independently at each physical location and transmitted wirelessly to the administration building, which is located approximately 1/4 mile from the vault system if a wireless radio system were installed. Data loggers supply onboard data storage, allowing data transmission in bursts. Data receipt in the administration building could occur on a portable computer supplied for this purpose. Although data could be stored on a computer in the administration building, data are not intended to be processed in the administration building and no data processing software has been provided for that purpose.

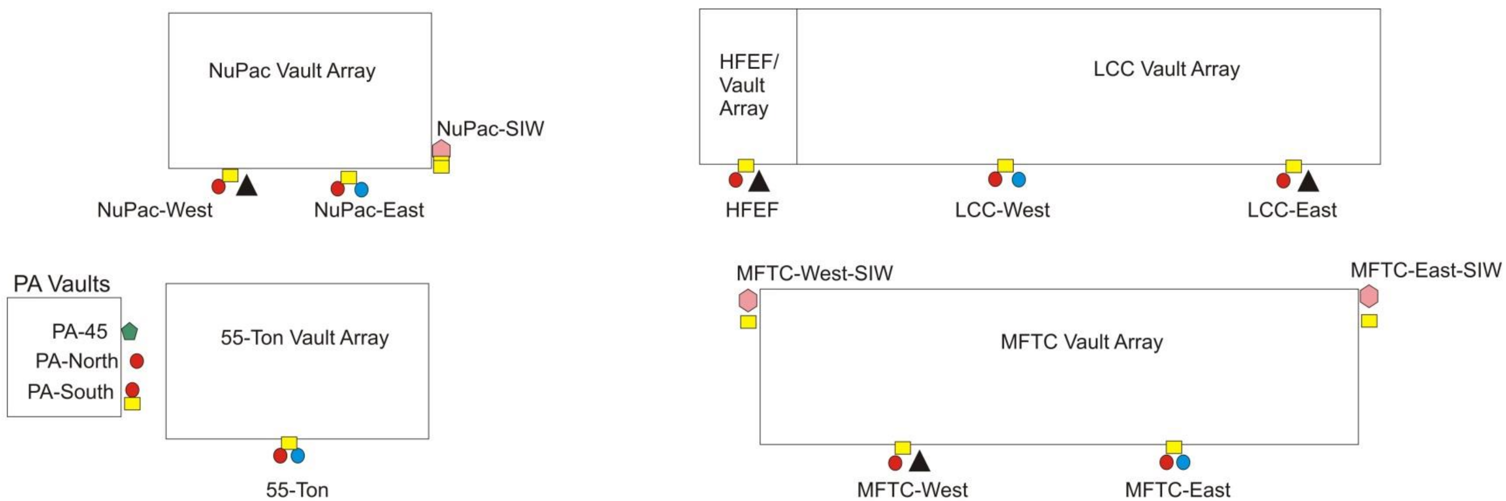
Power is supplied to the data loggers and instruments at each monitoring location using solar panels minimally sized to recharge a per-well battery. The ability to transition to permanent 120-V power is provided at each location. The solar power system design life expectancy is approximately 24 months. Protection of the data loggers is provided by weather-proof enclosures.

3.2 System Configuration

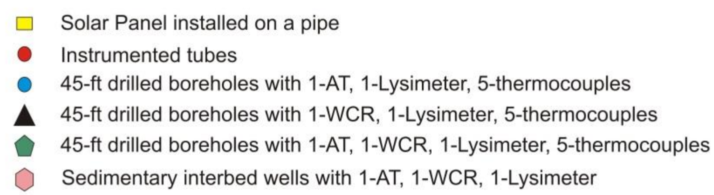
This section describes the instrumented tubes, boreholes, wells, and instrumentation that make up the characterization and monitoring system. The discussion is provided for each of the instrument cluster locations shown in Figure 6 relative to the vault arrays.

3.2.1 Performance Assessment Confirmation Vault Instrumentation

Two instrumented tubes and one 45-ft drilled borehole are located on the east side of the PA Confirmation Vaults (see Figure 3 for location of the PA Confirmation Vaults and Figures 6 and 7 for instrumented tube/borehole locations relative to the vaults). The PA-South instrumented tube extends through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium and contains an advanced tensiometer (AT) and water content reflectometer (WCR) at depths of 12, 18, 26, and 29-ft measured from the top of the plug (see Figure 8 and Table 3). The PA-North instrumented tube passes through the alluvial fill and drainage course material, terminating in the Stratum II alluvium and contains an AT and WCR at depths of 26-ft and 29-ft, respectively, measured from the top of the plug (see Figure 9 and Table 3). The PA-45 drilled borehole extends through the vault perimeter drainage material, drainage course material, Stratum II alluvium, and terminates in the Stratum III alluvium at a depth of 43-ft measured from the top of the plugs (see Figure 10). It contains a lysimeter, AT, WCR, and five thermocouples at the depths shown in Figure 10.



Naming Convention			
Vault Array	Instrumented Tubes	45-ft Drilled Boreholes	Sedimentary Interbed Wells
PA Vaults	PA-South PA-North	PA-45	
55-Ton	55-Ton-South	55-Ton-South-45	
NuPac	NuPac-West NuPac-East	NuPac-West-45 NuPac-East-45	NuPac-SIW
HFEF	HFEF-South	HFEF-South-45	
LCC	LCC-West LCC-East	LCC-West-45 LCC-East-45	
MFTC	MFTC-West MFTC-East	MFTC-West-45 MFTC=East-45	MFTC-West-SIW MFTC-East-SIW



not to scale

Figure 6. Plan view showing the locations of the instrumented tubes, 45-ft drilled boreholes, sedimentary interbed wells, and solar panels relative to the vault arrays.

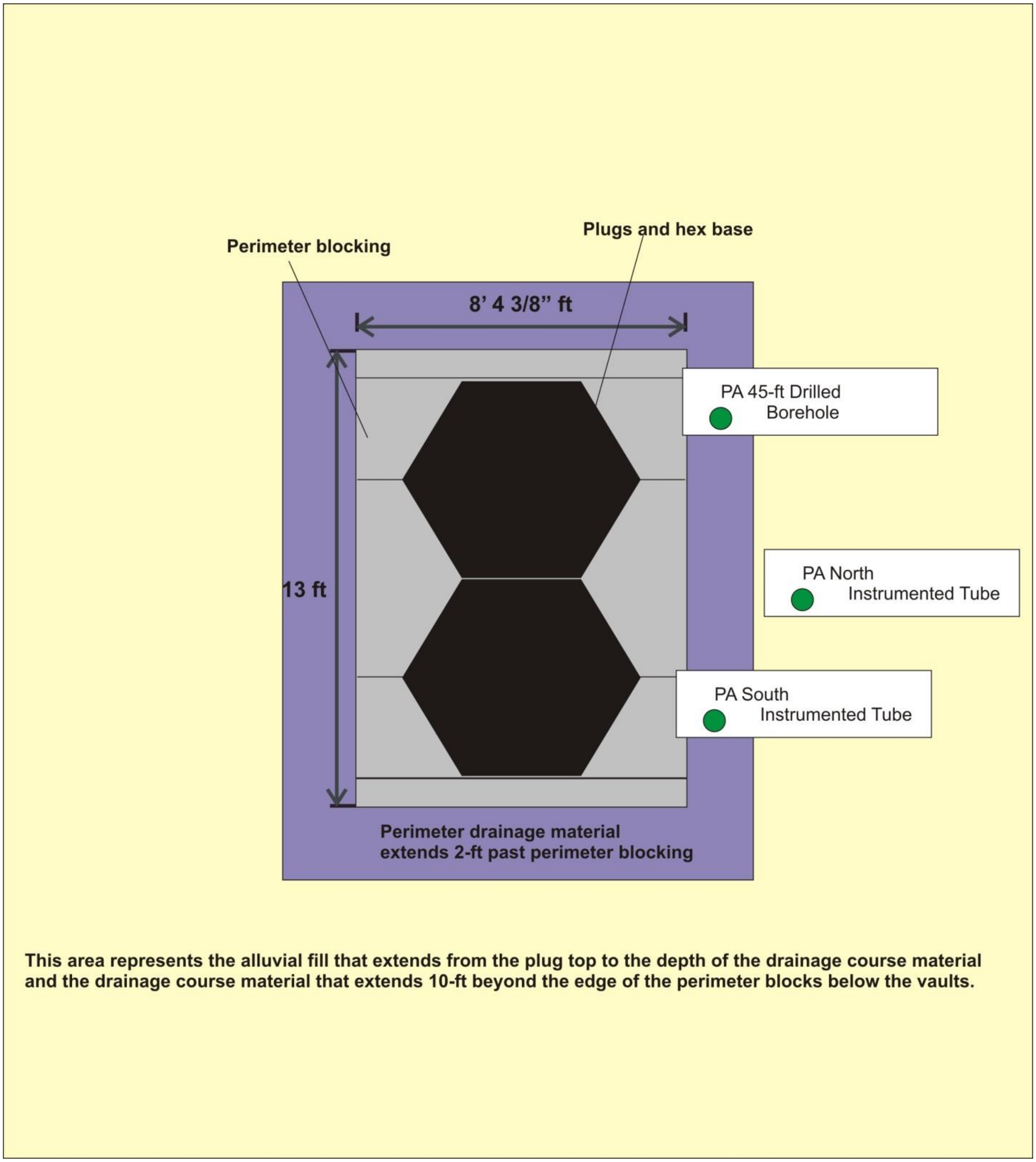


Figure 7. Plan view showing the locations of the PA-South instrumented tube, PA-North instrumented tube, and PA-45 drilled borehole relative to the PA Confirmation Vaults.

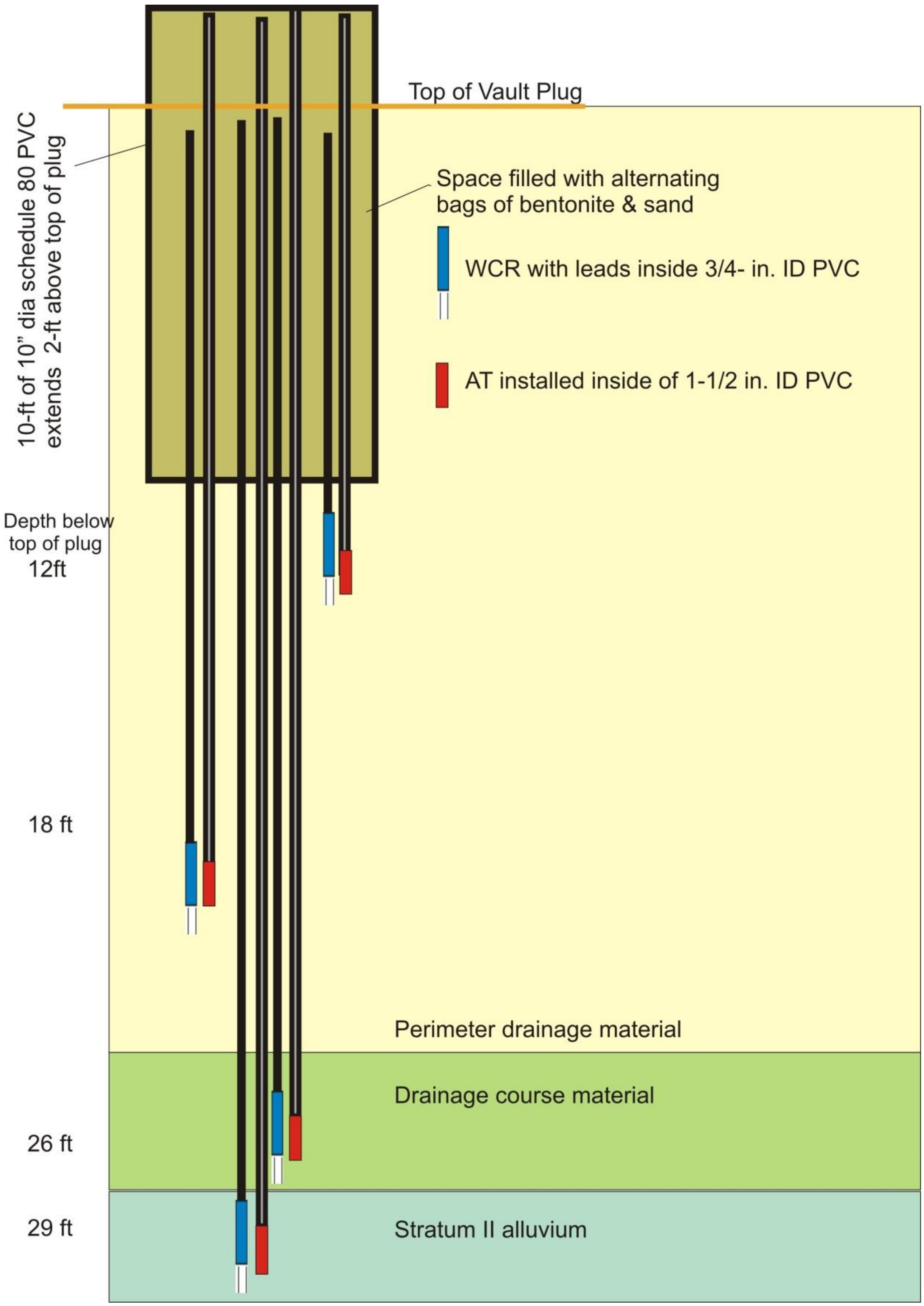


Figure 8. Vertical section showing instrument locations in the PA-South instrumented tube.

Table 3. Sensors, locations, and installation depths for the PA South and PA North instrumented tube locations.

