ENVIRONMENTAL CALCULATION COVER PAGE

Section 1: Completed by the Responsible Manager

Project: 200-DV-1

Date: 08/07/2019

Calculation Title & Description: B-Complex Perched Zone Geoframework, 200 East, Hanford Site

RELEASE / ISSUE

DATE: Sep 11, 2019 HANFORD RELEASE

Section 2: Completed by Preparer

Calculation No.: ECF-200DV1-18-0036 **Revision No.:** 0

Revision History

Revision No.	Description	Date	Affected Pages ADD ROW
0	Initial issue.	08/07/2019	All
			☒

Section 3: Completed by the Responsible Manager

Document Control:

Is the document intended to be controlled within the Document Management Control System (DMCS)? ☒ Yes ☐ No

Does document contain scientific and technical information intended for public use? ☒ Yes ☐ No

Does document contain controlled-use information? ☐ Yes ☒ No

Section 4: Document Review & Approval

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Section 5: Applicable if calculation is a risk assessment or uses an environmental model

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Terms

CCU	Cold Creek unit upper sand and silt
CCU-PZSd	Cold Creek unit – Perched Zone silty sand
CCU-PZSt	Cold Creek unit – Perched Zone basal silt
CCUg	Cold Creek unit gravel
CPVZ	Central Plateau Vadose Zone
ECF	environmental calculation file
GFM	Geoframework Model
Hf	Hanford formation
OU	operable unit
Rwai	Ringold Formation Member of Wooded Island unit A
UWI	unique well identifier
WMA	Waste Management Area

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1 Purpose

This environmental calculation file (ECF) details the development of the B Complex Perched Zone Geoframework Model (GFM), an important local feature within the larger Central Plateau Vadose Zone (CPVZ) GFM. The CPVZ GFM is a three-dimensional representation of the vadose zone stratigraphic units beneath the Central Plateau portion that covers the 200 East and 200 West Areas of the Hanford Site. The purpose of the B Complex Perched Zone GFM is to support site-specific fate and transport modeling in the B Complex.

The level of detail in the CPVZ, while appropriate for regional purposes, is not sufficient to accurately define the features of the Perched Zone. Therefore, it was necessary to construct a more detailed, smaller-scale model of the lithologic units within the B Complex Cold Creek unit where saturated conditions have been observed. The Perched Zone GFM locally defines three Cold Creek unit subunits in such a way that the Cold Creek unit upper sand and silt (CCU) and Cold Creek unit gravel (CCUg) surfaces from the regional scale CPVZ GFM form the top and the base of the perched zone structure, respectively.

2 Background

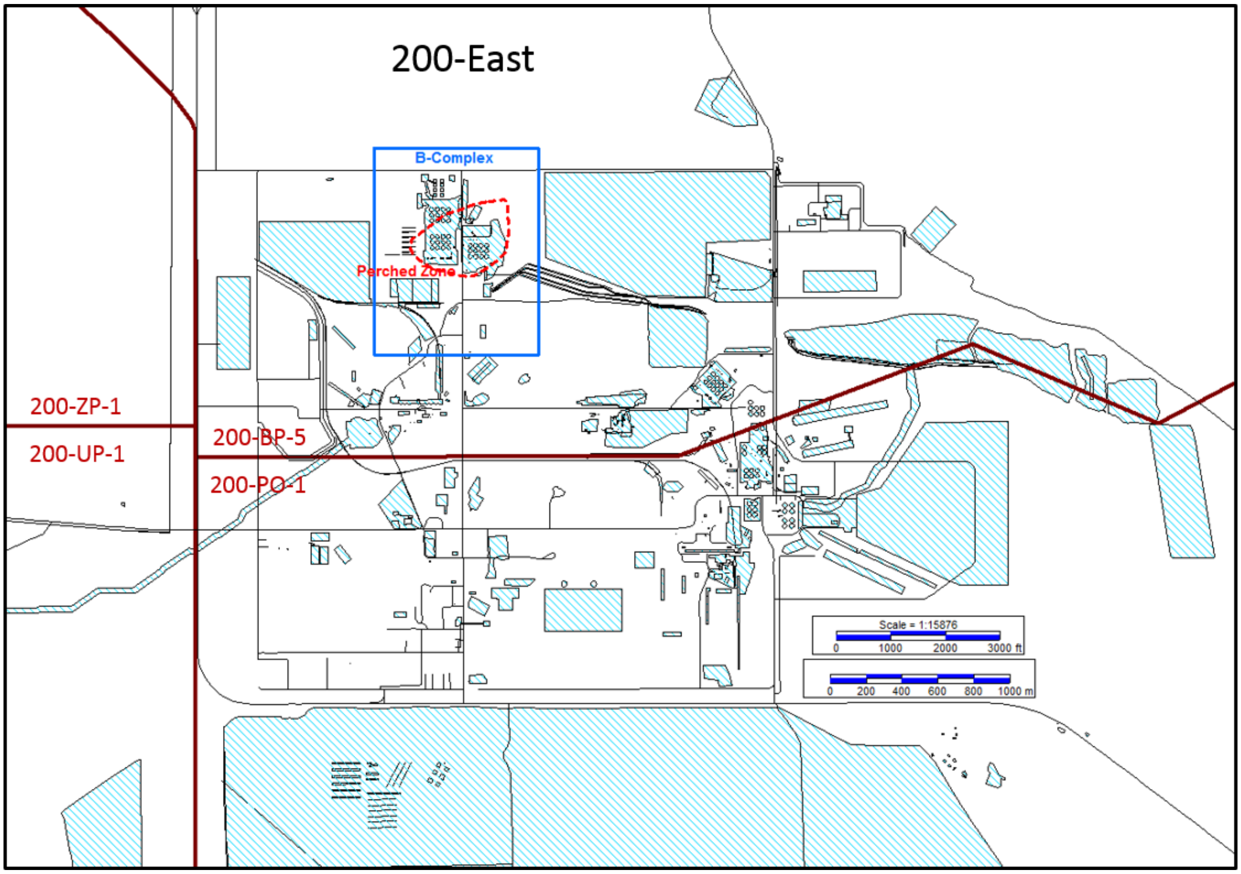
The B-Complex Perched Zone is located within the 200 East Area of the Central Plateau portion of the Hanford Site (Figure 2-1). The B Complex encompasses the B-BX-BY Tank Farms and the surrounding waste sites, many of which are part of the 200-DV-1 Source Operable Unit (OU). The perched zone is approximately 0.16 km^2 (0.06 mi^2) in area, sitting beneath several 200-DV-1 OU waste sites (216-B-8, 216-B-7 A&B, 216-11 A&B) and the Waste Management Area (WMA)-B, WMA-BX, and southeastern portion of the WMA-BY tank farms.

The Perched Zone was first recognized in 1991 during drilling of *Resource Conservation and Recovery Act of 1976* wells to characterize groundwater contamination in the underlying unconfined aquifer in the 200-BP-5 OU (DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*). The perched water zone occurs 3 to 7 m (9.8 to 23 ft) above the regional unconfined aquifer and is contaminated with uranium, technetium-99, and nitrate resulting from past-practices of discharges and unplanned releases from nearby tank farms and cribs.

Perched water conditions have been observed in other parts of the Hanford Site, such as in 200 West Area, but are generally a transient phenomenon that recedes with the cessation of effluent disposal. The specifics of why the B Complex perched zone persists are still being studied but the structure of the feature and lithologic characteristics of the perched zone layers appear to be the dominant controlling factors.

2.1 Geologic/Geophysical Data in the Perched Zone

When a borehole is drilled on the Hanford Site, information about the subsurface lithologies encountered become available through observation of drill cuttings returned to the surface during drilling. These observations are recorded in either a driller's log or borehole log with some amount of textural description. A good quality borehole log will describe the sediment classification in the context of sand/gravel/mud ratios, mineralogic composition, color, grain size variation, degree of cementation, reaction to hydrochloric acid, and other sedimentary features which may aid a stratigraphic interpretation.



Note: Waste Sites are displayed along with major roads and *Comprehensive Environmental Response, Compensation and Liability Act of 1980* groundwater OU boundaries. The B Complex lies within the 200-BP-5 OU boundaries.

Figure 2-1. Perched Zone and B-Complex Location Map

In addition, it is a standard process to collect downhole geophysical logs. The most common of the geophysical logs at the Hanford Site are spectral gamma ray logs which can differentiate natural radionuclide spectra from manmade signatures. The dominant natural gamma emitters present in sediments are potassium, thorium, and uranium. The amounts of those constituents detected in the logs can be good lithology indicators. For example, clay minerals often have more potassium and thorium than siliciclastic sands. Therefore, high spectral gamma peaks often indicate an increase in clay minerals. Carbonate minerals tend to have higher concentrations of natural uranium and lower concentrations in potassium. This is a helpful signature for interpreting caliche paleosol horizons or other zones of secondary mineralization.

The combination of the borehole log observations with the geophysical logs, in addition to an understanding of regional geologic conceptual models and depositional environments, form the foundation for making stratigraphic unit top interpretations in individual boreholes. A discussion of preferred geologic conceptual models can be found in CP-60925, *Model Package Report: Central Plateau Vadose Zone Geoframework*; PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington;* and PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington.*

There are 244 boreholes within the mapped boundaries of the Perched Zone. Most of these boreholes are either too shallow to have intersected the Perched Zone itself (many are shallow tank farm “dry-wells” that were used to monitor the shallow vadose zone for any tank leaks) or have little to no data to use in our interpretation. Out of these, 27 wells were selected to form the Perched Zone model. In addition, four wells had to be created as pseudo-control points in areas where the borehole data were not sufficient to constrain the lateral extent. This brings the total well set to 32 wells/boreholes for constructing the Perched Zone model (Table 2-1). Many are groundwater monitoring wells that pass through the Perched Zone and monitor the aquifer below. There are three wells that are currently extracting contaminated groundwater from the Perched Zone (299-E33-344, 299-E33-350, and 299-E33-351). The 200-DV-1 OU project drilled two characterization boreholes into the Perched Zone in 2016 (C9487 and C9488). All of these categories of wells are included in this model (Table 2-1). A key assumption for this modeling is that the wells and boreholes are vertical, with no noticeable deviation. Therefore, the measured depths in the wells and boreholes are assumed to be the true vertical depths.