	Depths of Instrument Installation Relative to Top of the Vault Plug			
Sensor Type	PA-South Instrumented Tube	PA-North Instrumented Tube	PA-45 Drilled Borehole	Material Instrumented
ATs and WCRs	12 ft	NA	NA	Vault perimeter drainage material
	18 ft	NA	NA	Vault perimeter drainage material
	26 ft	26 ft	NA	Drainage course material
	29 ft	29 ft	NA	Stratum II alluvium just below the drainage course material
	NA	NA	43 ft	Stratum III alluvium above the first basalt contact
Suction Lysimeter	NA	NA	43 ft	Stratum III alluvium above the first basalt contact
Thermocouple	NA	NA	12 ft	Alluvial fill
			18 ft	Alluvial fill
			26 ft	Drainage course material
			34 ft	Stratum II alluvium
			43 ft	Stratum III alluvium

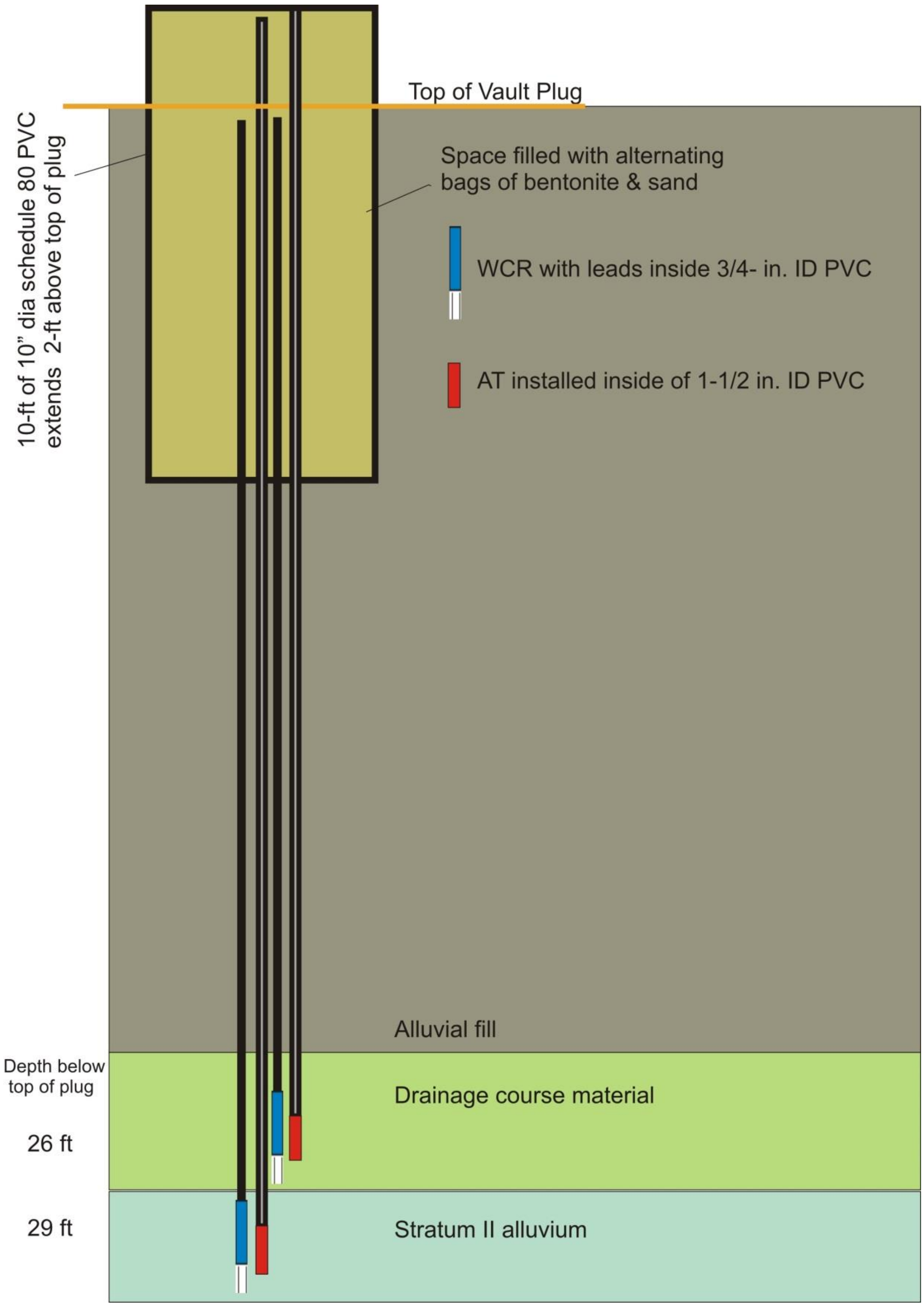


Figure 9. Vertical section showing instrument locations in the PA-North instrumented tube.

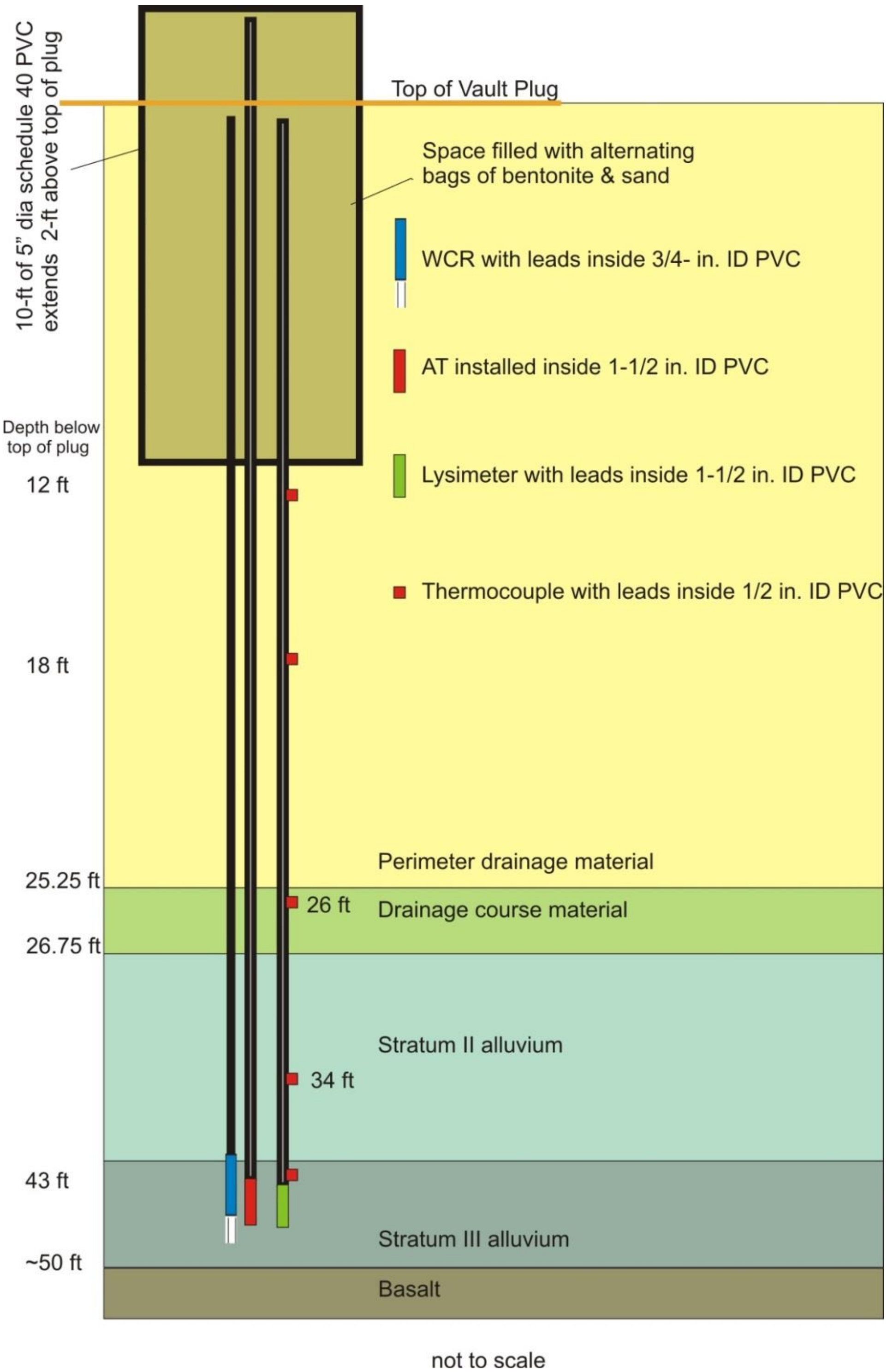


Figure 10. Vertical section showing instrument locations in the PA-45 drilled borehole.

3.2.2 55-Ton Vault Array Instrumentation

One instrumented tube (55-Ton-South) and one 45-ft drilled borehole (55-Ton-South-45) are located on the south side of the 55-ton vault array (see Figure 6). The 55-Ton-South instrumented tube extends through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium (see Figure 11 for the vertical cross section) and contains two ATs, two WCRs, and one suction lysimeter at the depths indicated in Table 4. The 55-Ton-South-45 drilled borehole contains one AT, one suction lysimeter, and five thermocouples (Figure 12) at the depths indicated in Table 4.

Table 4. Sensors, locations, and installation depths for the 55-Ton-South instrumented tube and 55-Ton-South-45 drilled borehole.

Sensor Type	Depths of Instrument Installation Relative to Top of the Vault Plug		Material Instrumented
	55-Ton-South Instrumented Tube	55-Ton-South-45 Drilled Borehole	
ATs and WCRs	26 ft 29 ft NA	NA NA 40 ft (1 AT, no WCR)	Drainage course material Stratum II Alluvium just below the drainage course material Stratum III alluvium above the first basalt contact
Suction Lysimeter	29 ft	40 ft	Drainage course material and Stratum III alluvium above the first basalt contact
Thermocouple	NA	12 ft 18 ft 26 ft 34 ft 40 ft	Alluvial fill Alluvial fill Drainage course material Stratum II alluvium Stratum III alluvium

Note that the 55-Ton and PA Confirmation Vaults are the same overall height (see Table 2). Therefore, depth to the top of the drainage course material and top of the Stratum II alluvium is the same. However, as indicated in Tables 3 and 4, the top of the Stratum III alluvium is shallower at the 55-Ton-South-45 location.

3.2.3 NuPac Vault Array Instrumentation

Two instrumented tubes and two 45-ft drilled boreholes are located on the south side of the NuPac vault array (see Figure 6 for locations relative to the NuPac vault array). The NuPac-West and NuPac-East instrumented tubes extend through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium (see Figure 13 for vertical cross section) and contain two ATs, two WCRs, and one suction lysimeter at the depths indicated in Table 5.

The NuPac-West-45 drilled borehole contains one WCR, one suction lysimeter, and five thermocouples as (Figure 13) at the depths indicated in Table 5. The NuPac-East-45 drilled borehole contains one AT, one suction lysimeter, and five thermocouples (Figure 14) at the depths indicated in Table 5. Placing either an AT or WCR in each of these boreholes instead of using both instruments reduced the volume occupied by the polyvinyl chloride (PVC) carrier pipes to allow better compaction of materials around the instruments when the auger was reversed during installation. This is in contrast to the PA-45 drilled borehole, where one AT and one WCR were installed through the 4-in. ID hollow stem auger.

The NuPac, HFEF, LCC, and MFTC vaults are all 4 ft shorter than the 55-ton and PA Confirmation Vaults. Therefore, the depth to the top of the drainage course material and the Stratum II alluvium is 4 ft shallower for the NuPac, HFEF, LCC, and MFTC vaults compared to the 55-ton and PA vault instrument sets. The set depths for instruments were determined by the depth to the top of the Stratum III alluvium, which is slightly shallower than the set depths shown in Table 5.

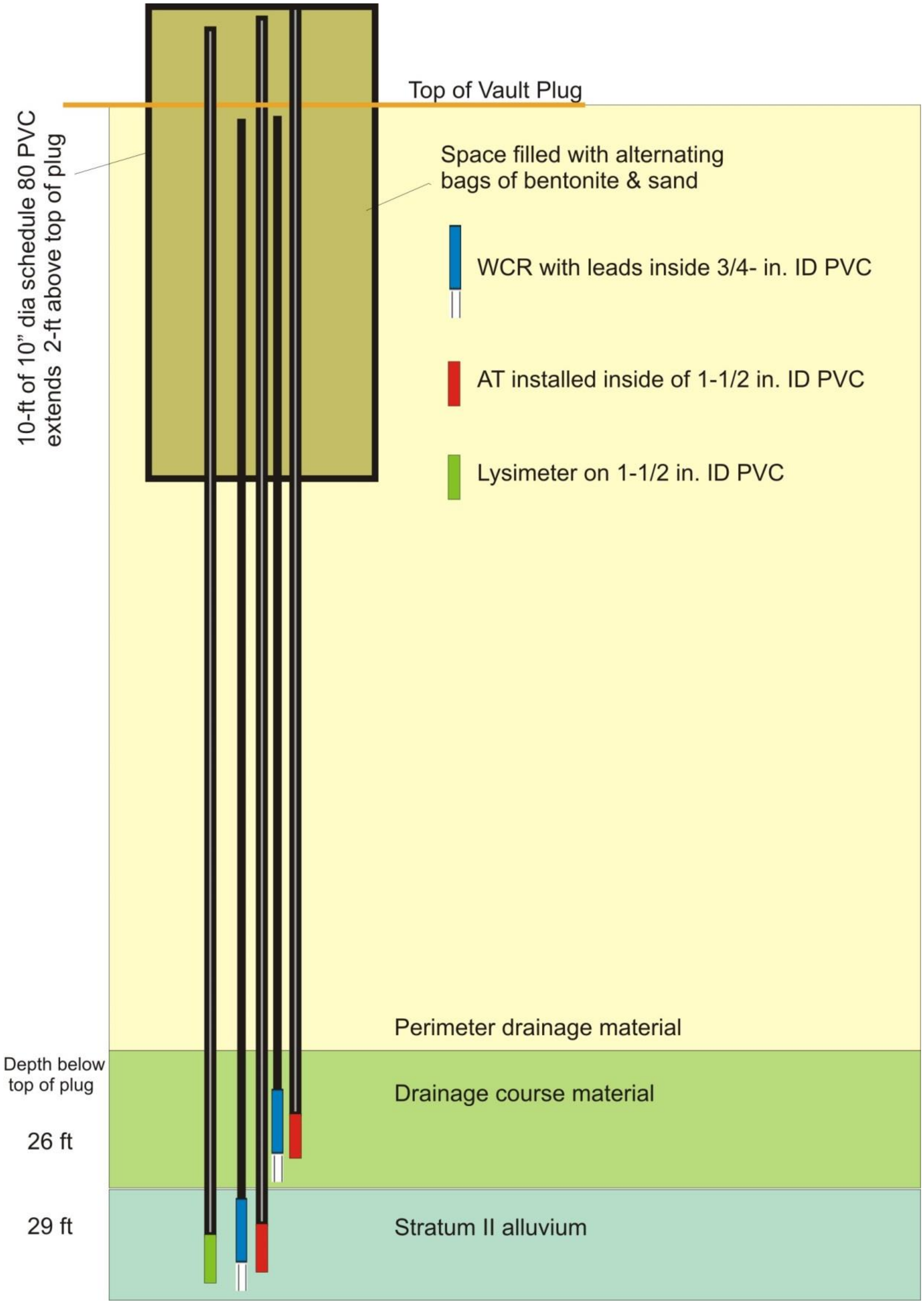


Figure 11. Vertical section showing instrument locations in the 55-Ton-South instrumented tube.

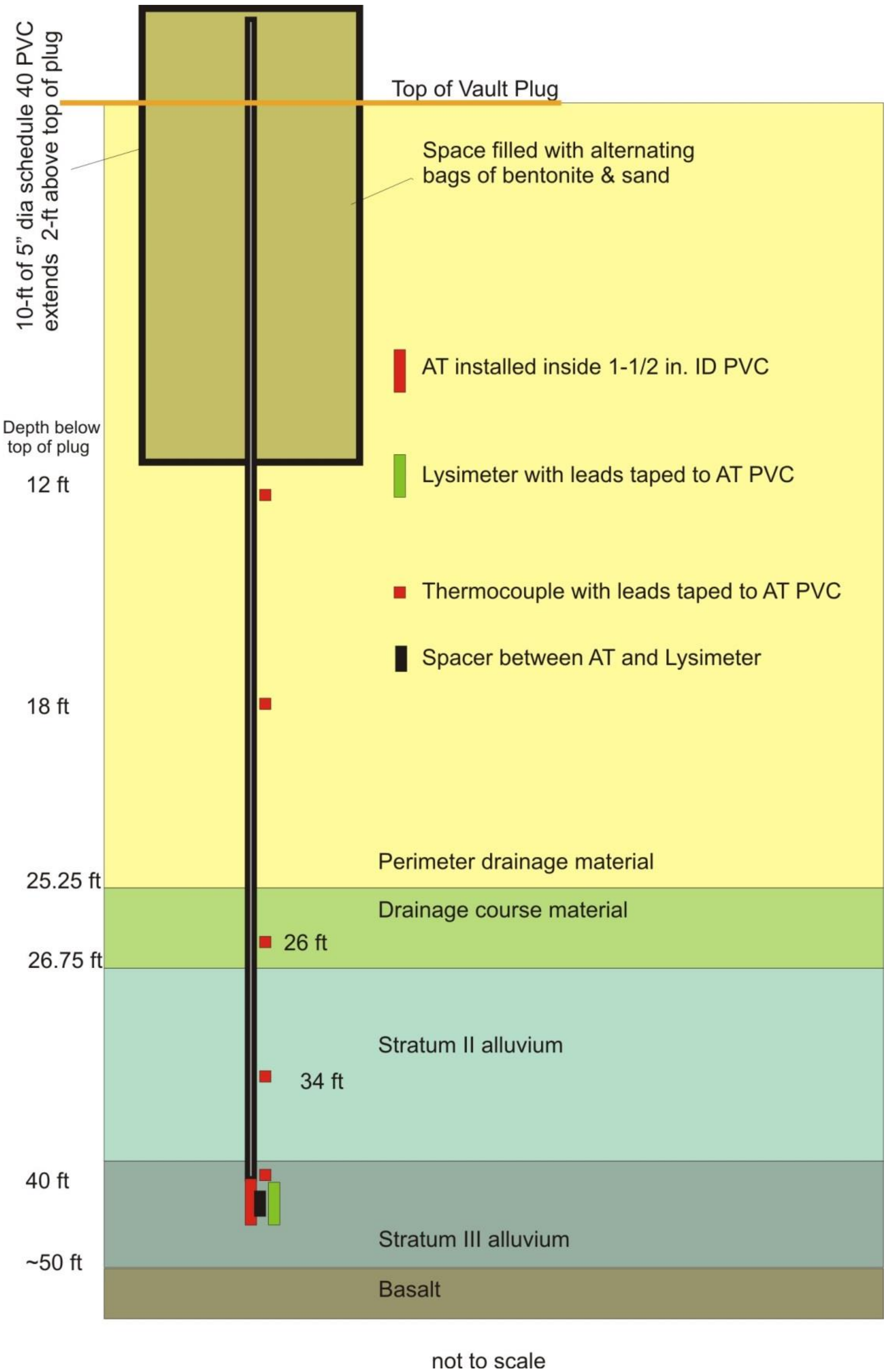


Figure 12. Vertical section showing instrument locations in the 55-Ton-South-45 drilled borehole. Note there is one AT and no WCR.