Table 2-1. Boreholes Used in Perched Zone Geoframework

Well Name	Northing (m)	Easting (m)	Ground Surface Elevation (m/ft)	Total Depth (m/ft)
299-E33-9	137485.9	573646.83	199.2/653.5	83.8/275
299-E33-14	137567.2	573985.61	190.0/623.4	70.1/230
299-E33-15	137540.7	573810.29	191.4/628.1	76.5/251
299-E33-16	137465.3	573791.69	194.3/637.6	78.6/258
299-E33-17	137167.2	573878.52	193.1/633.4	74.4/244
299-E33-18	137386.1	573779.17	197.1/646.5	84.7/278
299-E33-19	137422.7	573847.63	195.2/640.3	76.8/252
299-E33-20	137397.9	573847.6	195.8/642.4	77.4/254
299-E33-21	137293.2	573474.47	203.4/667.4	86.0/282
299-E33-27	137338.2	573668.07	201.0/659.4	77.7/255
299-E33-41	137369.9	573707.19	199.6/654.8	80.2/263
299-E33-44	137469.2	573706.41	196.0/643.1	77.7/255
299-E33-45	137350.6	573693.14	200.2/656.8	79.2/260
299-E33-47	137295.5	573916.48	197.8/648.8	82.0/268.9
299-E33-48	137162.1	573781.45	202.6/664.7	88.7/290.9
299-E33-49	137212.8	573647.48	203.2/666.8	88.0/288.8
299-E33-205	137406.2	573633.38	200.3/657.2	82.5/270.6
299-E33-337	137193.9	573821.8	202.0/662.7	87.2/286
299-E33-343	137382.3	573743.98	198.8/652.3	80.4/263.8
299-E33-344	137387.3	573782.91	199.1/653.3	73.8/242.1

Table 2-1. Boreholes Used in Perched Zone Geoframework

Well Name	Northing (m)	Easting (m)	Ground Surface Elevation (m/ft)	Total Depth (m/ft)
299-E33-345	137388.2	573780.87	199.1/653.2	80.4/263.8
299-E33-350	137426.6	573786.57	199.3/654	71.6/234.9
299-E33-351	137405.8	573744.19	199.3/654	71.3/234
299-E33-360	137386.9	573772.05	198.9/652.7	83.2/272.8
C3104	137347.6	573471.18	202.0/662.7	80.3/263.5
C9487	137396	573802.00	198.8/652.22	71.6/235
C9488	137468.4	573784.71	195.5/641.4	68.7/225.5
PerchedZone_Control5	137292.1	573964.74	197.8/648.8	91.4/300
PerchedZone_Control6	137426.1	573975.03	197.5/648	91.4/300
PerchedZone_Control7	137195.79	573883.15	201.2/660	91.4/300
PerchedZone_Control8	137173.35	573827.59	201.2/660	91.4/300

2.2 Stratigraphy and Lithology of the Perched Zone

The CPVZ GFM is composed of seven stratigraphic units in the B Complex vadose zone, as follows:

1. Hanford formation (Hf)
   a. Hf1 (uppermost gravel-dominated unit)
   b. Hf2 (middle sand-dominated unit)
   c. Hf3 (basal gravel-dominated unit)
2. Cold Creek unit
   a. CCU
   b. CCUg
3. Ringold Formation
   a. Ringold Formation Member of Wooded Island unit A (Rwia)
4. Columbia River Basalt Group – Saddle Mountain Basalt Formation
   a. Basalt (common name used for undifferentiated basalt flows and the designation for the base of the CPVZ GFM)

The Perched Zone is contained within the upper Cold Creek unit and can be divided into three distinct lithologic units that are not observed in other parts of the B Complex or 200 East Area. These three lithologic units are defined as CCU, Cold Creek unit – Perched Zone sand (CCU-PZSd), and Cold Creek unit – Perched Zone basal silt (CCU-PZSt), where CCU-PZSd is the silty sand lens within the two silt dominated (CCU and CCU-PZSt) units. The details are presented in the following sections.

2.2.1 Cold Creek Unit Upper Sand and Silt

The uppermost silt-dominated unit of the Cold Creek unit is designated as CCU. It is the stratigraphic unit that correlates in a broader regional sense to other areas of the 200 East Area, although it is generally more silt-rich in the vicinity of the Perched Zone. In 2016 the 200-DV-1 OU characterization project drilled a borehole near the center of the Perched Zone (C9487) that reached total depth just above the CCU-PZSt and collected intact core through the CCU and CCU-PZSd. The core lithology log describes the CCU as ranging from light olive brown silty clay (65% clay/35% silt) with high plasticity to dark grayish brown, moist silt with sand (90% silt/10% sand). Figure 2-2 is an image from the CCU core collected in C9487. The increase in clay with depth is visible in this core image.

There is lateral variability in the thickness and lithologic texture of the CCU across the Perched Zone. On the western side of the Perched Zone feature, between the BX and BY Tank Farms the CCU thins and grades to sandy silt (Figure 2-3). It is likely this textural variability that allows fluid and contaminants to pass through the upper silt unit to the sandy CCU-PZSd underlying it.

2.2.2 Cold Creek Unit – Perched Zone Sand

The CCU-PZSd is coarser-grained than the CCU described in the previous section and the CCU-PZSt in Section 2.2.3. It grades from medium-grained sand to sandy silt but is generally categorized as silty sand (30% silt/70% sand) in the center of the Perched Zone. The top of the unit is delineated by a decrease in natural gamma constituents from the relatively more clay-rich natural gamma peak of the CCU overlying it. The silty sand of the CCU-PZSd is described as light olive brown, micaceous very fine sand with a moderate reaction to hydrochloric acid (Figure 2-4)

2.2.3 Cold Creek Unit – Perched Zone Basal Silt

The basal silt in the Perched Zone feature varies in silt and clay composition, ranging from 100% silt and clay to silty sand with just 30% silt. In most of the Perched Zone boreholes cementation, iron-oxide staining and hydrochloric acid reactions were noted in the CCU-PZSt. The natural potassium, thorium, and uranium spectral gamma ray logs often display a signature consistent with calcium carbonate minerals in the CCU-PZSt, namely a peak in natural uranium corresponding with a decrease in natural thorium and potassium. The signature differs from the typical caliche signature seen in 200 West Area geophysical logs, in that the natural potassium and thorium, while lower than the natural uranium values, stay somewhat constant through the cemented zones of the CCU-PZSt. That is interpreted to reflect the presence of clay minerals high in potassium in the CCU-PZSt. Well 299-E33-18 is a good example of where this carbonate signature (Figure 2-5) helps differentiate the CCU-PZSt from the units above it when the driller's log does not provide the level of detail needed to identify the three lithologic units.