Table 5. Sensors, locations, and installation depths for the NuPac-West instrumented tube, NuPac-East instrumented tube, and the NuPac-West-45 and NuPac-East-45 drilled boreholes.

Sensor Type	Depths of Instrument Installation Relative to Top of the Vault Plug NuPac-West Instrumented Tube	NuPac-East Instrumented Tube	NuPac-West-45 Drilled Borehole	NuPac-East-45 Drilled Borehole	Material Instrumented
ATs and WCRs	22 ft 26 ft NA	22 ft 26 ft NA	NA NA 42.5 ft (no AT, 1 WCR)	NA NA 41 ft (1 AT, no WCR)	Drainage course material Stratum II alluvium just below the drainage course material Stratum III alluvium above the first basalt contact
Suction Lysimeter	26 ft	26 ft	43 ft	43 ft	Drainage course material Stratum III alluvium above the first basalt contact
Thermocouple	NA	NA	12 ft 18 ft 26 ft 34 ft 42.5 ft	12 ft 18 ft 26 ft 34 ft 41 ft	Alluvial fill Alluvial fill Stratum II alluvium Stratum II alluvium Stratum III alluvium

Notes:
1. NuPac-West-45 drilled borehole contains 1 WCR and no AT.
2. NuPac-East-45 drilled borehole contains 1 AT and no WCR. This was done to reduce the volume in the borehole occupied by the PVC and to allow better compaction of materials around the instruments when the auger was reversed during installation.
3. Set depth for instruments in NuPac-West-45 and NuPac-East-45 differ because of the depth to the Stratum III alluvium.

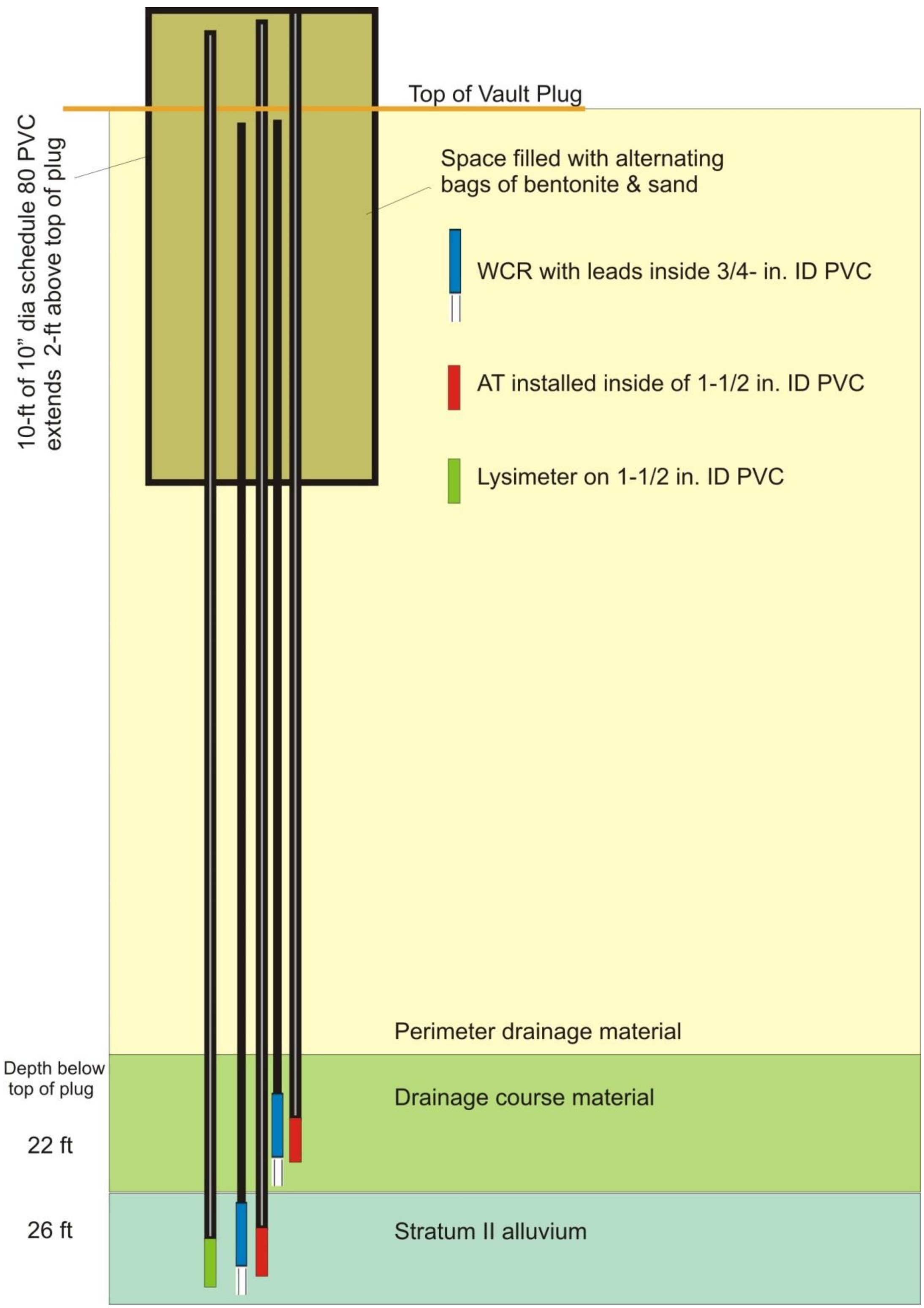


Figure 13. Vertical section showing instrument locations in the NuPac-West and NuPac-East instrumented tubes

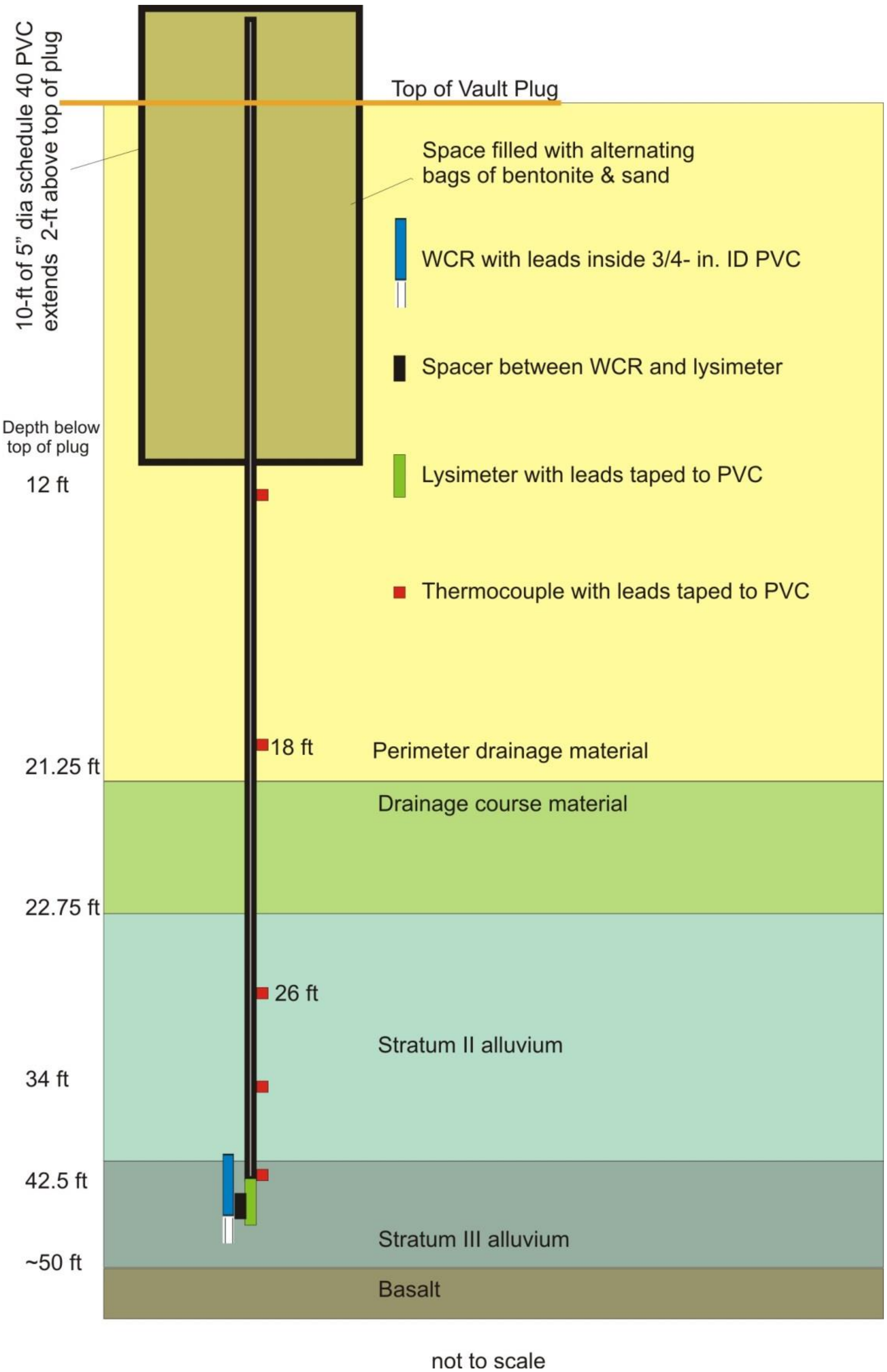


Figure 14. Vertical section showing instrument locations in the NuPac-West-45 drilled borehole. This borehole has one WCR, but does not have an AT.

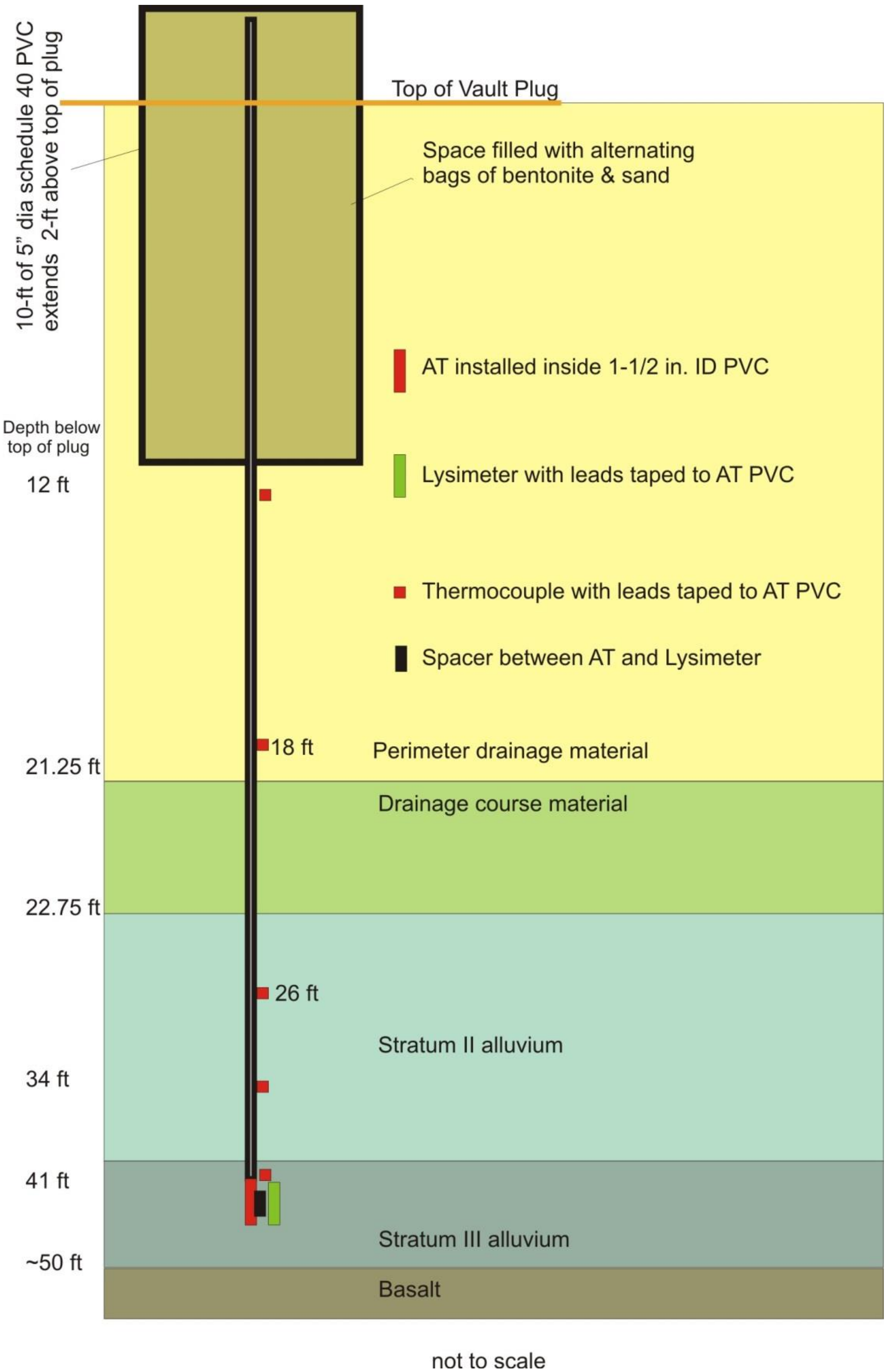


Figure 15. Vertical section showing instrument locations in the NuPac-East-45 drilled borehole. This borehole has one AT, but does not have a WCR.

3.2.4 Hot Fuel Examination Facility Vault Array Instrumentation

One instrumented tube and one 45-ft drilled borehole are located on the south side of the HFEF vaults (see Figure 6 for locations relative to the HFEF vaults in the HFEF/LCC vault array). The HFEF-East instrumented tube extends through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium (see Figure 16 for the vertical cross section) and contains two ATs, two WCRs, and one suction lysimeter at the depths indicated in Table 6.

The HFEF-East-45 drilled borehole contains one WCR, one suction lysimeter, and five thermocouples (Figure 17) at the depths indicated in Table 6. This preserves an AT-WCR-AT-WCR sequence along the vault array and use of at least one of these instruments in each well (Figure 6). Placing a single WCR in this borehole instead of using both an AT and WCR reduced the volume occupied by the PVC carrier pipes to allow better compaction of the materials around the instruments when the auger was reversed during installation. This is in contrast to the PA-45 drilled borehole where one AT and one WCR were installed through the 4-in. ID hollow stem auger.

The HFEF, LCC, NuPac, and MFTC vaults are the same overall height (see Table 2) and are 4-ft shorter than the 55-ton and PA Confirmation Vaults. Therefore, the depth to the drainage course material and instrument set depths are 4-ft shallower for them. The deepest instrument set depth was determined based on depth to the Stratum III alluvium. This is reflected by the set depths shown in Table 6.

3.2.5 Large Concept Cask Vault Array Instrumentation

Two instrumented tubes and two 45-ft drilled boreholes are located on the south side of the LCC vaults (see Figure 6 for locations relative to the LCC vaults). The LCC-West and LCC-East instrumented tubes extend through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium (see Figure 18 for the vertical cross section) and contain two ATs, two WCRs, and one suction lysimeter at the depths indicated in Table 7.

The LCC-West-45 drilled borehole contains one AT, one suction lysimeter, and five thermocouples (Figure 19) at the depths indicated in Table 7. The LCC-East-45 drilled borehole contains one WCR, one suction lysimeter, and five thermocouples (Figure 20) at the depths indicated in Table 7. This preserves the AT-WCR-AT-WCR sequence shown in Figure 6. Placing either an AT or WCR in each of these boreholes instead of using both instruments reduced the volume occupied by the PVC carrier pipes to allow better compaction of the materials around the instruments when the auger was reversed during installation. This is in contrast to the PA-45 drilled borehole where one AT and one WCR were installed through the 4-in. ID hollow stem auger.

The HFEF, LCC, NuPac, and MFTC vaults are the same overall height (see Table 2) and are 4-ft shorter than the 55-ton and PA Confirmation Vaults. Therefore, the depth to the top of the drainage course material and top of the Stratum II alluvium is 4-ft shallower for them. The instrument set depths were determined based on depth to the top of the Stratum III alluvium as shown in Table 7.

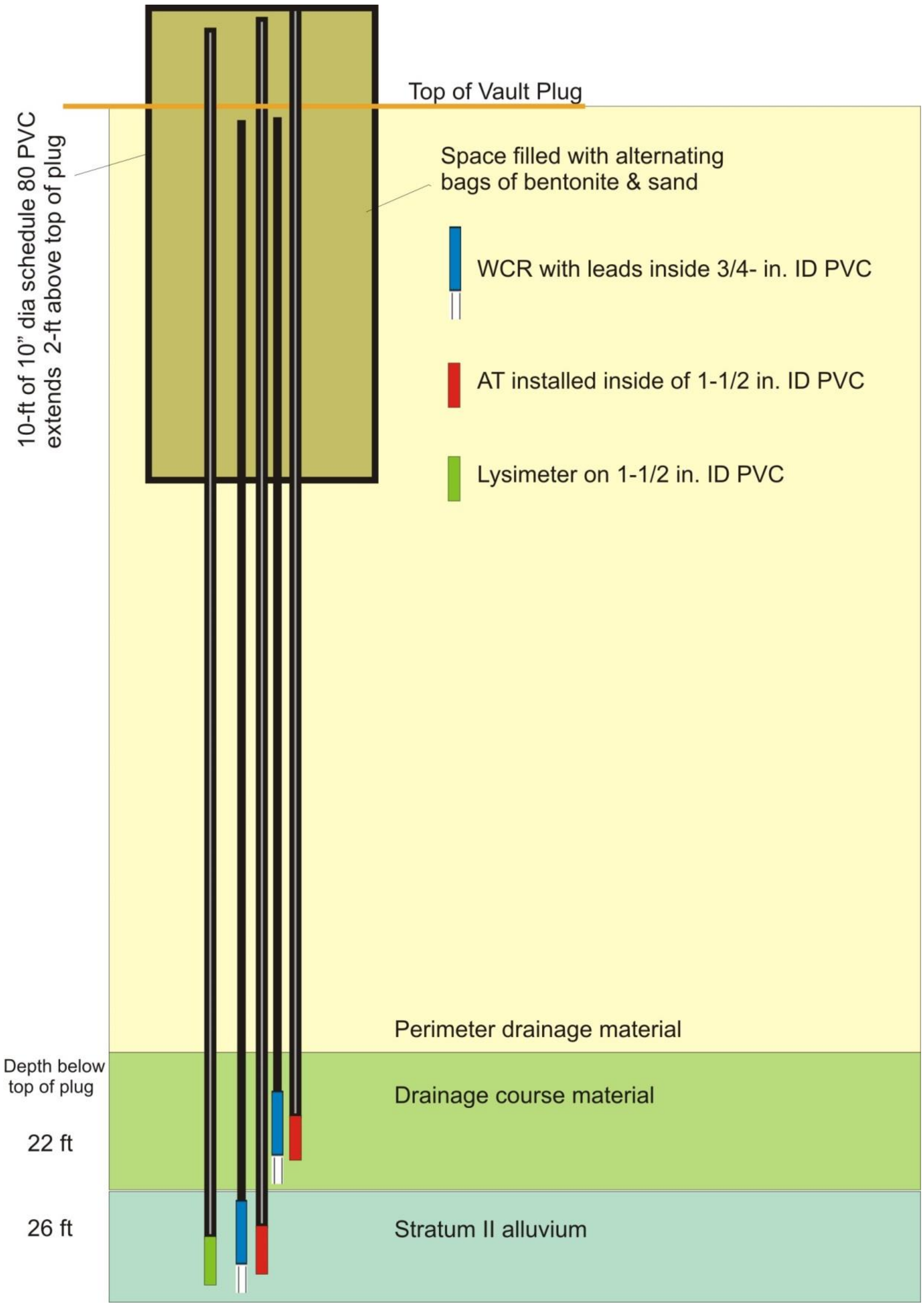


Figure 16. Vertical section showing instrument locations in the HFEF-East instrumented tube.

Table 6. Sensors, locations, and installation depths for the HFEF-South instrumented tube and HFEF-East-45 drilled borehole.

Sensor Type	Depths of Instrument Installation Relative to Top of the Vault Plug HFEF-South Instrumented Tube	HFEF-South-45 Drilled Borehole	Material Instrumented
ATs and WCRs	22 ft 26 ft NA	NA NA 42-ft (no AT, 1 WCR)	Drainage course material Stratum II alluvium just below the drainage course material Stratum III alluvium above the first basalt contact
Suction Lysimeter	26-ft	42-ft	Drainage course material (HFEF-East) Stratum III alluvium above the first basalt contact (HFEF-East-45)
Thermocouple	NA	12 ft 18 ft 26 ft 34 ft 42 ft	Alluvial fill Alluvial fill Stratum II alluvium Stratum II alluvium Stratum III alluvium

Note that the HFEF-East-45 drilled borehole contains one WCR and no AT. This preserves an AT-WCR-AT-WCR sequence along the vault array and use of a single one of these instruments in each well (Figure 6). This was done to reduce the volume in the borehole occupied by the PVC and to allow better compaction of the materials around the instruments when the auger was reversed during installation.

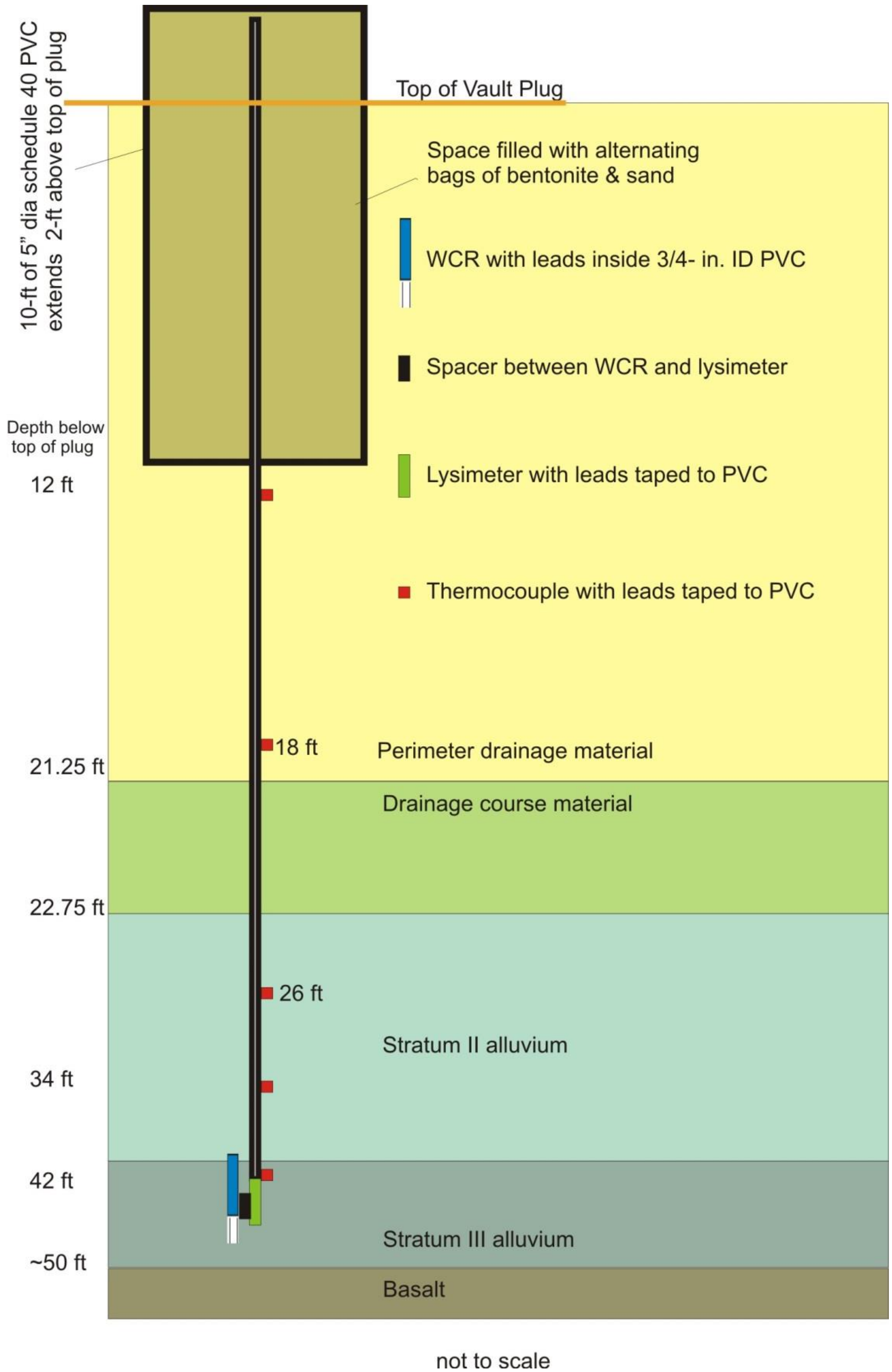


Figure 17. Vertical section showing instrument locations in the HFEF-East-45 drilled borehole. This borehole has no AT but does have a WCR.

Table 7. Sensors, locations, and installation depths for the LCC-West instrumented tube, LCC-East instrumented tube, and the LCC-West-45 and LCC-East-45 drilled boreholes.

Sensor Type	Depths of Instrument Installation Relative to Top of the Vault Plug: LCC-West Instrumented Tube	LCC-East Instrumented Tube	LCC-West-45 Drilled Borehole	LCC-East-45 Drilled Borehole	Material Instrumented
ATs and WCRs	22 ft 26 ft NA	22 ft 26 ft NA	NA NA 41.75 ft (1 AT, no WCR)	NA NA 43.75 ft (no AT, 1 WCR)	Drainage course material Stratum II Alluvium just below the drainage course material Stratum III alluvium above the first basalt contact
Suction Lysimeter	26 ft	26 ft	41.75 ft	43.75 ft	Stratum II alluvium (instrumented tubes) Stratum III alluvium above the first basalt contact (45-ft drilled boreholes)
Thermocouple	NA	NA	12 ft 18 ft 26 ft 34 ft 41.75 ft	12 ft 18 ft 26 ft 34 ft 43.75 ft	Alluvial fill Alluvial fill Stratum II alluvium Stratum II alluvium Stratum III alluvium

Note that the LCC-West-45 drilled borehole contains one AT and no WCR. The LCC-East-45 drilled borehole contains one WCR and no AT. This was done to reduce the volume in the borehole occupied by the PVC and to allow better compaction of the materials around the instruments when the auger was reversed during installation. This preserves the AT-WCR-AT-WCR sequence shown in Figure 6.

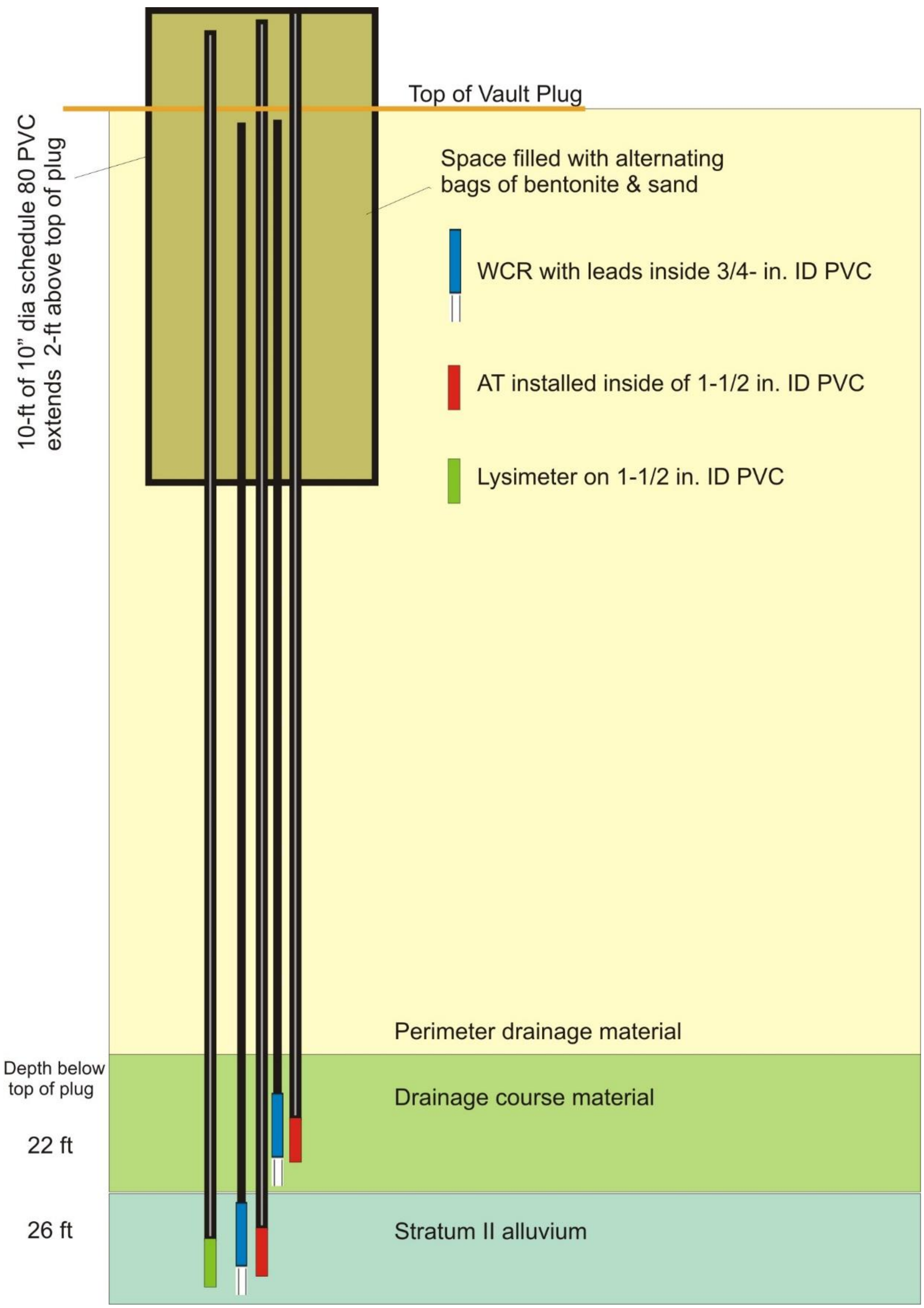


Figure 18. Vertical section showing instrument locations in the LCC-West and LCC-East instrumented tubes.