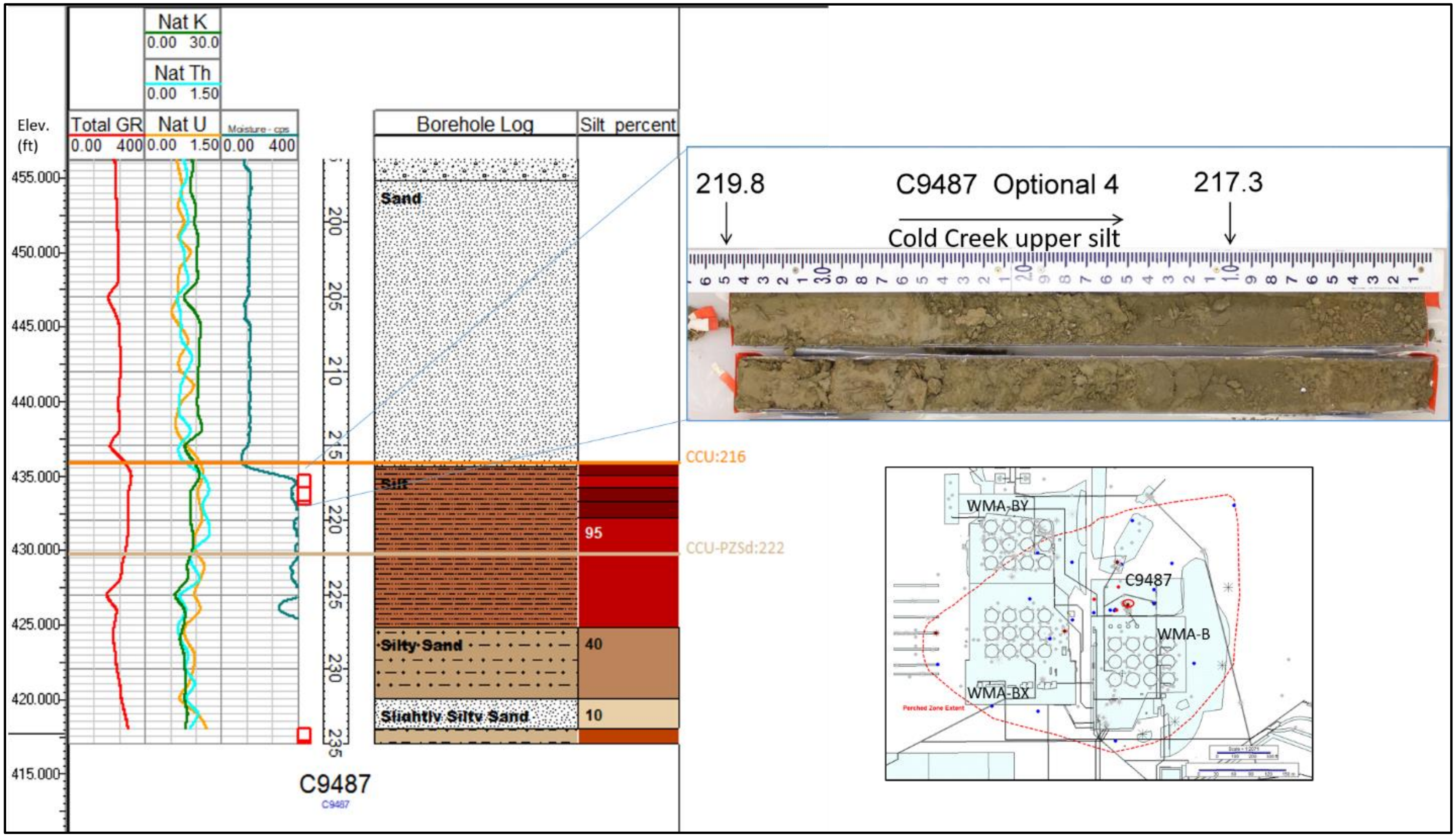


Figure 2-2. C9487 Composite Log with Core Image of the CCU

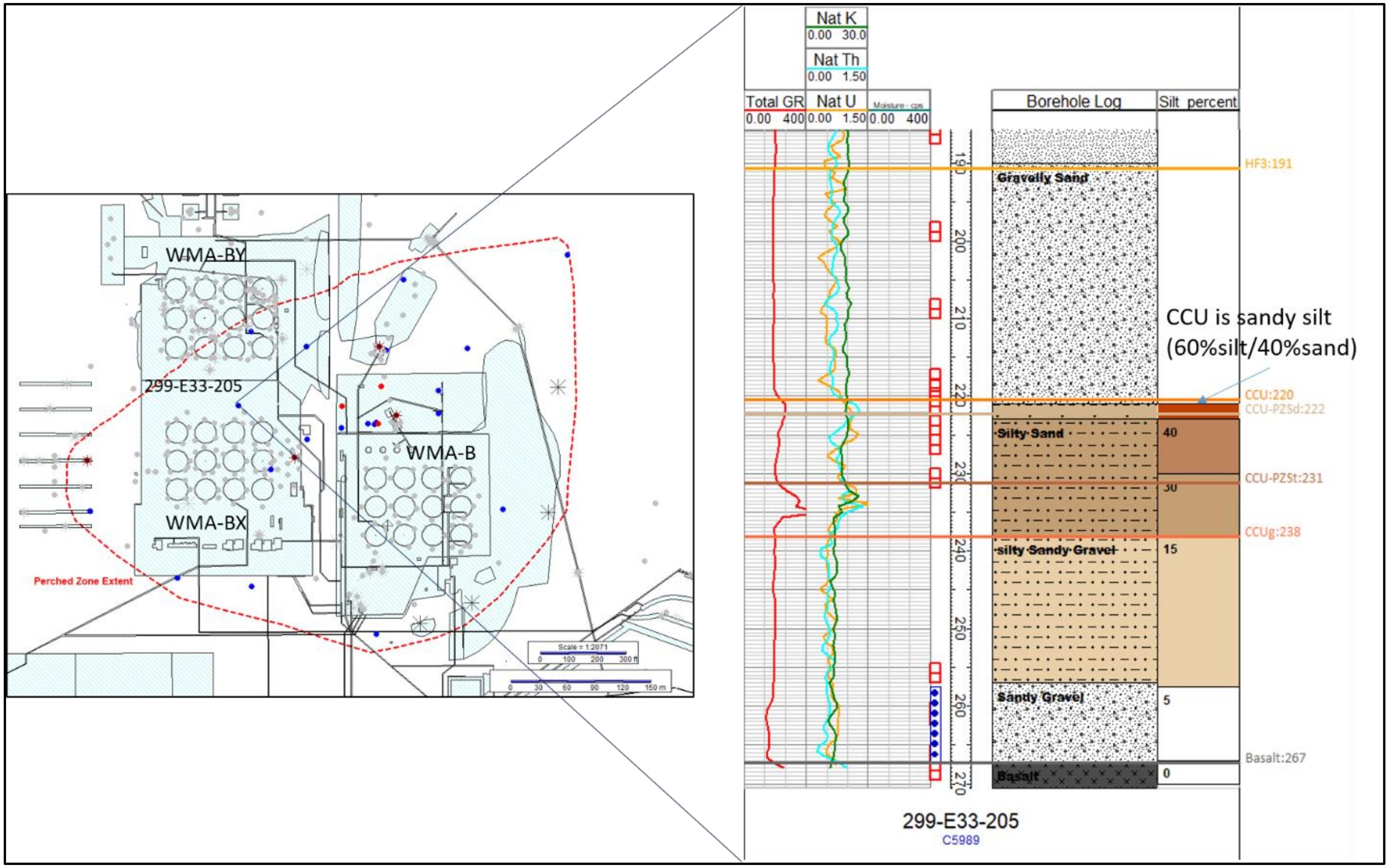


Figure 2-3. 299-E33-205 Composite Log Showing the Lateral Variations in the CCU

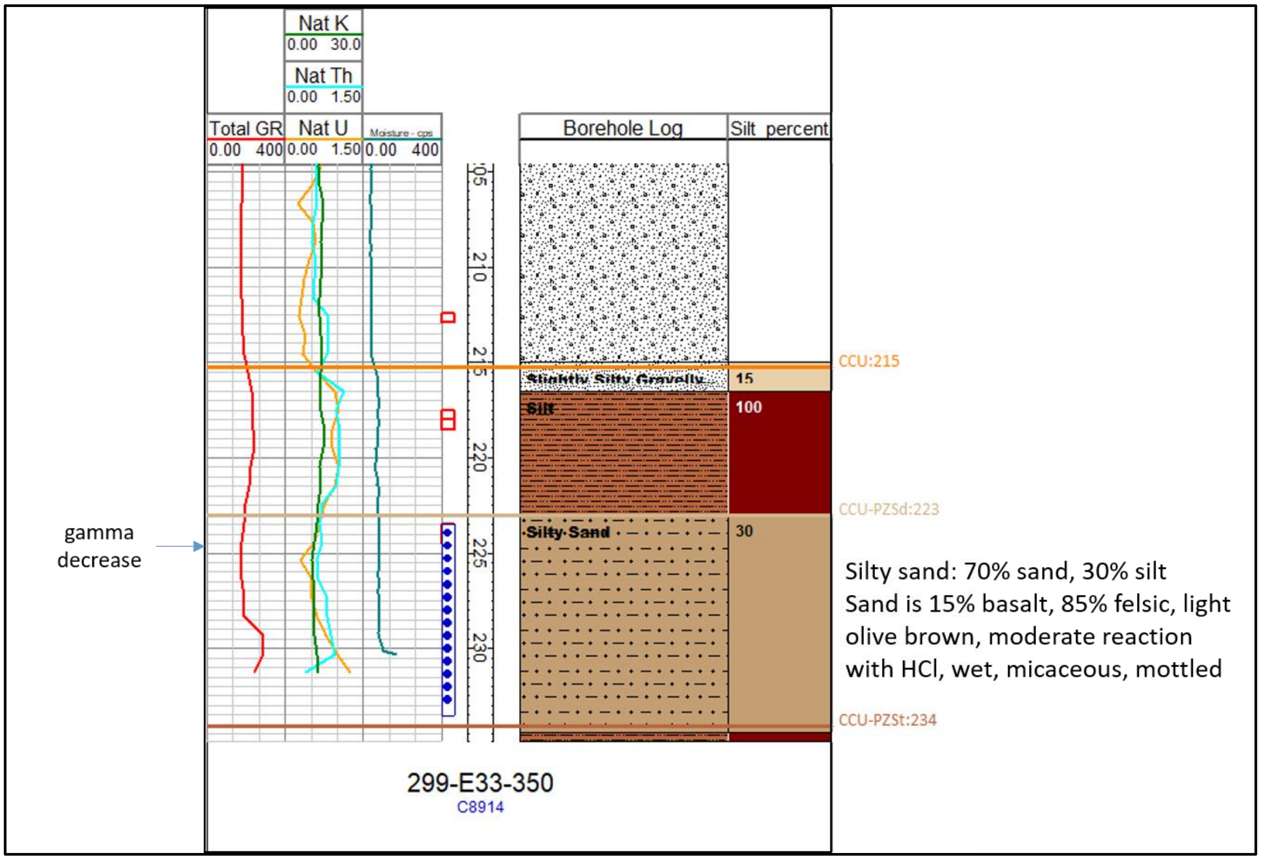


Figure 2-4. 299-E33-350 Composite Log, a Perched Zone Extraction Well, Showing the Characteristics of the CCU-PZSd in Both Geophysical and Borehole Logs

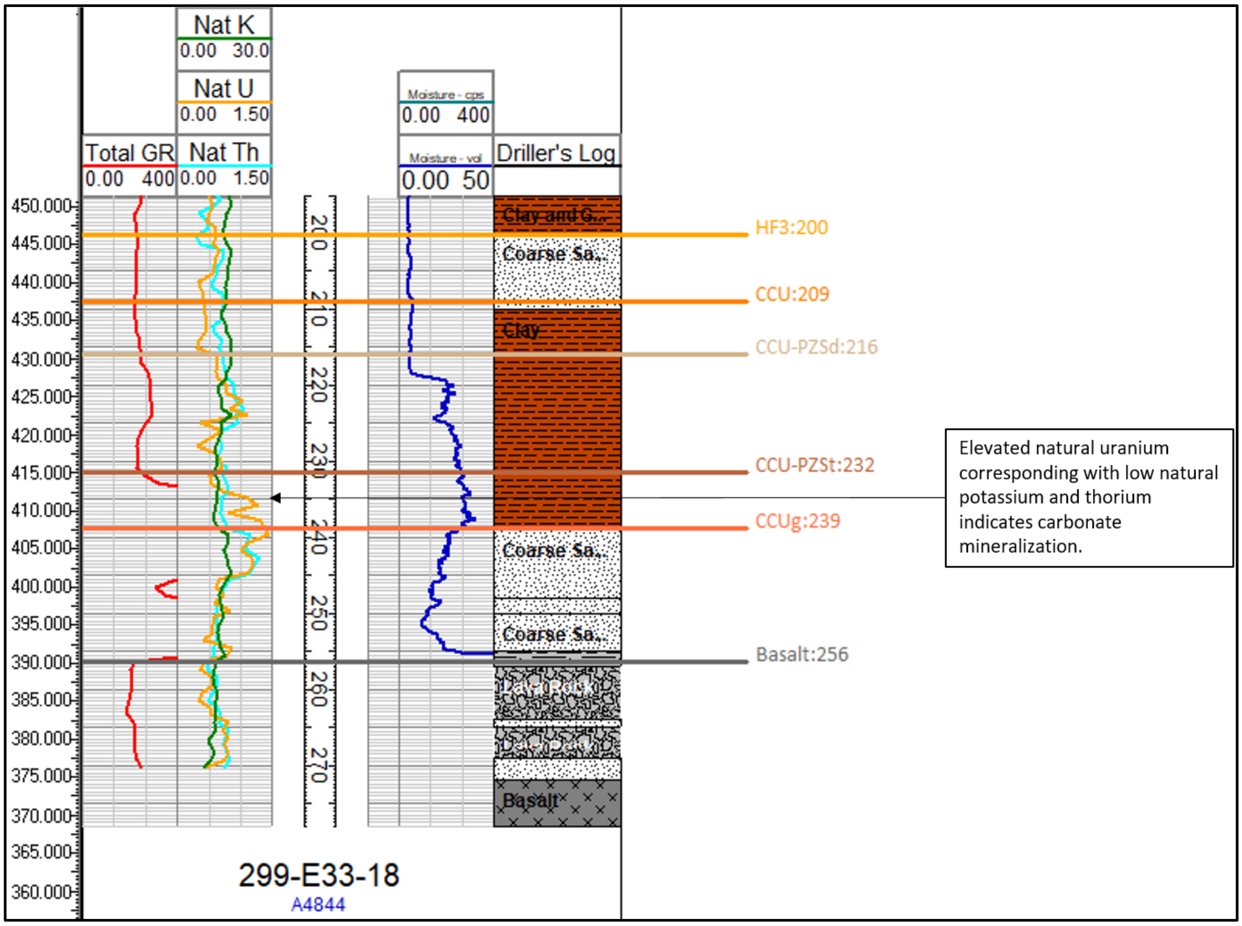


Figure 2-5. 299-E33-18 Borehole Composite Log with Spectral Gamma Data Plotted with Driller's Log Summary

2.2.4 Cold Creek Unit Gravel

The CCUg is persistent across much of the 200 East Area. It ranges from silty-sandy-gravel (40% gravel, 45% sand, 15% silt) to sandy-gravel (50% sand/50% gravel) with areas of gravelly sand (75% sand/25% gravel). The CCUg is generally more immature in texture than the Rwia that underlies it; the pebbles, cobbles, and sand are slightly more angular and there are usually more basaltic gravels. These are indicators that the CCUg is younger than the Rwia and are useful characteristics to use in stratigraphic interpretation in the B Complex. In the Perched Zone area, there are zones of carbonate cementation and caliche noted in the uppermost portion of the CCUg.