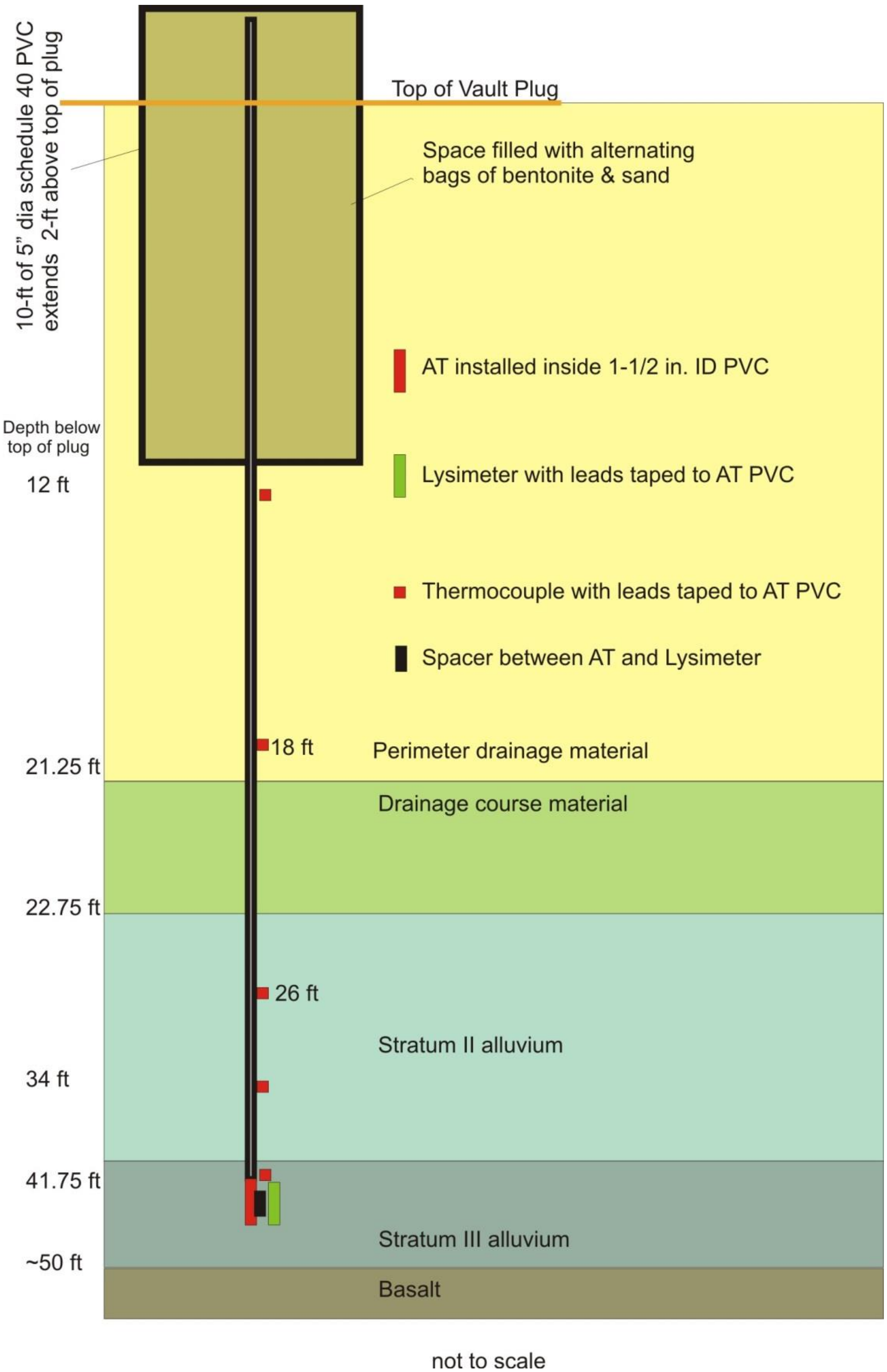


Figure 19. Vertical section showing instrument locations in the LCC-West-45 drilled borehole. This borehole has one AT but does not have a WCR.

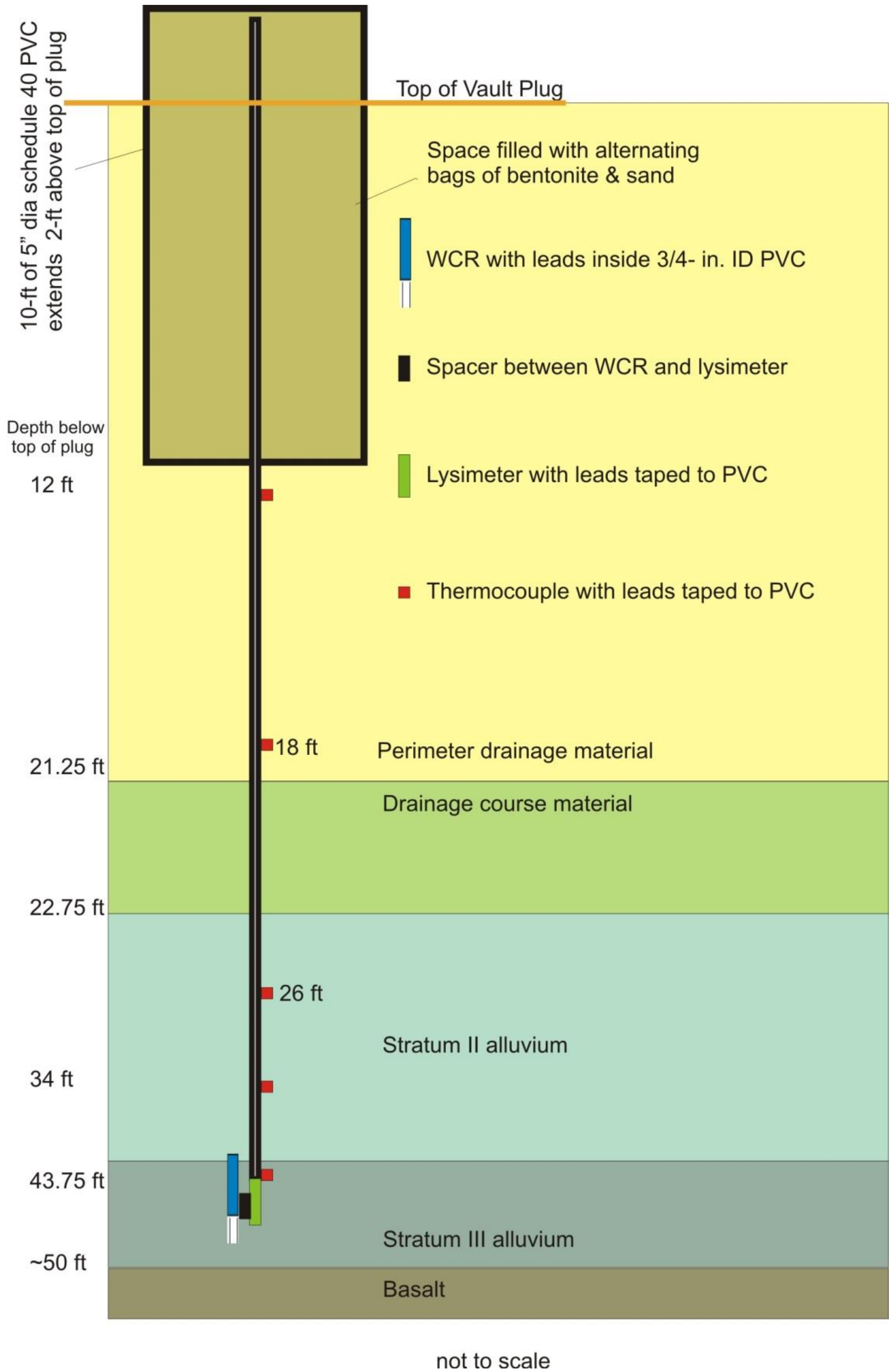


Figure 20. Vertical section showing instrument locations in the LCC-East-45 drilled borehole. This borehole has no AT but does have a WCR.

3.2.6 Modified Facility Transfer Container Vault Array Instrumentation

Two instrumented tubes and two 45-ft drilled boreholes are located on the south side of the MFTC vaults (see Figure 6 for locations relative to the MFTC vaults). The MFTC-West and MFTC-East instrumented tubes extend through the vault perimeter drainage material and drainage course material, terminating in the Stratum II alluvium (see Figure 21 for the vertical cross section) and contain two ATs, two WCRs, and one suction lysimeter at the depths indicated in Table 8.

The MFTC-West-45 drilled borehole contains one WCR, one suction lysimeter, and five thermocouples (Figure 22) at the depths indicated in Table 8. The MFTC-East-45 drilled borehole contains one AT, one suction lysimeter, and five thermocouples (Figure 23) at the depths indicated in Table 8. This preserves the AT-WCR-AT-WCR sequence shown in Figure 6. Placing either an AT or WCR in each of these boreholes instead of using both instruments reduced the volume occupied by the PVC carrier pipes to allow better compaction of the materials around the instruments when the auger was reversed during installation. This is in contrast to the PA-45 drilled borehole, where one AT and one WCR were installed through the 4-in. ID hollow stem auger.

The HFEF, LCC, NuPac, and MFTC vaults are the same overall height (see Table 2) and are 4-ft shorter than the 55-ton and PA Confirmation Vaults. Therefore, the depth to the drainage course material is 4-ft shallower for them. The instrument set depths were determined by the depth to the Stratum III alluvium as shown in Table 8.

3.2.7 Sedimentary Interbed Well Instrumentation

Three sedimentary interbed wells are drilled to depths of 168 to 173 ft below the surface finished grade. The wells are installed in the southeast corner of the NuPac vault array and the northwest and northeast corners of the MFTC vault array as shown in Figure 3 and Figure 6. All three wells contain an AT, WCR, and lysimeter as shown in Figure 24 and Table 9. Depths of the instrument installations vary slightly with each well as shown in Table 9.

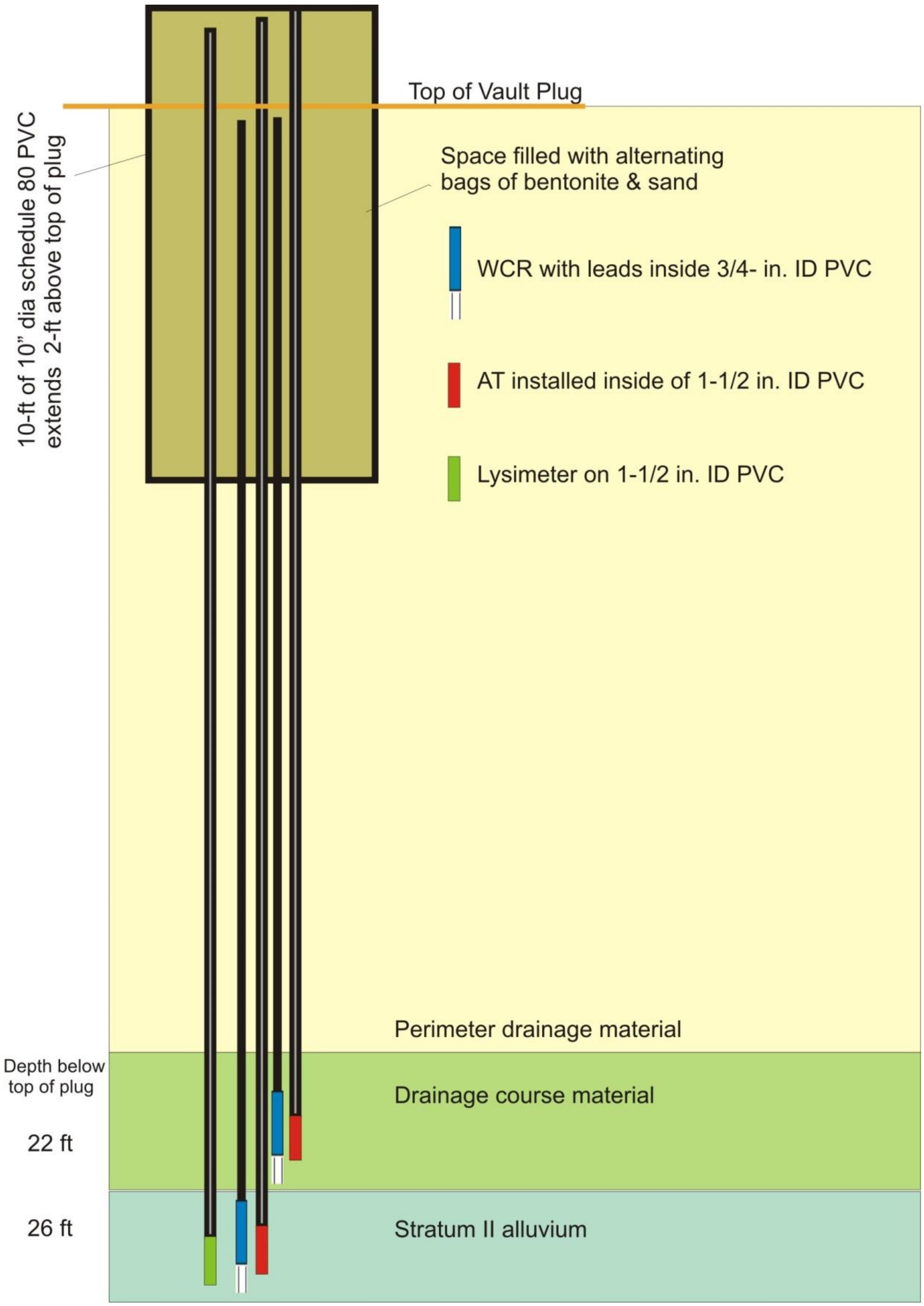


Figure 21. Vertical section showing instrument locations in the MFTC-West and MFTC-East instrumented tubes.

Table 8. Sensors, locations, and installation depths for the MFTC-West instrumented tube, MFTC-East instrumented tube, and MFTC-West-45 and MFTC-East-45 drilled boreholes.

Sensor Type	Depths of Instrument Installation Relative to Top of the Vault Plug				Material Instrumented
	MFTC-West Instrumented Tube	MFTC-East Instrumented Tube	MFTC-West-45 Drilled Borehole	MFTC-East-45 Drilled Borehole	
ATs and WCRs	22 ft 26 ft NA	22 ft 26 ft NA	NA NA 43.8 ft (1 WCR, no AT)	NA NA 41.75 ft (1 AT, no WCR)	Drainage course material Stratum II alluvium just below the drainage course material Stratum III alluvium above the first basalt contact
Suction Lysimeter	26 ft	26 ft	43.8 ft	41.75 ft	Stratum II alluvium (instrumented tubes) Stratum III alluvium above the first basalt contact (45-ft drilled boreholes)
Thermocouple	NA	NA	12 ft 18 ft 26 ft 34 ft 43.8 ft	12 ft 18 ft 26 ft 34 ft 41.75 ft	Alluvial fill Alluvial fill Stratum II alluvium Stratum II alluvium Stratum III alluvium

Note that the MFTC-West-45 drilled borehole contains 1-WCR and no AT. The MFTC-East-45 drilled borehole contains 1 AT and no WCR. This was done to reduce the volume in the borehole occupied by the PVC and to allow better compaction of the materials around the instruments when the auger was reversed during installation. This preserves the AT-WCR-AT-WCR sequence shown in Figure 6.

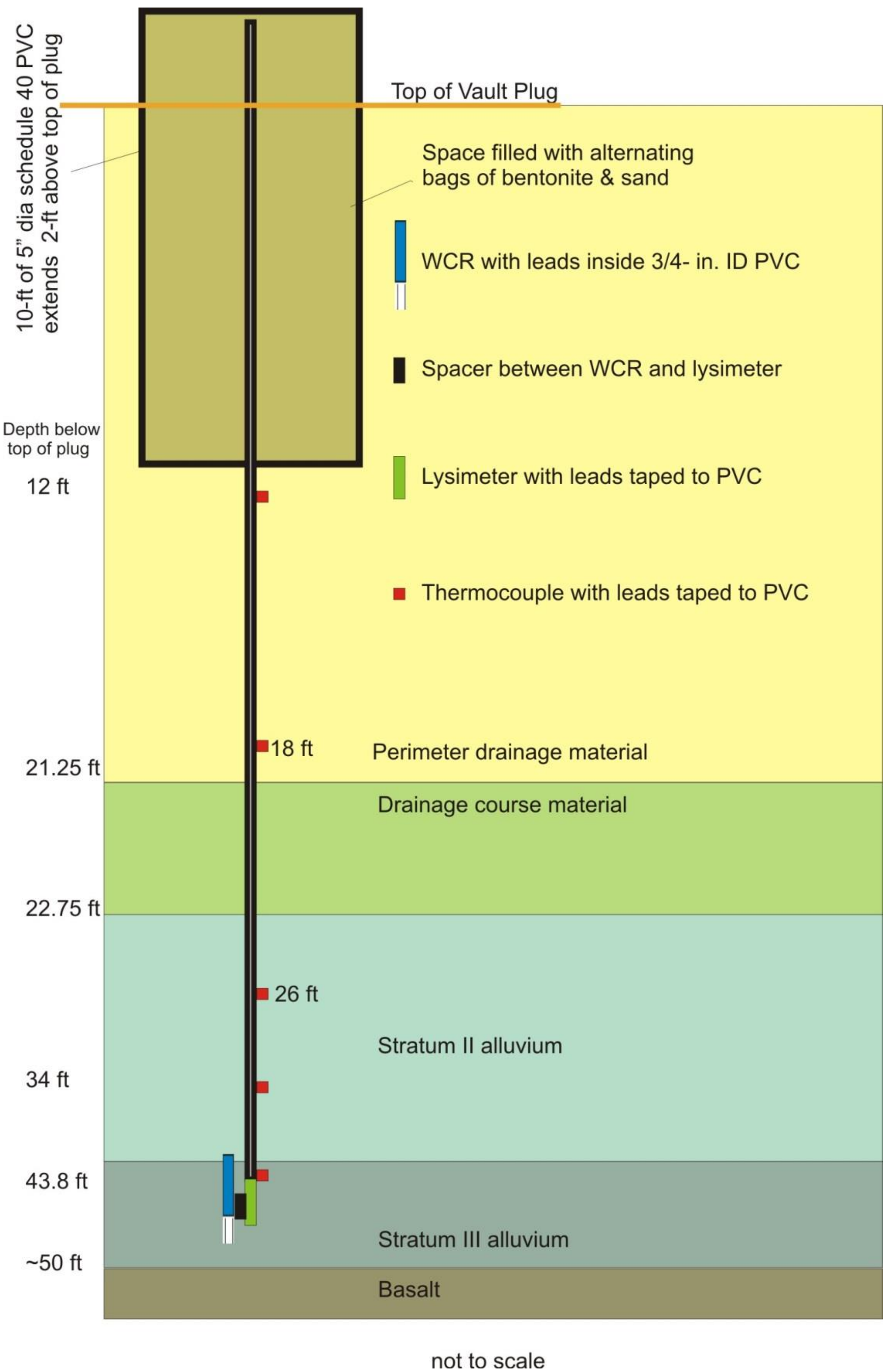


Figure 22. Vertical section showing instrument locations in the MFTC-West-45 drilled borehole. This borehole has one WCR, but does not have an AT.

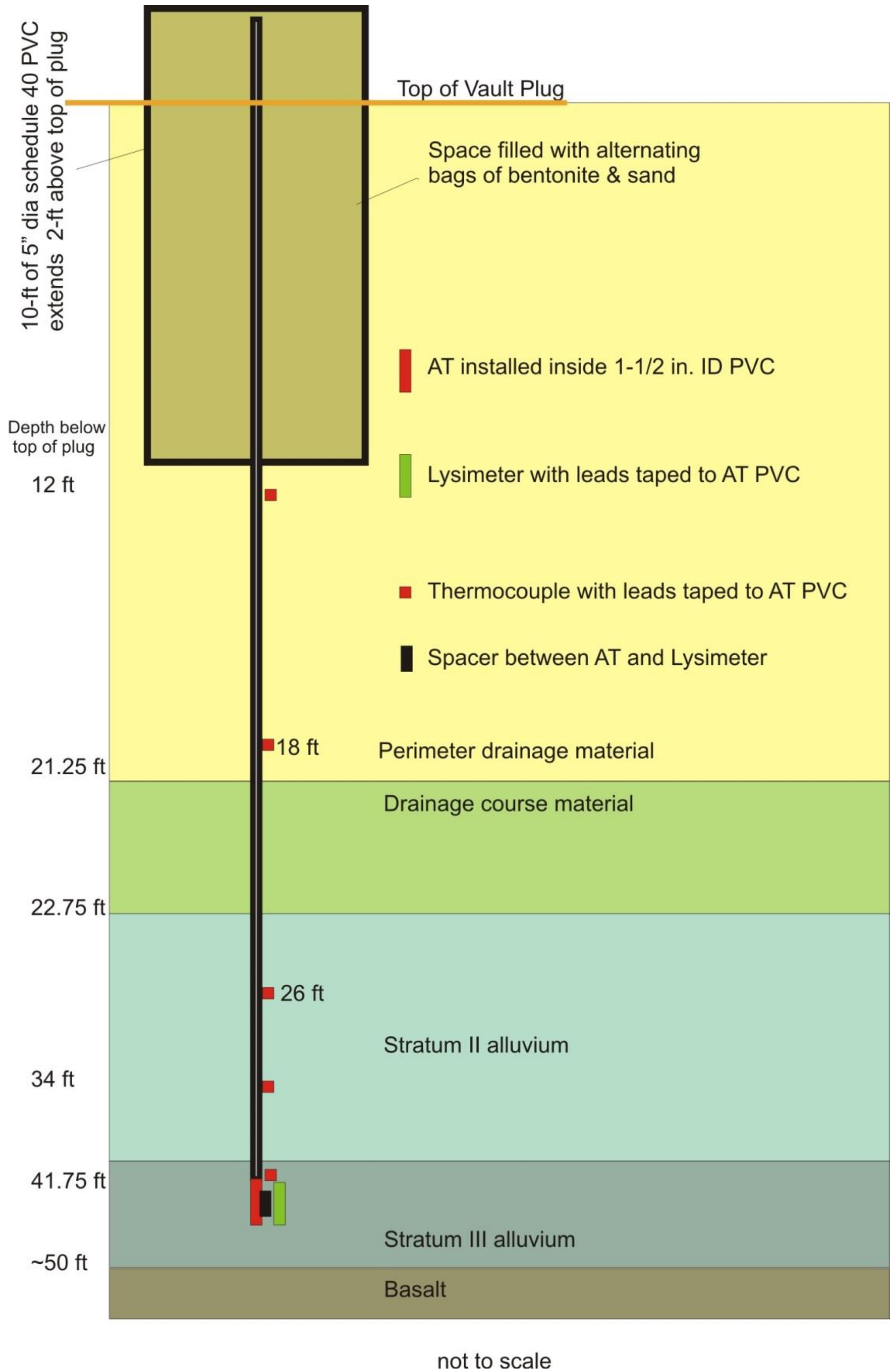


Figure 23. Vertical section showing instrument locations in the MFTC-East-45 drilled borehole. This borehole has one AT, but does not have a WCR.

Table 9. Sensors, locations, and installation depths for the three sedimentary interbed wells.

	Depths Relative to Surface Finished Grade[a]			
Sensor or Material Interface	NuPac-SIW Sedimentary Interbed Well	MFTC-West-SIW Sedimentary Interbed Well	MFTC-East-SIW Sedimentary Interbed Well	Material Instrumented
Depth to basalt	Not recorded	42 ft	Not recorded	NA
Depth to the interbed	168.5 ft	173 ft	168 ft	NA
Total drilled depth	173 ft	176.6 ft	172 ft	NA
Depth of the instruments	170.5 ft	176 ft	171 ft	NA
Depth to the top of the bedding sand after instrument installation	166.5 ft	169.6 ft	164 ft	NA
Depth of sand beneath the sensors	2.5 ft	0.6 ft	1 ft	NA
ATs and WCRs	170.5 ft	176 ft	171 ft	About 20-ft thick sedimentary interbed located at a depth of about 170 ft
Suction lysimeter	170.5 ft	176 ft	171 ft	

a. Instrument depths are measured relative to the surface finished grade because, unlike other boreholes and instrumented tubes, these wells are not directly adjacent to the vault plugs.

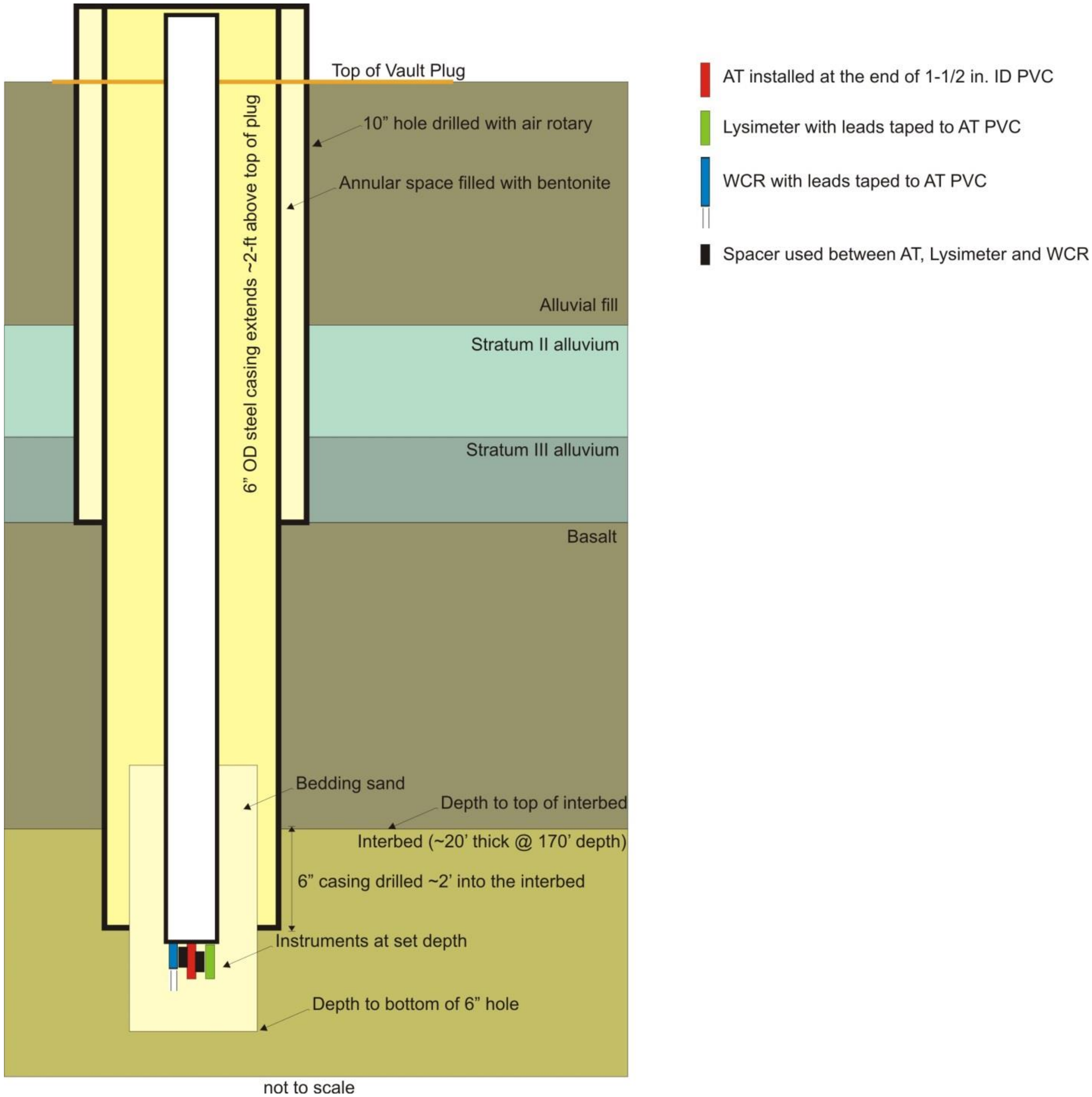


Figure 24. Vertical section showing instrument locations in the sedimentary interbed wells.

4. INSTALLATION METHODS

4.1 Instrumented Tubes

Instrumented tubes were installed during emplacement of drainage course material and alluvial backfill around the vault arrays. The process followed these steps:

1. As shown in Figure 4, the entire vault array area was excavated to the total depth required for emplacement of the geotextile material, drainage course material, vault bases, vault upper riser sections, and plugs, leaving the elevation of the top of the vault plugs at 4,940 ft.
2. After excavation, the geotextile material (see Figure 5) was laid out in the section being prepared.

3. The vault array being installed was surveyed in, providing the location of the instrumented tubes.
4. A 2 × 2 ×2-ft plywood box open on the top and bottom was placed on top of the geotextile material at the location of each instrumented tube. The geotextile was cut and a 2-ft deep hole was dug into the Stratum II alluvium.
5. One lysimeter, one AT, and WCR (all connected to PVC pipes) were installed at the bottom of the dug hole, leaving adequate space between the instruments to ensure appropriate infilling around them with the Stratum II alluvium that had been excavated from the hole.
6. The 2-ft deep hole was backfilled using the Stratum II alluvium excavated from the hole.
7. After placing 6-in. of drainage course material in the bottom of the box, one AT and one WCR were installed, leaving adequate space between the instruments and between the PVC risers extending from the deeper set of instruments. The box was then backfilled with the drainage course material and all four of the PVC risers were grouped together, leaving enough of the WCR tubing to reach land surface hanging on the PVC.
8. The drainage course material was then installed in lifts, compacting around the PVC riser tube bundle.
9. After 18-in. of drainage course material was installed, the plywood box was removed and the vault perimeter drainage material or the alluvial fill material was installed in lifts around the tube bundles, with the material used being dependent on distance from the concrete vaults (see Figure 5).
10. When the fill depth reached the top of the 20-ft PVC riser sections, the WCR tubes were fed through a new section and the new section of PVC was glued to the buried section.
11. After the PVC was within 8-ft of the elevation of the tops of plugs, a 10-in. ID Schedule 80 PVC pipe was lowered over the PVC tube bundle and the backfilling operation continued.
12. At the top of the 10-in. PVC pipe (2-ft above the top of the vault plugs), a flange was installed to hold the weather-proof box.
13. The weather-proof box was installed, allowing installation of the solar panel batteries, the charging regulator, and the data logger. All electrical connections were made.

4.2 45-ft Drilled Boreholes

The 45-ft drilled boreholes were installed using a 12-in. outer diameter hollow stem auger.