2.2.5 Using Geologic/Geophysical Data to Form Stratigraphic Interpretations

The Kingdom® Geology Suite software allows the interpreter to view each of these boreholes individually or compare them to surrounding boreholes to interpret where the changes in lithology are and whether they make sense in context of the regional geology. Using the lithologic criteria described in Section 2.2 of this report, the interpreter can select the depth at which the different Perched Zone units occur in each borehole. An example of a correlation section can be found in Figure 2-6.

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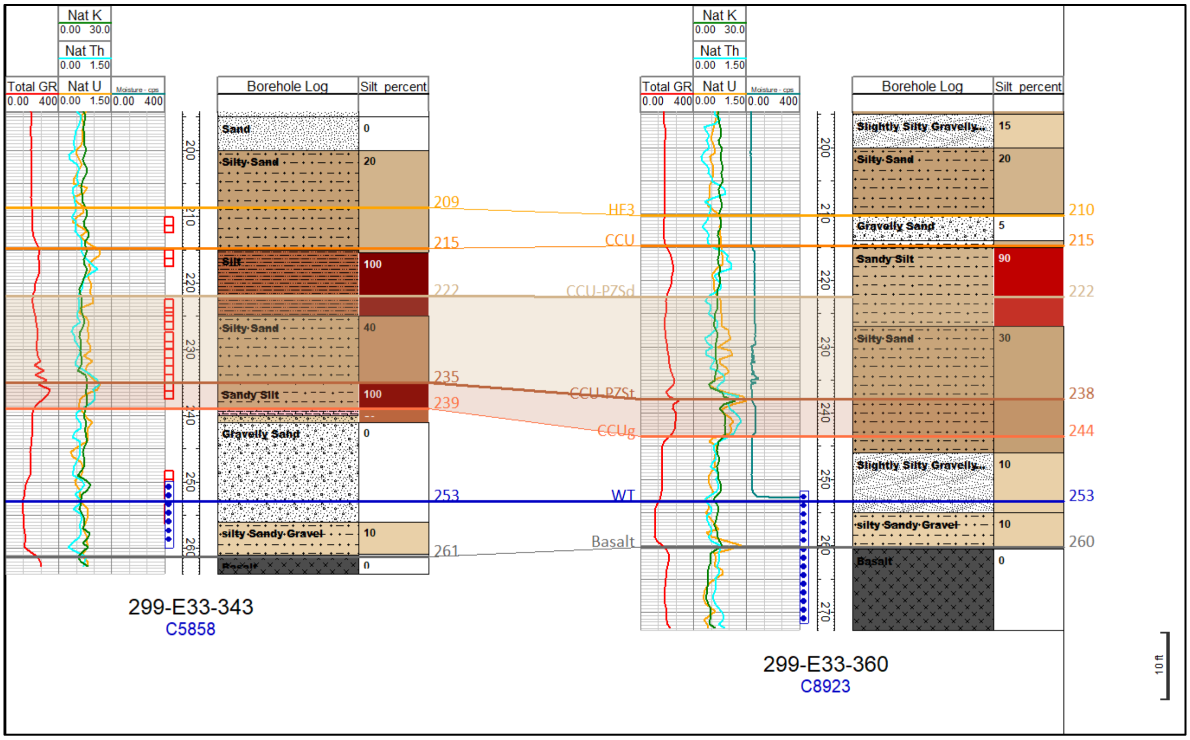


Figure 2-6. Correlation Cross Section Near the Center of the Perched Zone

The top of the CCU-PZSd, in wells 299-E33-343 and 299-E33-360 (Figure 2-6), is interpreted at the same inflection in the total gamma log, which is an indication of the grain size or amount of clay minerals decreasing. That decrease occurs approximately 0.3 m (1 ft) shallower than the lithology change noted in the borehole log. This is typical in well datasets. Geophysical data are collected at a higher resolution than the grab samples that inform borehole logs. A similar change in gamma peak in both boreholes is where the CCU-PZSt is interpreted, although that peak is exaggerated due to a casing change in the boreholes. During drilling it was important to case off the perched waters to prevent cross contamination between the perched aquifer and the unconfined aquifer below it. As soon as the drillers would note a change in drilling speed and a decrease in water saturation, they would downsize casing. This is a helpful indicator for the top of the CCU-PZSt. The CCUg was similarly interpreted based on an inflection in the geophysical logs indicating a coarsening of the sediments.

The edges of the Perched Zone structure are defined by the higher structural elevation and relative thinness of the CCU. The CCU gets so thin along the margins that it is not possible to ascertain any stratification within it. For instance, well 299-E33-48, on the south flank of the Perched Zone structure, has a silt zone just 0.6 m (2 ft) thick at 66 m (216 ft) bgs. This thin silt zone separates the Hanford gravels (Hanford formation unit 3) above from the CCUg below. However, the borehole data are not a high enough resolution to discern layering within that 0.6 m (2 ft) that could be assigned to the CCU-PZSd or CCU-PZSt. Therefore, the stratigraphic contact depths were estimated between the CCU and CCUg tops in a way that made most sense for maintaining the perching structure.

It is only through thorough examination of all these data in each well and correlation to nearby wells that a stratigraphic top interpretation can be made. The individual profiles with available data and interpreted stratigraphic tops for all 30 boreholes in the model can be found in Appendix A of this ECF. The stratigraphic tops interpreted for each borehole, the datapoints that ultimately form the Perched Zone geoframework, are listed in Table 2-2.

Table 2-2. Perched Zone Stratigraphic Top Contact Depths

Well Name	CCU (ft bgs)	CCU-PZSd (ft bgs)	CCU-PZSt (ft bgs)	CCUg (ft bgs)
299-E33-9	199.23	207.14	207.98	211.95
299-E33-14	165.78	166.95	167.39	169.54
299-E33-15	180.16	183.92	184.92	190.23
299-E33-16	202.36	208.31	219.4	226.86
299-E33-17	200.15	205.37	213.31	216.15
299-E33-18	209.06	216.05	231.55	238.79
299-E33-19	209.09	212.68	223.65	228.24
299-E33-20	209.84	214.1	222.78	229.57
299-E33-21	220.25	221.5	222.00	224.48
299-E33-27	223.42	229.66	239.53	241.70
299-E33-41	218.23	224.59	237.76	241.81
299-E33-44	206.69	211.42	218.50	224.24
299-E33-45	219.24	226.67	235.18	239.38
299-E33-47	210.19	218.08	219.07	223.60
299-E33-48	215.84	216.46	216.85	217.57
299-E33-49	217.13	219.78	221.84	224.23
299-E33-205	220.14	222.36	231.18	238.10
299-E33-335	220.39	222.37	225.11	227.67
299-E33-343	214.77	222.01	235.07	238.96
299-E33-344	215.97	222.48	238.67	NDE [a]
299-E33-345	217.13	223.04	238.54	245.34
299-E33-350	215.27	223.04	234.1	NDE [a]
299-E33-351	214.23	220.00	233.09	NDE [a]
299-E33-360	214.75	222.44	237.88	243.55
C3104	215.93	216.87	217.1	218.63
C9487	216.18	222.25	NDE [a]	NDE [a]
C9488	206.23	211.88	223.2	NDE [a]
PerchedZone_Control5 [b]	194.33	196.07	197.49	199.74
PerchedZone_Control6 [b]	193.56	195.26	196.67	198.98

Table 2-2. Perched Zone Stratigraphic Top Contact Depths

Well Name	CCU (ft bgs)	CCU-PZSd (ft bgs)	CCU-PZSt (ft bgs)	CCUg (ft bgs)
PerchedZone_Control7 [b]	210.14	210.64	211.13	211.89
PerchedZone_Control8 [b]	210.69	211.30	211.96	213.00

a. The acronym NDE (not deep enough) is used when the borehole total depth stops short of the stratigraphic contact.

b. Control point boreholes were added in areas of the Perched Zone with little data to control the shape of the structure. These control point boreholes are discussed in Chapter 4 of this environmental calculation form.

bgs = below ground surface

CCU = Cold Creek unit upper sand and silt

CCUg = Cold Creek unit gravel-

CCU-PZSd = Cold Creek unit – Perched Zone silty sand

CCU-PZSt = Cold Creek unit – Perched Zone basal silt

2.3 Structure and Depositional Environment

As mentioned earlier in this document, the structure of the Perched Zone is one of the controlling variables that enables the unique perching conditions encountered in the B Complex. The Perched Zone sits within a bowl-shaped structure where the CCUg at the base is deeper in the center than along the margins of the Perched Zone. That bowl-shaped structure is then filled in with the CCU-PZSt, CCU-PZSd and the CCU (from oldest/deepest to youngest/shallowest).

The Cold Creek unit was deposited in a fluvial environment prior to the cataclysmic paleofloods that deposited the overlying Hanford formation.[1] The bowl-shaped structure, the fine-grained nature of the sediments filling it, and the presence of secondary mineralization indicates that the Perched Zone feature is likely an abandoned channel/oxbow lake of the ancestral river. As a result, the CCU-PZSd and CCU-PZSt units were deposited in more of a lacustrine setting. The ancestral lake that forms the Perched Zone was then buried under the thick paleoflood deposits of the Hanford formation, with the bowl-shaped or lake-like structure preserved at depth. This interpretation would explain the differences in lithologic character between the Perched Zone units and the alluvial overbank deposits that form the upper CCU in the 200 West Area. Lacustrine deposits are more likely to be stratified as silt/clay followed by silty-sand sequence. The silt/clay lithology of the upper CCU could be the beginnings of another sequence of lacustrine deposition that was subsequently eroded by the overlying Hanford formation. Or the CCU could also represent the silt and clay left in suspension after the sandier CCU-PZSd settled at the bottom of the lake.

[1] For a good discussion about the incision of the Ringold Formation by the CCU and the Pliocene depositional setting of the CCU, see DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments within the Central Pasco Basin.*

Conceptualizing the depositional environment of the Perched Zone feature helps to interpolate between well data. It is necessary to interpret how the thicknesses of the different Perched Zone units relate to one another, especially along the flanks of the structure. If the Perched Zone structure was the result of channel fill (i.e., part of a channelized system where deposition occurred relatively rapidly) we may expect flat bedding with the CCU-PZSt filling just the deepest part of the bowl, followed by CCU-PZSd and topped with CCU (Figure 2-7). The issue with a channel fill morphology is that the sandy CCU-PZSd would be in contact with the CCUg along the flanks of the bowl and the structure would be unlikely to contain water for any substantial amount of time. However, if the Perched Zone structure deposition occurred in a quiescent lacustrine setting, deepening over time as it slowly filled, we may expect the CCU-PZSt to drape thinly along the flanks, effectively sealing off the CCU-PZSd from the porous CCUg.

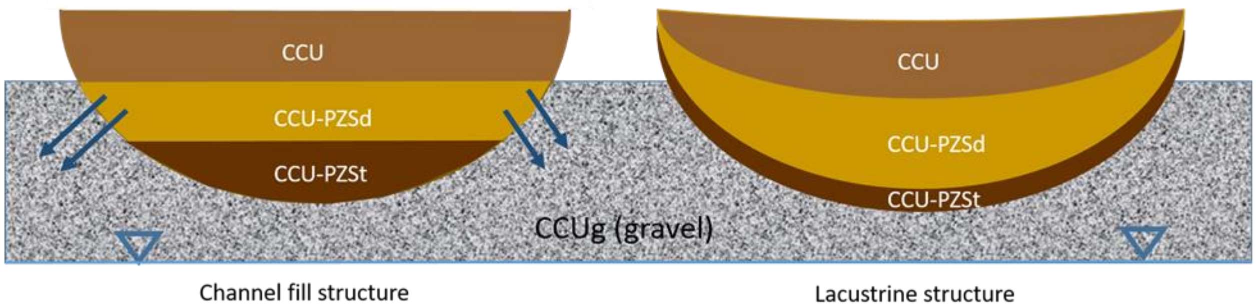


Figure 2-7. Diagram Illustrating the End-Member Depositional Morphologies Possible in the Perched Zone Structure

The spatial distribution of available well data in the Perched Zone means either morphology could be interpreted. There is good well control in the center of the Perched Zone bowl and along the boundaries of the structure. The conceptual model we utilize will determine how the surfaces are interpolated between those well data points. We interpreted this system to be more lacustrine in nature and therefore draped the CCU-PZSt along the base of the entire structure. It should be noted that lacustrine features are not commonly recognized in the Cold Creek unit elsewhere, the Cold Creek unit is understood to represent a period of regional base-level drop and rapid incision into the Ringold Formation below (DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*). However, the Cold Creek caliche of the 200 West Area is the remnant of a time when the Cold Creek unit was subaerially exposed, forming a calcic paleosol. The Perched Zone structure could be of equivalent age, representing a period of quiescent deposition occurring in a lacustrine setting.

3 Methodology

3.1 Creating a Model in Kingdom

The methodology followed for the Perched Zone sub-model is similar to the methodology described in CP-60925 for creating a GFM in the Kingdom Geology Suite, with one notable exception. The CPVZ generated vadose zone surfaces from formation tops (hereafter referred to simply as "tops" to align with the Kingdom terminology) and control points. The purpose of the CPVZ GFM was to generate a central plateau-wide geoframework, the stratigraphic surfaces included therein are appropriate for that regional level of detail. If a site-specific model like the Perched Zone GFM requires more detailed lithologic interpretation within those stratigraphic surfaces, it is simple enough to use the CPVZ stratigraphic surfaces as input to the site-specific model. In this case, the CPVZ CCU and CCUg surfaces formed the top and base of the Perched Zone GFM.

The model described in this document cannot be exactly reconstructed, but a very similar model can be constructed following the subsequent steps:

1. Open Kingdom software and create a new project.

   b. Be sure you've checked with the Kingdom administrator to get license and Structured Query Language server access.
   c. For this project it would be best to use the author name PZGFM_R0.

2. Assign the appropriate project options when prompted (Figure 3-1).

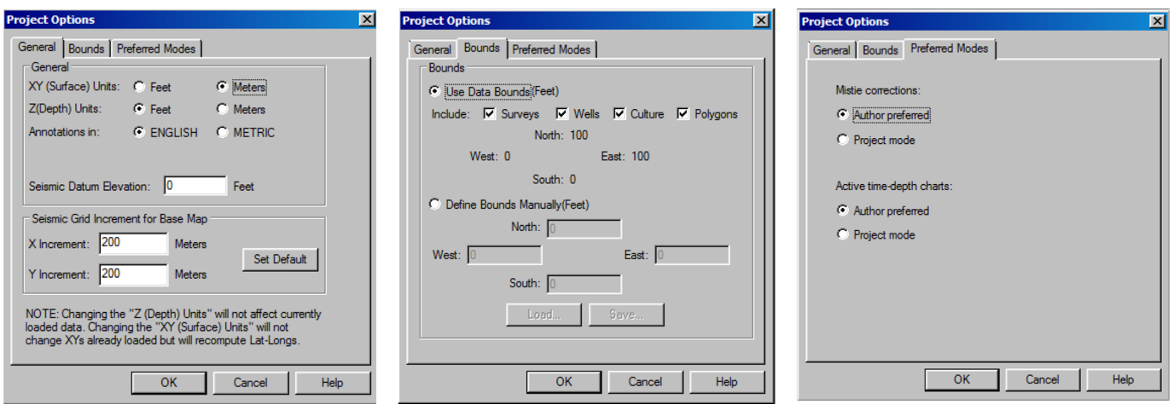


Figure 3-1. Project Option Specifics

3. Select project coordinate system (Figure 3-2).

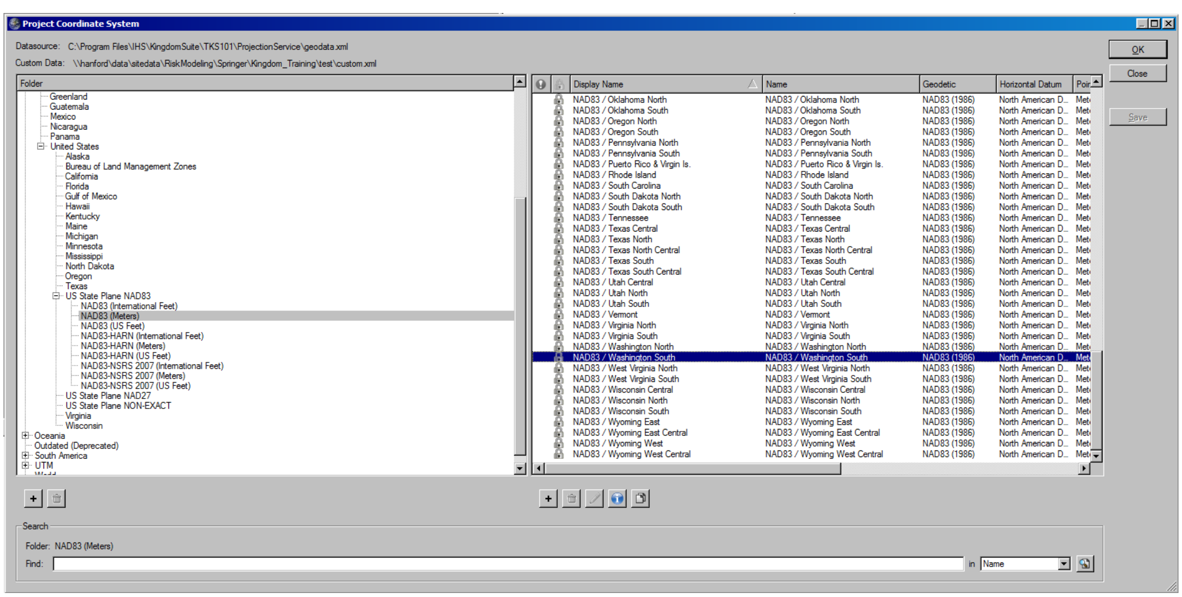


Figure 3-2. Project Coordinate System

4. Import coordinates for the 27 boreholes used in this model (Table 2-1).

    a. In Kingdom, select “Wells” from the project tree, right-click and select “import” and then “file import.” In the Well Import window, select “Wells” and OK. Browse to the appropriate file if batch loading wells from a data file, you can also add each well one-by-one through the well explorer module in Kingdom. Be sure to select “Other Files” in the drop-down menu in the lower right corner of the window to be able to see your data file. Toggle “UWI as it exists in import data (Unique Well Identifier [UWI] in import data will not be altered)” and then Next.

    b. Assign the appropriate categories to each column. Hanford ID is called UWI in Kingdom and all well data is indexed to UWI. Northing is the Y-coordinate, Easting is the X-coordinate, elevation should be in feet, and elevation reference is ground surface; total depth should be in feet. Click the Next button.

    c. A Specify Units for Input Data prompt window will open to . Remember that the convention we selected for the Hanford project is for X-Y surface data to be meters and depth to be U.S. ft. Click the OK button.

    d. Another opportunity to define the coordinate system of the imported data will come up. Choose the same project coordinate system as previously stated.

    e. The Available Wells for Import window will come up. Toggle the “Add: Create new wells only” and click Next. The program should then generate the import report. Scroll through the report to verify that everything looks correct (remember that for this model there should be 27 wells added).

5. Import stratigraphic top data for the 27 boreholes used in this model (Table 2-2). The process for selecting these tops is sketched out in the previous paragraphs; it is not generally a prescriptive process. Selecting the stratigraphic tops is largely interpretive and relies on the experience and knowledge of the interpreter. In this part of the process we are working from stratigraphic tops selected as shown in Table 2-2.

    a. Select “Formation Tops” from the project tree, right-click and select “import.” Browse to the appropriate file and select Next.

    b. The File Format Selection window will open. The easiest way to import tops into a Kingdom project is when the tops are in line order. Therefore, tops files exported for this GFM will be in line order. Toggle that selection and click Next. Toggle “UWI as it exists in import data (UWI in import data will not be altered)” and then Next.

    c. Assign the column categories appropriately (remember to make the “Lines to Skip” field at the top of the window say “1” to avoid importing the column headers as data). The columns should be UWI, Depth, Formation Top Name, and Author Name. Click Next.

    d. The Available Wells for Import window will open, make sure all are selected and click Next. If any of the well names are grayed out, some troubleshooting may be necessary.

    e. The Data Import Options window will open, be sure the selected data are “Formation Tops” and import options is “Add and Update Data.” Click Next.

    f. In the Author Assignment window be sure to assign the appropriate author (the project author name chosen in step 1). Click Next.

g. The Select Depth/Time Type window will open. The Depth Type selected from the drop-down menu should be MD. Click Next. In the Selection Summary window click Next again.

h. The Import Report is generated. Be sure it looks correct and click Finish.

6. Import stratigraphic grid data from the CPVZ GFM. The grids should come from the latest revision of the CPVZ GFM. The Revision 0 of the Perched Zone GFM corresponds to Revision 1 of the CPVZ GFM. Maintenance and updates to the main CPVZ GFM and the resulting sub-models like the Perched Zone GFM sub-model is detailed in Chapter 6 of CP-60925.

   There are two sets of grids that need to be imported here. The first set are the Cold Creek Unit and CCUg surfaces that come from the CPVZ GFM and form the top and base of the Perched Zone GFM. The next few steps will detail how to use those grids as input to generate the model. However, it will also be necessary to import the grids originally created for this GFM, specifically those for CCU-PZSd and CCU-PZSt, to check the repeatability of the dynamic model update methodology in Kingdom. When it is time to import the CCU-PZSd and CCU-PZSt grids, follow these same import steps.

   a. In the Kingdom project tree right-click on Grids and select "Import." A navigation window will come up immediately, browse to the correct folder and select the grid.

      i. Note: the convention set forth in Chapter 6 of CP-60925 is to export grid files in a comma-delimited data file that contains the XYZ data for the grid in meters. This is the best data format for ease of communication across modeling platforms.

   b. The Import Grid window will come up (Figure 3-3). The program should read in the x/y min/max and grid increment from the file. It should only be necessary to assign the Author, New Grid Name, Data Type, and toggle Meters.