1. The 12-in. truck-mounted auger was positioned as close as possible adjacent to each of the instrumented tubes at each target location.
2. Holes were drilled until the Stratum III material was reached. The auger easily drilled through the vault perimeter drainage material at all locations (and the alluvial fill material at the PA-45 location), the drainage course material, geotextile material, and Stratum II alluvium. The Stratum III alluvium offered higher resistance to drilling and was encountered at a depth of about 40-ft from the top of the vault plugs.
3. After the target depth (i.e., either 45-ft or the top of the Stratum III alluvium) was reached, 6-in. of sand was placed into the bottom of the hole to provide bedding for the lysimeter, AT, or WCR.
4. The lysimeter, AT, or WCR were inserted through the 6-in. ID hollow cavity.
5. Prior to instrument installation, the instruments installed at the bottom of the PVC carrier tube (typically either the AT or lysimeter) were glued to the PVC, the other instruments were taped to the PVC with wires taped to the outside, and the thermocouples were taped to the PVC.

6. After the bedding sand was poured into the hole, the PVC carrier pipe was lowered into the hole, and backfilled with another bag of sand.
7. The auger was reversed, compacting the native materials and drainage materials around instruments and the PVC pipe.

4.3 Sedimentary Interbed Wells

The sedimentary interbed wells were drilled using air rotary with following steps (the depths for each of the three sedimentary interbed wells are shown in Table 9):

1. A 10–in. diameter surface casing was drilled/advanced from land surface to the top of basalt.
2. The bit was changed to allow installation of 6-in. casing down to the sedimentary interbed located at approximately 165 to 175 ft below the top of the vault plugs. The total depth of each hole is approximately 2-ft below the bottom of the 6-in. casing.
3. Six inches of sand was placed in the bottom of the hole.
4. Instruments shown in Table 9 were placed in the bedding sand.
5. Bedding sand was placed over the instruments and the depth noted.
6. Bentonite was placed in the annular space between the 10-in. casing and the 6-in. casing (i.e., between the top of basalt and land surface).
7. The 10-in. casing was then removed.

5. POWER

Power has been supplied to each monitoring location for operation of all installed sensors and data collection systems:

- Temporary power includes a solar panel, voltage regulator, and a battery located at each wellhead.
- The solar panels are installed adjacent to the wellhead enclosure and are mounted on a galvanized pipe. Electrical cabling, cable protection, and connections have been provided between the solar panels and the weather-proof enclosure. The conduit was installed at least 12-in. deep.

The ability to transition to permanent 120-V power is provided at each location.

6. DATA COLLECTION/COMMUNICATION SYSTEM

The data collection/communication system was designed/selected to allow automatic collection and transmittal of data from the data loggers to a central collection point in the administration building for processing.

- Collection and temporary storage of data occur using individual data loggers, with data transmission capability installed at each wellhead.
  - Data collection frequency is programmable and determined by facility operations requirements.
  - Data processing software other than that used to transmit or receive the data (i.e., add-on software for data visualization) is not provided.
- Future data transmission can be from each data logger or to a single data logger for subsequent transmission (i.e., using a short-range radio to a single data logger and a single cell modem for data transmission to the administration building).

- All data can be transmitted to the central collection point in the administration building without pre-filtering. All required hardware, including antennas, cabling, and cell modems can be provided at each wellhead for necessary data transmission capabilities.
- At this time, no data transmission capabilities have been installed, but the instrumentation has been procured.

6.1 Sensor Installation and Data Logger Wiring Diagrams

6.1.1 Wiring the Advanced Tensiometer Sensors

Two wiring conventions (A and B) are used for the AT sensors. The different AT wiring protocols are identified by the ground wire as follows:

- Convention A Wiring: If there is not a white wire, the ground is the bare wire and Convention A is used.
  - Bare wire → Ground. Connect the bare wire to any terminal on the data logger with the "ground" symbol.
  - Black wire → Signal. Connect the black wire to terminal U1 (for first AT) or U2 (for second AT).
  - Red wire → 12-V power. Connect to the 12-V power terminal.
- Convention B Wiring: If there are black, white, red, and bare wires, first cut off the bare wire and use Convention B.
  - Black wire → Ground. Connect the bare wire to any terminal on the data logger with the "ground" symbol.
  - White wire → Signal. Connect the black wire to terminal U1 (for first AT) or U2 (for second AT).
  - Red wire → 12-V power. Connect to the 12-V power terminal.

6.1.2 Seating the Advanced Tensiometers

ATs must be seated in the stopper above the ceramic cup. To maintain ATs, the following procedure is used:

1. Measure the voltage across the AT (between the ground and signal (U1) terminals).
2. Pour about17 oz of water down the tube on top of the AT.
3. Lift the AT 3 in. out of the stopper being careful to not pull the wires out of the data logger. This allows the water to pass the seal into the cup, ensuring the interface between the stopper and cup are clean. Gently lifting and lowering the AT will flush out air and any potential debris that may be contaminating the seal surface at this stage.
4. Replace the ATs by applying a small downward pressure and rotating slightly to set the seals. Do not overpressure the seals. After a short time period, the suction caused by the unsaturated media will seat the ATs more securely.
5. Re-measure the voltage across the ground and signal terminals, watching the voltage decrease as the suction increases in the ceramic cup. If the suction does not increase as indicated by decreasing voltage, reseat the AT again following steps 2 through 4.

6.1.3 Wiring the Solar Panels

Power to the data loggers is supplied through the battery, with the battery connected to the solar panel through the charging regulator as follows:

1. Connect a red (power) and black (ground) wire from the data logger to the terminals labeled G and 12-V on the CH150 charging regulator (bottom terminals in Figure 25 left).
2. Connect a red (power) and black (ground) wire from the battery to the charging regulator terminals (top terminals in Figure 25 left to battery shown in Figure 25 right).
3. Connect a red (power) and black (ground) wire to the ground terminal and solar terminals on the regulator (middle two wires in Figure 25 left) to the solar panel.

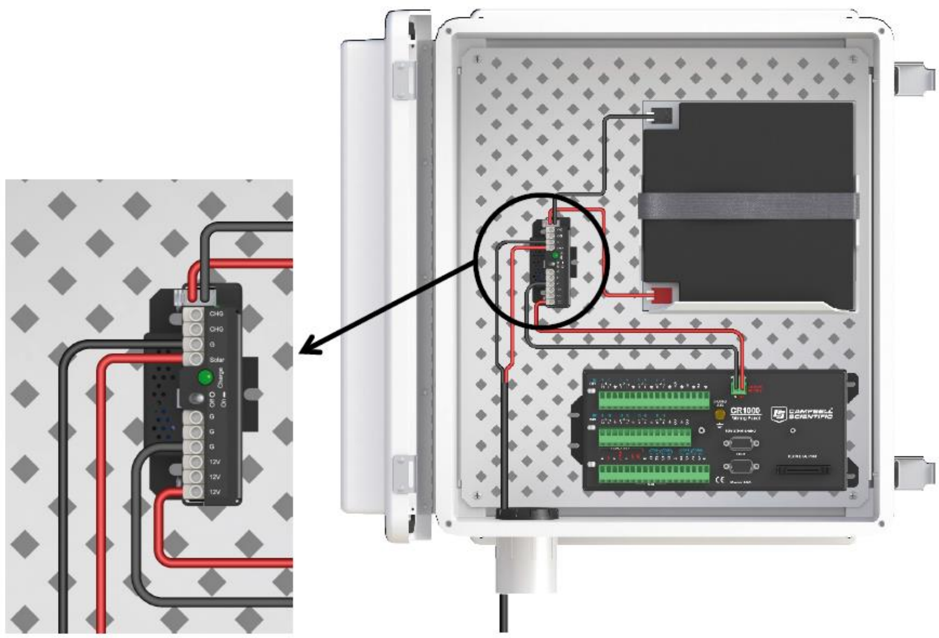


Figure 25. Solar panel and battery to data logger wiring for the CR1000 data loggers. The wiring is the same for the CR6 data loggers.

6.1.4 Wiring the Water Content Reflectometers

There are black (ground), orange (ground), clear, red, and green wires on the WCRs, with the function of each shown in Table 10.

Table 10. Wire color, function, and data logger connection for the WCRs.

Wire Color	Function	Data Logger Connection
Green	SDI-12 Data	C terminals (C1, C3…)
Red	SDI-12 Power	12-V
Black	SDI-12 Reference	G
Clear	Shield	G
Orange[1]	Not Used	G

Note: The orange wire on some WCRs has faded to yellow from sun exposure.

6.1.5 Instrumented Tube Wiring

All instrumented tube installations along the vault arrays (i.e., excepting the PA vaults) have two ATs, two WCRs, and one lysimeter. The lysimeter does not require power. They have been wired consistently as shown in Table 11 and Figure 26.

Table 11. Wiring for the instrumented tube locations along the vault arrays (except the PA vaults).

Instrument	Wire Color	Function	Data Logger Connection	Comment
Shallow AT	Red	12-V power	12V terminal	
	Black	Ground	Ground terminal	
	White	Signal	U2	
Deep AT	Red	12-V power	12-V terminal	
	Black	Ground	Ground terminal	
	White	Signal	U1	Data in Table 1 will occur for the deep sensors first.
Shallow WCR	Black, Orange, Clear	Ground	First ground at bottom of Figure 26	
	Red	12-V Power	12-V terminal	
	Green	Signal	C3	Requires changing the wiring diagram in the PC200W Program for this sensor (default is C1).
Deep WCR	Black, Orange, Clear	Ground	Second ground at bottom of Figure 26	
	Red	12-V Power	12-V terminal	
	Green	Signal	C1	Data in Table 1 will occur for the deep sensor first.

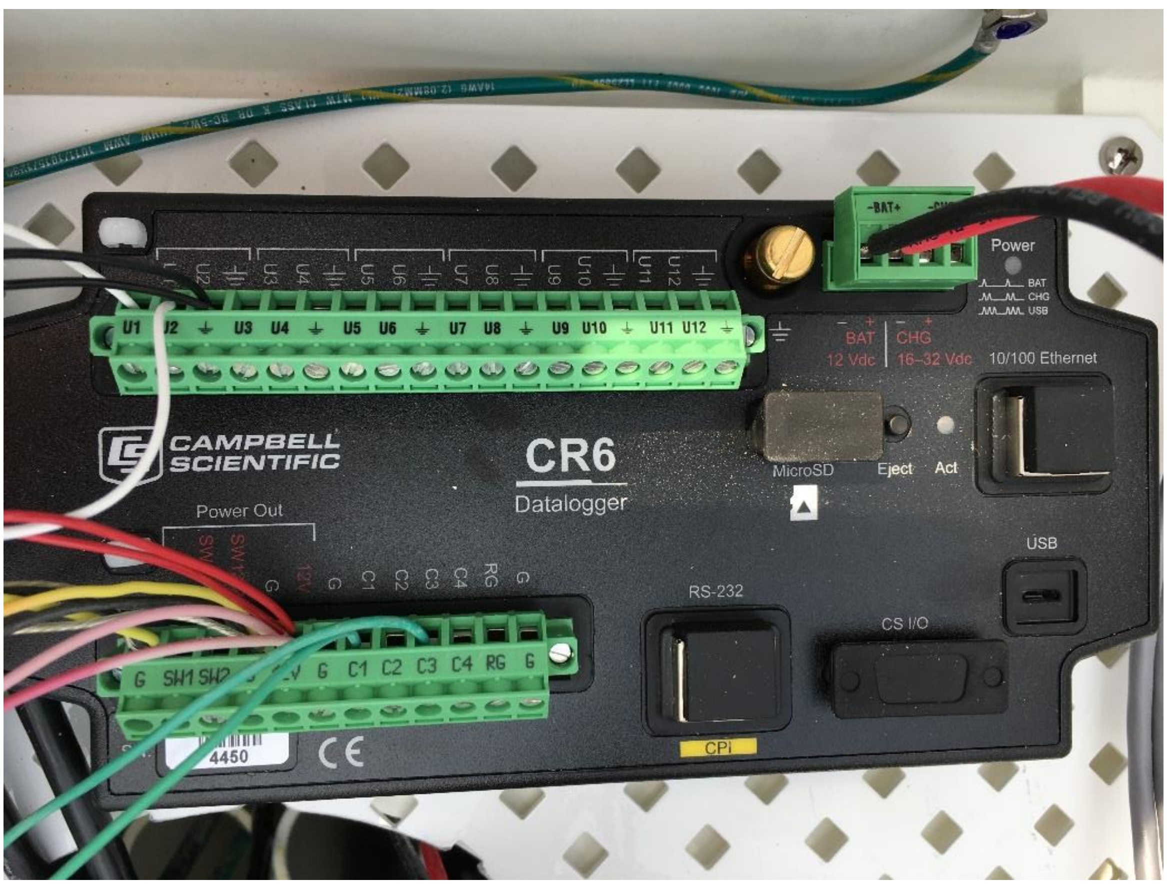


Figure 26. Data logger wiring for the instrumented tubes along the vault arrays.

6.1.6 Wiring for the 45-ft Boreholes with Advanced Tensiometers

There are thermocouples, one AT, and one lysimeter in these types of 45-ft boreholes. There is no wiring required for the lysimeter. The thermocouples and ATs are wired as shown in Table 12 and Figure 27.

Table 12. Wiring for the 45-ft boreholes with ATs installed in them along the vault arrays (except the PA vaults).

Instrument	Wire Color	Function	Data Logger Connection	Comment
AT	Red	12-V power	12-V terminal	Wires connected to the bottom left bar in Figure 27.
	Black	Ground	Ground terminal	
	White	Signal	U11	
Thermocouples				
12-ft	Purple	Diff High	U1	The resistance measured between the High and Low terminals will increase with depth when an ohm meter is used to verify continuity.
	Red	Diff Low	U2	
	Bare	Ground	Ground	
18-ft	Purple	Diff High	U3	
	Red	Diff Low	U4	
	Bare	Ground	Ground	
26-ft	Purple	Diff High	U5	
	Red	Diff Low	U6	
	Bare	Ground	Ground	
34-ft	Purple	Diff High	U7	
	Red	Diff Low	U8	
	Bare	Ground	Ground	
45-ft	Purple	Diff High	U9	
	Red	Diff Low	U10	
	Bare	Ground	Ground	

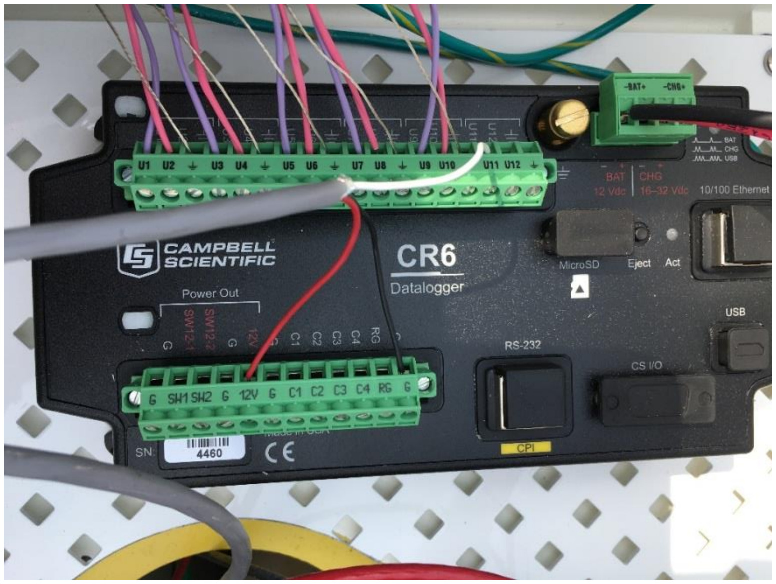


Figure 27. Data logger wiring for the 45-ft boreholes with ATs installed along the vault arrays.

6.1.7 Wiring for the 45-ft Boreholes with Water Content Reflectometers

There are thermocouples, one WCR, and one lysimeter in these types of 45-ft boreholes. There is no wiring required for the lysimeter. The thermocouples and WCRs are wired as shown in Table 13 and Figure 28.

Table 13. Wiring for the 45-ft boreholes with ATs installed in them along the vault arrays (except the PA vaults).