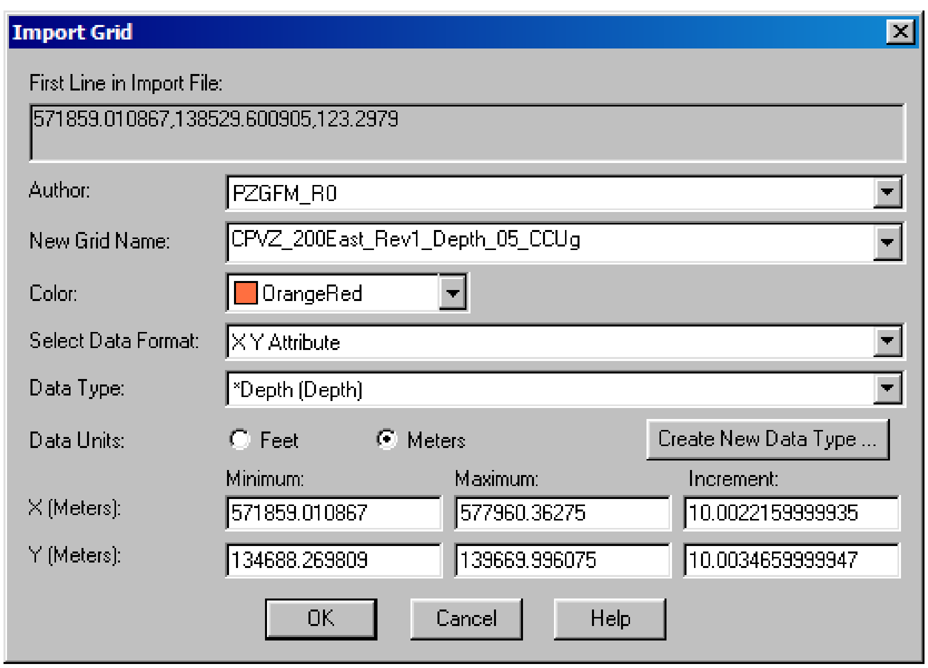


Figure 3-3. Import Grid Dialogue Window

c. Importing the grid file in this way leaves the depth type undefined, so it is necessary to go in and define the depth to subsea. (As Kingdom is an oil and gas industry software, most of the terminology is needs to be translated to our nomenclature. In this case, subsea actually means elevation. When a grid is created, the z value is elevation rather than depth below ground surface.)

   i. Right-click on the grid name in the project tree and select “properties.” Under depth type select “subsea” from the drop-down menu and click OK.

d. Repeat these steps for both the Cold Creek Unit and CCUg grids.

7. Create the GFM using the Dynamic Map Update Module in Kingdom.

   a. Under the Grids drop-down menu in the top menu bar, select “Dynamic Depth Conversion and Map Update” (Figure 3-4). This is a module developed by Kingdom to create velocity models to convert seismic data from two-way travel time to depth. The same concepts to create those models can be employed in the development of GFMs.

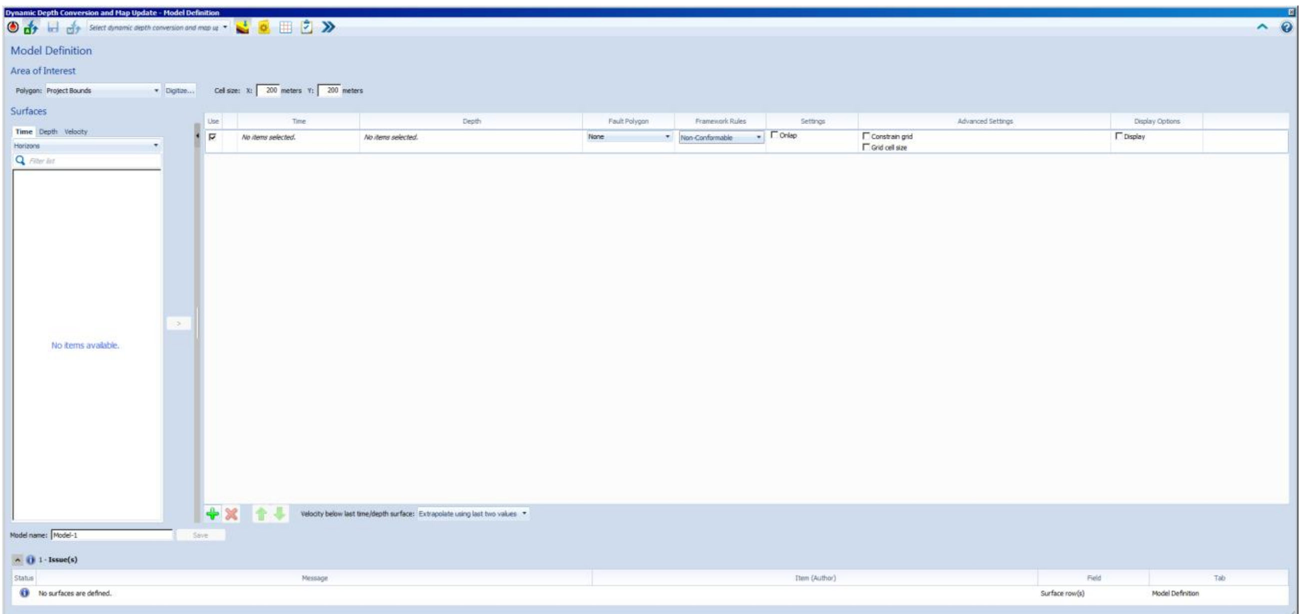


Figure 3-4. Kingdom’s Dynamic Depth Conversion and Map Update Module

   b. Name the model in the lower-left field for Model name and save. The grids you create in this module will be saved with that model name as the prefix.

   c. Select an area of interest polygon (for this project it is called Perched Zone Extent).

   d. The cell size employed for the Perched Zone grids is 5m x 5m; enter those values in the fields at the top of the window.

   e. To add surfaces to the model, select the Depth tab under “Surfaces.” To first add the two grids, select “Grids” from the drop-down menu.

   f. Select the “Cold Creek Unit” grid and move to the right into the larger window. It will move into the Layer 1 position.

g. Repeat these steps using the input parameters in Table 3-1.

h. Once the parameters are set up, run the model by selecting the "Update "button in the upper left. A dialogue window will open showing the operations occurring and listing any warnings or errors. The result should be a set of four surfaces and isopach grids you can interrogate in the main map module.

Table 3-1. Kingdom Dynamic Model Update Parameters
Model Name: 200 East Perched Zone GFM Rev. 0
Area of Interest Polygon: CPVZ_Rev1_Combined

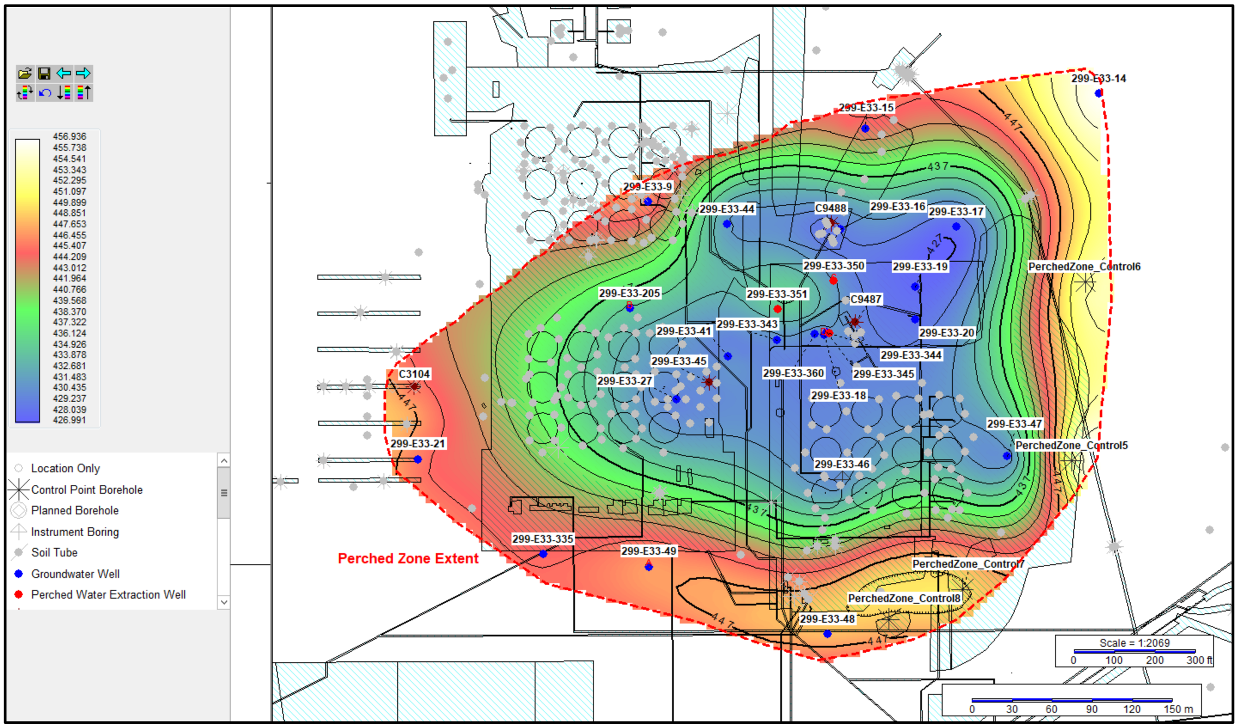
Layer	Input depth data (Author) (Data Type)	Framework Rules	Onlap	Constraints
1	CPVZ_200East_Rev1_Depth_04_Cold Creek Unit (CPVZ_Rev1) (Grid)	Non-Conformable	No	None
2	Cold Creek Perched Zone Sand (PZGFM_R0) (Tops)	Conform to surface below	No	Convex hull – 20m
3	Cold Creek Perched Zone Silt (PZGFM_R0) (Tops)	Conform to surface below	No	Convex hull – 20m
4	CPVZ_200East_Rev1_depth_05_CCUg (CPVZ_Rev1) (Grid)	Non-Conformable	No	None

Note: No fault polygons were used in this project, so that field can remain blank in the dynamic model update window.