Instrument	Wire Color	Function	Data Logger Connection	Comment
WCR	Red	12-V power	12-V terminal	Wires connected to the bottom left bar in Figure 28.
	Black, Orange, Clear	Ground	Ground	
	Green	Signal	C1	
Thermocouples				
12-ft	Purple	Diff High	U1	The resistance measured between the high and low terminals will increase with depth when an ohm meter is used to verify continuity.
	Red	Diff Low	U2	
	Bare	Ground	Ground	
18-ft	Purple	Diff High	U3	
	Red	Diff Low	U4	
	Bare	Ground	Ground	
26-ft	Purple	Diff High	U5	
	Red	Diff Low	U6	
	Bare	Ground	Ground	
34-ft	Purple	Diff High	U7	
	Red	Diff Low	U8	
	Bare	Ground	Ground	
About 45-ft	Purple	Diff High	U9	
	Red	Diff Low	U10	
	Bare	Ground	Ground	

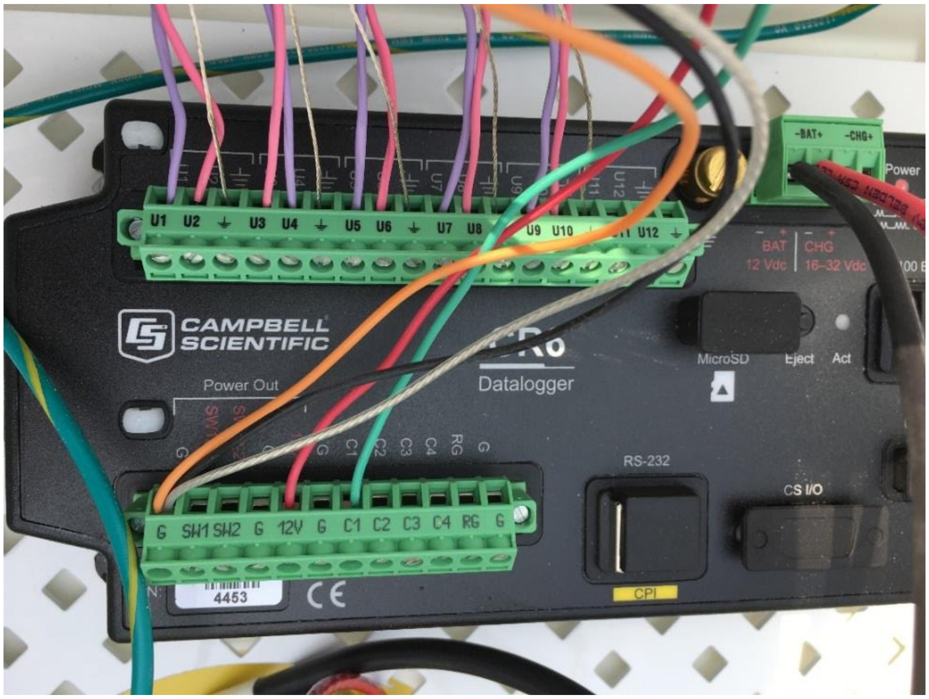


Figure 28. Data logger wiring for the 45-ft boreholes with WCRs installed along the vault arrays.

6.1.8 Wiring for the 175-ft Sedimentary Interbed Wells

The sedimentary interbed wells have one AT, one WCR and one lysimeter. The lysimeter is not connected to the data logger. Wiring for the AT and WCR are shown in Table 14 and Figure 29.

Table 14. Wiring for the 175-ft sedimentary interbed wells.

Instrument	Wire Color	Function	Data Logger Connection	Comment
AT	Red	12-V power	12-V terminal	
	Black	Ground	Ground	Terminal (between the U1 and U3 terminals) in Figure 29.
	White	Signal	U1	
WCR	Black, Orange, Clear	Ground	First ground at bottom of Figure 26	
	Red	12-V power	12-V terminal	Terminal on left bottom bar in Figure 29.
	Green	Signal	C1	

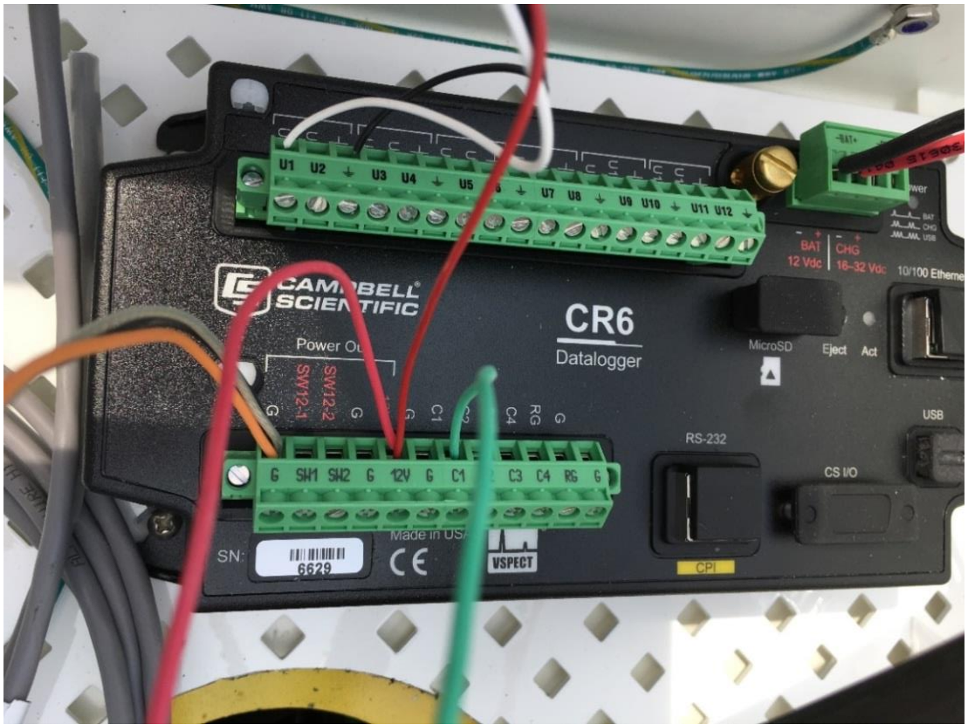


Figure 29. Data logger wiring for the 175-ft sedimentary interbed wells.

6.2 Data Logger Programming

The procedure for setting up the data loggers is provided by the following steps:

1. Add a new data logger to the PC200W program by doing the following:
   a. Start the PC200W data logger program.
   b. Connect the CR6 data logger to the laptop using the mini USB cable.
   c. In PC200@, add a new data logger giving it the monitoring location name by selecting the “+data logger icon” with the green arrow on the upper PC200W main menu bar.
      1) Select CR6 in the Communication Setup menu.
      2) Name the data logger the monitoring location (i.e., NuPac-East).
      3) The COM port is CR6 (Com4).
      4) Select next without making modifications to the default settings until the Communications TEST menu item appears, then use that menu item to perform the test. If the test fails, correct the errors and try the test again.
      5) Set the data logger clock to the computer clock by pressing the SET Data logger clock menu icon.
      6) Finish the data logger setup and exit.
2. Create a program for the data logger
   a. Select the new data logger and connect to it.
   b. Select the red icon on the upper menu bar of the main PC200W menu window.
      1) Add TYPE E THERMOCOUPLES first.

a) Add these one at a time otherwise you cannot change the wire locations or name of the thermocouple.

b) Select Type E thermocouple and press arrow to add it to the right menu panel.

c) Change the name to be Temp@45ft (example depth).

d) Select the thermocouple and edit the wiring diagram to be correct.

2) Add the CS655 WATER CONTENT REFLECTOMETERS using the menu sequence: CR6 →SENSORS→SOIL→CS650/CS655 water content reflectometer →CS650/CS655 Water Content Reflectometer (VWC, EC,T,P,PA,VR,SDI-12) and press the arrow to add the sensor to the output column on the right. This selection outputs the following in the data logger output Table 1 file:

a) VWC (volumetric water content) m^3/m^3

b) EC (electrical conductivity) dS/m

c) T (temperature) use units of Deg C

d) P (permittivity) unit less

e) PA (period average) nanoseconds

f) VR (voltage ratio) unit less

g) SDI-12 Address (0)

h) Measure sensor hourly.

3) Change the wiring diagram for the WCR

a) Select the WCR on the right panel and edit it.

b) Go to the Wiring Submenu.

c) Select the C1 Data, Green item (select C1).

d) Change the wire location to be where the WCR is plugged in.

4) Add tensiometers ONE AT A TIME --- GENERIC→SINGLE ENDED

5) Check the wiring diagram see if the pole is correct and change if necessary

a) Select the OFFSET leave it at 1 and 0 (that is: OUTPUT=Voltage*multiplier+OFFSET) leave it at 1 and 0 so the voltage (mv) is output ---- do the calibration manually.

c. Set up the output for the program.

1) After adding all instruments, press the next menu icon to go to the output selection items to setup Table 1 data.

a) Select all WCR entries under Measurement and the SAMPLE button in the middle column.

b) Select the Thermocouples and AVERAGE the data.

c) Select the TENSIOMETERS and AVERAGE the data.

d) Set the data store interval (i.e., store the data every 10 minutes).

2) Name the *.SCW file the name of the monitoring location in C:\Campbellsci/SCWin.

3) Compile the program and send it to the data logger.

4) Check the Wiring Diagram against the data logger to ensure it is correct and if not, go back and fix the program by editing each incorrect entry.

7. WELLHEAD ENCLOSURES AND WELLHEAD PROTECTION

The surface casing for the instrumented tubes and drilled boreholes extends about 2 ft above the adjacent vault plug and about 2 ft above the surface finish grade for the sedimentary interbed wells. A wellhead enclosure has been provided at the top of each surface casing to house/protect equipment.

The weatherproof enclosures house the electronic components, including the following:

- One data logger
- Temporary backup power battery
- Voltage regulator for the solar panel
- All electrical connections.

8. EQUIPMENT LIST

Table 15 contains the equipment list for primary components.

9. OBSERVATIONS AND RECOMMENDATIONS

The following observations are relevant to the as-built characterization and monitoring system.

9.1.1 Radiologic Fields

The RH-LLW Disposal Facility has been designed to receive waste canisters with exposure levels of as much as 30,000 R/hour in the NuPac, HFEF, and MFTC vault arrays and 60,000 R/hour in the 55-ton and LCC vault arrays.

The monitoring system contains PVC riser tubes, flexible polyethylene, and poly-coated wiring installed in the perimeter drainage material. Components of the monitoring system, primarily the PVC riser tubes, flexible polyethylene, and poly-coated wiring, will be subjected to radiologic fields associated with the disposed waste. WCRs, ATs, and lysimeters are installed in the drainage material beneath the vaults and, therefore, the potential for radiological degradation of the instrument is reduced. The monitoring system PVC riser tubes, flexible polyethylene, and poly-coated wiring are located approximately 1 ft from the vault array perimeter blocks and approximately 2 to 3 ft from the outer wall of the 6-in. thick concrete vaults. The 6-in. concrete vault wall and fill material between the vaults and the monitoring system provide shielding, reducing the potential for radiologic degradation of the monitoring system components.

However, the PVC riser tubes, flexible polyethylene, and poly-coated wiring could become brittle over time. Continued maintenance of the monitoring system is specified as part of the PA/composite analysis maintenance plan. In the event instrumentation necessary to support compliance monitoring fails, the impact of the failure will be assessed via the facility change control process (SD-52.1.4) and the instrumentation repaired or replaced based on the evaluation.

9.1.2 Monitoring System Testing and Performance

As documented in the *Assessment of the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility Hydraulic Performance* (INL 2017a) several of the installed instruments in the PA South and PA North instrumented tubes do not appear to be functioning correctly. These instruments and potential corrective actions are identified in Table 16.

Table 15. Monitoring system materials (does not include well drilling/casing/backfill materials).

Equipment	Vendor	Description	Part #
General (for all wells)			
Wellhead protection (bollard posts, surface casing, and concrete pad)			
Weatherproof wellhead enclosures			
Temporary Power For Each PA Instrument Set			
Solar panels - Wellheads – 20-W Solar Panels	Campbell Scientific	20-W solar panels 15-ft cable SP 20-PT-SM	10893-1
12-V charging regulator	Campbell Scientific	CH150-SW	29289-1
12-V sealed rechargeable battery	Campbell Scientific	BP24	10074
Data Communications and Transmission			
Data logger	Campbell Scientific	CR6-NA-ST-SW	CR6-NA-ST-SW
Loggernet-D	Campbell Scientific	Data logger support software	31046-1
2G compact flash memory card	Campbell Scientific	CFMC2G	20578
Compact flash module	Campbell Scientific	CFM100-ST-SW	30639-17
CSL 1-channel Serial I/O	Campbell Scientific	SDM-SIO1	19456
900-MHz 1-W spread spectrum radio	Campbell Scientific	RF451	31412
Ethernet radio surge protection kit	Campbell Scientific	Surge protection kit - Type N to SMA, 700 to 2700 MHz, 18 in.	31314
Ethernet radio null modem cable	Campbell Scientific	Null modem cable 9-pin	18663
Antenna	Campbell Scientific	900-Mhz 3-dBd Omni antenna	14221
Antenna cable RG8 end-type male connector (long)	Campbell Scientific	Antenna cable RG8	16112-5
Communication cables	Campbell Scientific	Five conductor 22-AWG cable with drain	21968-85
Weather enclosures (16-in. X 18-in.)	Campbell Scientific	ENC16/18-DC-SB-NM	30709-147
Instruments			
Advanced Tensiometers	Soil Water Monitoring Systems	Complete assembly ready for install specialty item, purchase requires advanced assembly and payment	AT Model 1996
Suction lysimeters	Soil Moisture Equipment Corp	Suction lysimeter	1940
Suction lysimeters	Soil Moisture Equipment Corp	Vacuum tubing, green, 100-ft roll	1901PECGL0100
Suction lysimeters	Soil Moisture Equipment Corp	Pressure tubing, black, 100-ft roll	1901PECNL0100
Suction lysimeters	Soil Moisture Equipment Corp	Closure valves	0761G14
Suction lysimeters	Soil Moisture Equipment Corp	Pressure vacuum pump, hand powered	2006G2

Equipment	Vendor	Description	Part #
WCRs 12-cm water content reflector plus 50-ft cable per probe PT with tinned wires DS-SDI-12 address=0	Campbell Scientific	CS655-50-PT-DS	25471-240
WCRs 12-cm water content reflector plus 33-ft cable per probe PT with tinned wires DS-SDI-12 address=0	Campbell Scientific	CS655-33-PT-DS	25471-256
Type E thermocouple burial probe 35-ft cable per probe	Campbell Scientific	105E-L35	3548-123
Type E thermocouple burial probe 50-ft cable per probe	Campbell Scientific	105E-L50	3548-50
USB to RS-232 converter DB9 male, 6 ft	Campbell Scientific		17394

Table 16. Sensors, locations, and installation depths for the PA South and PA North instrumented tube locations that do not appear to be functioning correctly.

	Depths of Instrument Installation Relative to Top of the Vault Plug			
Sensor Type	PA-South Instrumented Tube	PA-North Instrumented Tube	PA-45 Drilled Borehole	Potential Corrective Action
WCR	NA	NA	43 ft	Monitor WCR response over time. It is likely soils around the PVC tube will self-consolidate and the signal response will be more reflective of the actual conditions.
AT	26 ft 29 ft	26 ft 29 ft	43 ft	The inner guide pipe will be pulled from these installations, the pressure transducer checked using the calibration procedure, and replaced if necessary. The ATs will be refilled to check the inner seals at the top of the ceramic cup. If the ceramic cups or inner seal have been damaged, no further data will be collectable using the ATs. Inability to collect data from the PA vault ATs will not affect facility compliance and performance monitoring.

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