4 Results

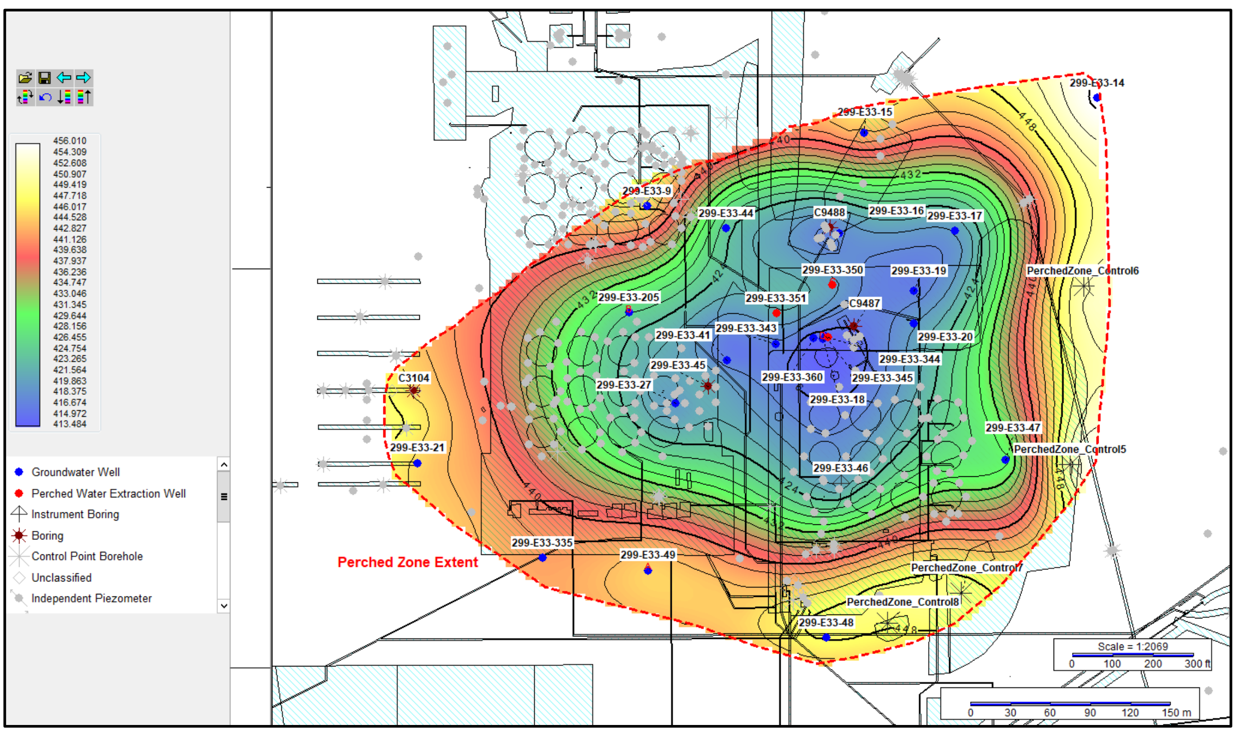
The results of the Perched Zone sub-model development are presented in this chapter. Figure 4-1 is a structural elevation map (in feet) of the top of the CCU-PZSd. High elevations are in yellow and low elevations are in blue, the contour interval is 0.6 m (2 ft). The geometry of the structure is somewhat oblong with a gentler slope on the west side and steep slopes along the north, east, and south sides of the structure. The margins of the Perched Zone structure along the southeast and east sides are controlled by the contacts at three wells (299-E33-48, 299-E33-47, and 299-E33-14). Four pseudo-boreholes were added to act as control points in all the stratigraphic units of the perched zone (PerchedZone_Control8, PerchedZone_Control7, PerchedZone_Control5, and PerchedZone_Control6) to maintain the bowl-shape of the structure. Without the control points the gridding algorithm generates low elevations between the three wells so that the margin of the structure resembles a sinusoidal shape. In flow simulations, that structure shape did not support perching of fluids above the CCU-PZSt, so the control boreholes were added to continue the same elevation trends observed at 299-E33-48 and 299-E33-14.

Figure 4-2 is a structural elevation map of the top of the CCU-PZSt. Like Figure 4-1, yellow represents higher elevations and blue is lower elevation, although the absolute values the colors represent are different because the CCU-PZSt is deeper than CCU-PZSd. The deepest part of the CCU-PZSt is at the center of the structure near the 299-E33-360, 299-E33-18, and 299-E33-345 well cluster.



Note: The CCU-PZSd is the saturated silty-sand – sandy-silt unit in the center of the Perched Zone sequence.

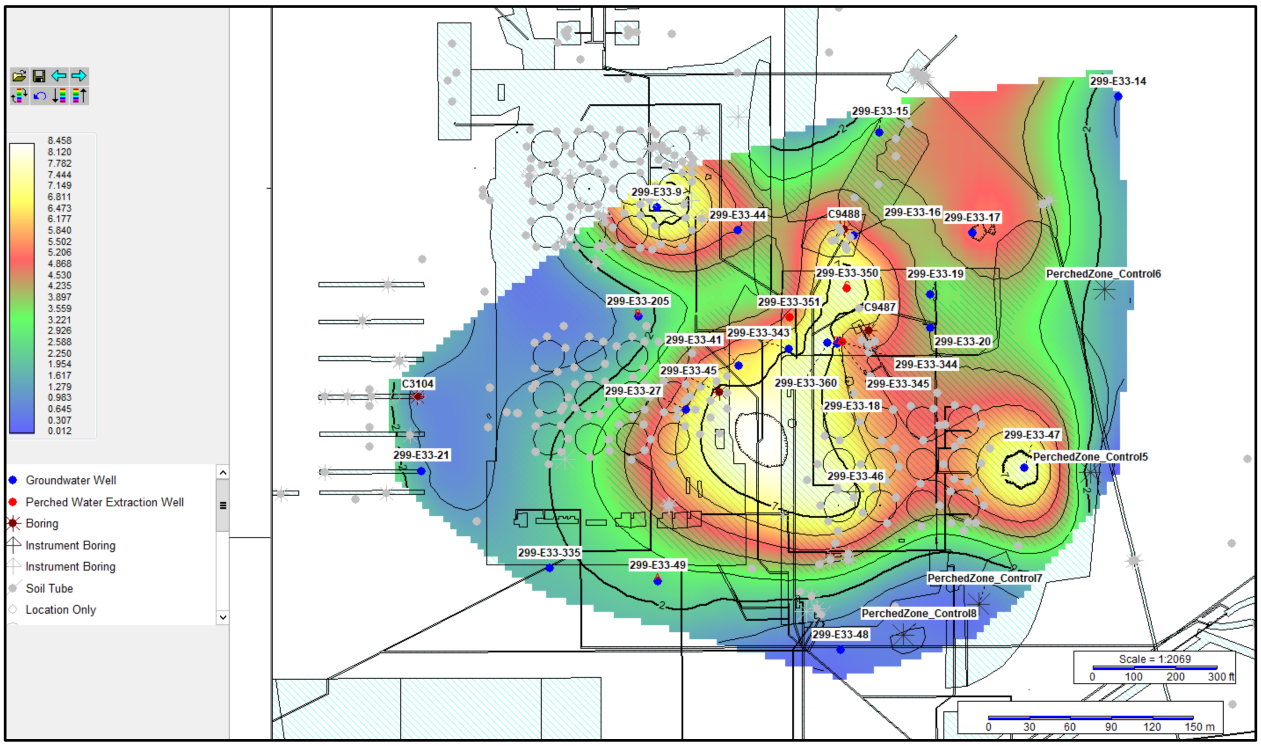
Figure 4-1. Structural Elevation Map (in feet) of the Top of the CCU-PZSd



Note: The CCU-PZSt is the sandy-silt – silt unit at the base of the Perched Zone structure.

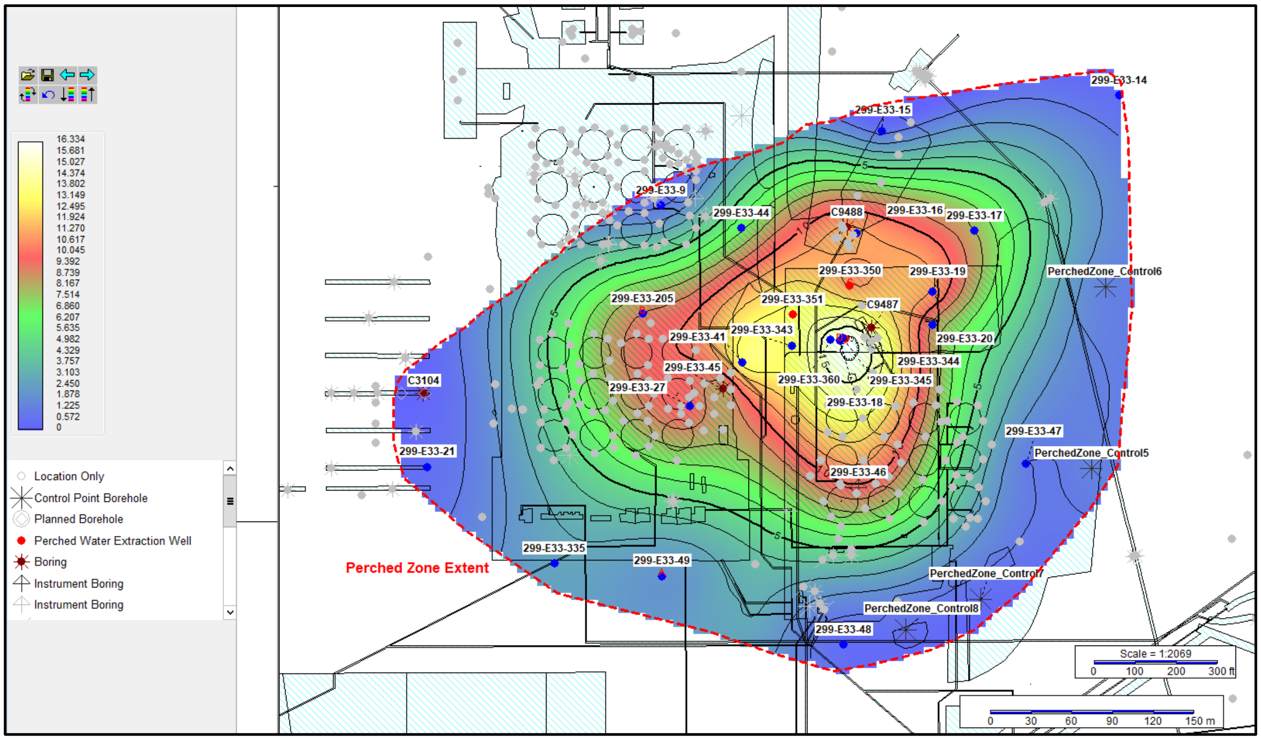
Figure 4-2. Structural Elevation Map (in feet) of the Top of the CCU-PZSt

Figures 4-3, 4-4, and 4-5 are isopach (thickness) maps of each of the Perched Zone units. The CCU at the top of the section has some variability in thickness with the thickest sections near 299-E33-47 and 299-E33-9 where the CCU is mapped as 2.4 m (8 ft) thick. This is a result of the CCU-PZSd sand pinching out at the margins of the Perched Zone. In the absence of the CCU-PZSd separating the CCU and CCU-PZSt, it is difficult to separate the two silt units. Therefore, the units get combined into the CCU. There is another thick area of the CCU through the center of the Perched Zone that is mostly notable for the contrast with the thin CCU through 299-E33-19 and 299-E33-20. These two wells have fairly poor quality data, so it is possible that the CCU is equally thick (about 2.3 m [7.5 ft] thick) through the entire core of the Perched Zone. The CCU-PZSd map (Figure 4-4) shows the thickest sandy section near the Perched Zone extraction wells (e.g., 299-E33-345 near extraction well 299-E33-344) at about 4.6 m (15 ft) thick, while the thickest CCU-PZSt is located at 299-E33-350 at about 2.7 m (9 ft) thick. Overall the CCU-PZSd is 1 to 4.8 m (3 to 16 ft) thick and the CCU-PZSt is 0.6 to 3 m (2 to 10 ft) thick.



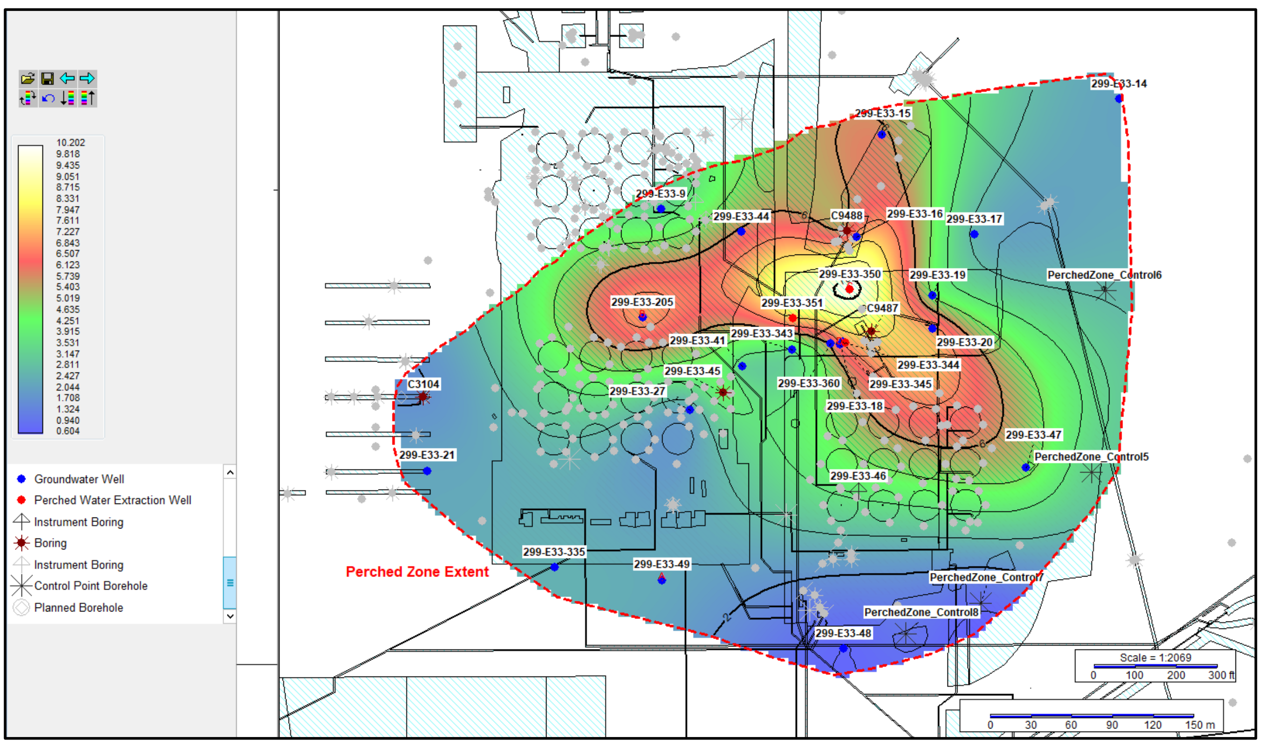
Note: Thickness is in feet between the uppermost CCU silt and the CCU-PZSd beneath.

Figure 4-3. Isopach Map for the Cold Creek Unit Upper Silt



Note: Thickness is in feet between the CCU-PZSd and CCU-PZSt.

Figure 4-4. Isopach Map of the CCU-PZSd

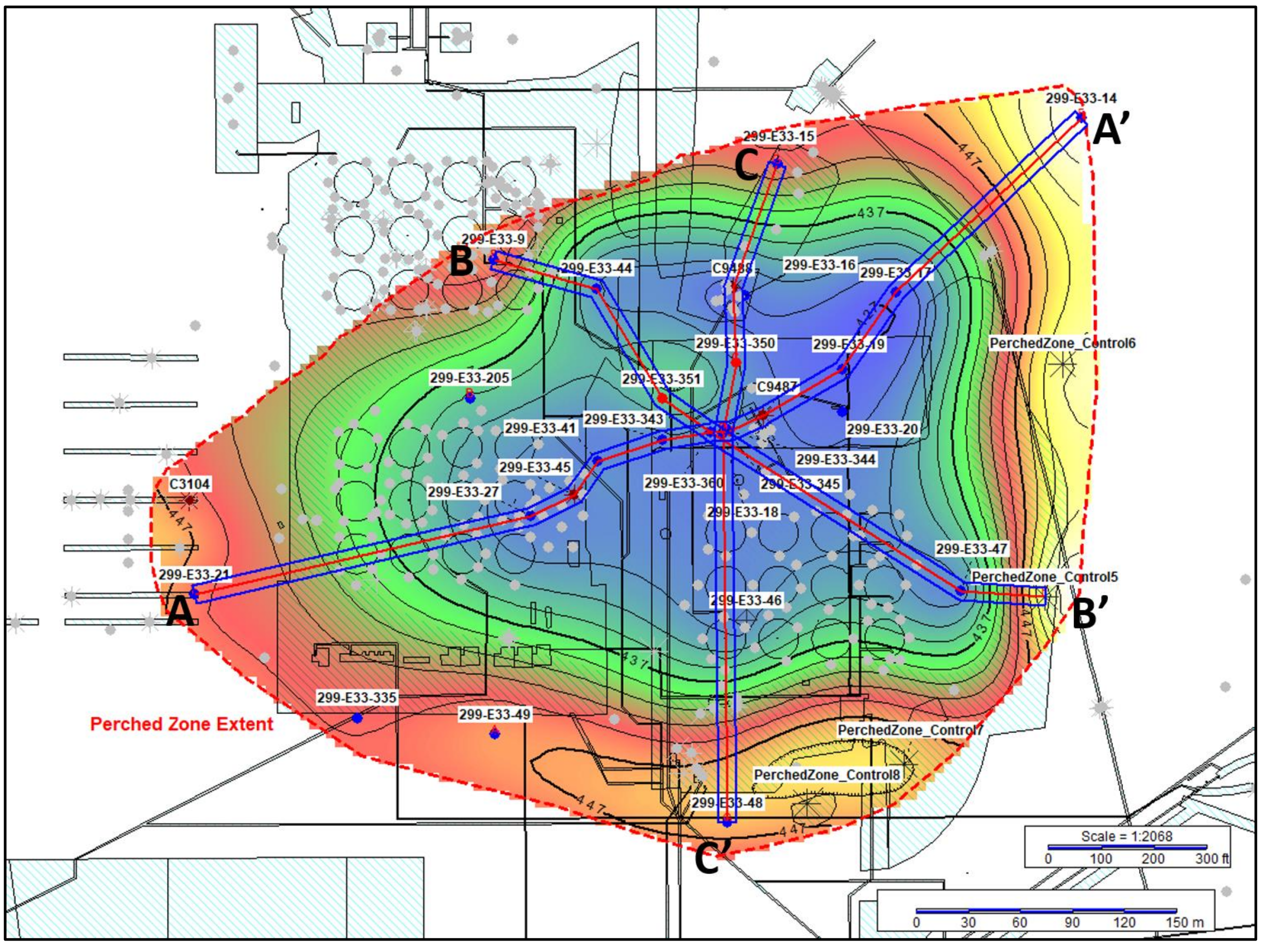


Note: Thickness is in feet between the CCU-PZSt and CCUg.

Figure 4-5. Isopach Map for the CCU-PZSt

Figures 4-6, 4-7, 4-8, and 4-9 show well-to-well cross sections through the Perched Zone. The cross sections are roughly 3x vertical exaggeration and are not full thickness, meaning there is approximately 53 m (175 ft) of Hanford formation above the top of these cross sections. These sections are designed to show the structure of the Perched Zone. Displaying the sections with no vertical exaggeration and with the full top-to-base section would make it very difficult to see any detail in the Perched Zone. The shape of the structure shown in the cross sections is irregularly bowl-shaped with steep walls along the margins.

One application of the Perched Zone GFM is the generation of saturated thickness maps, which are useful for extraction optimization activities. The saturated thickness of the Perched Zone is the volume between the top of the Perched Zone water table and the top of CCU-PZSt, which is assumed to be the base of the saturated portion of the Perched Zone. This is a necessary secondary calculation because the full thickness of the CCU-PZSd is not saturated.



Note: The structural elevation contours are the tops of the CCU-PZSd.

Figure 4-6. Cross Section Index Map Showing the Locations of the A-A', B-B', and C-C' Cross Sections

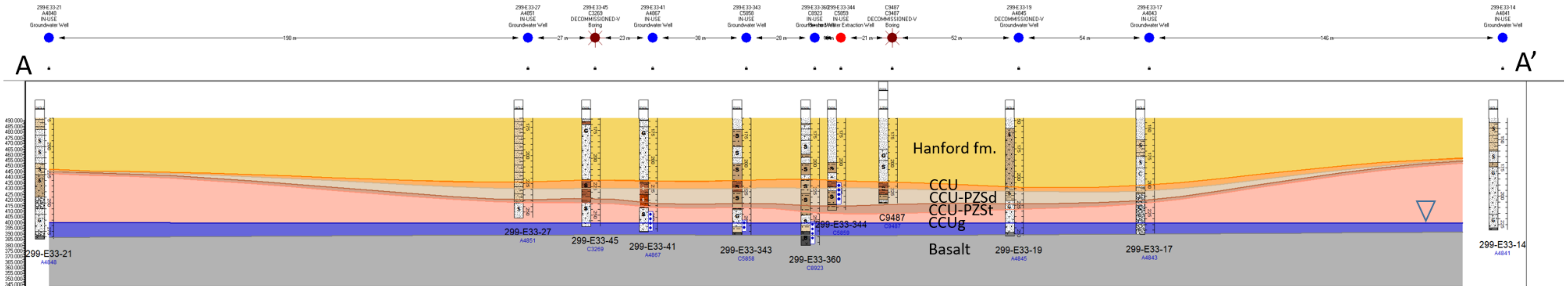


Figure 4-7. A-A’ (SW-NE) Cross Section Through the Perched Zone

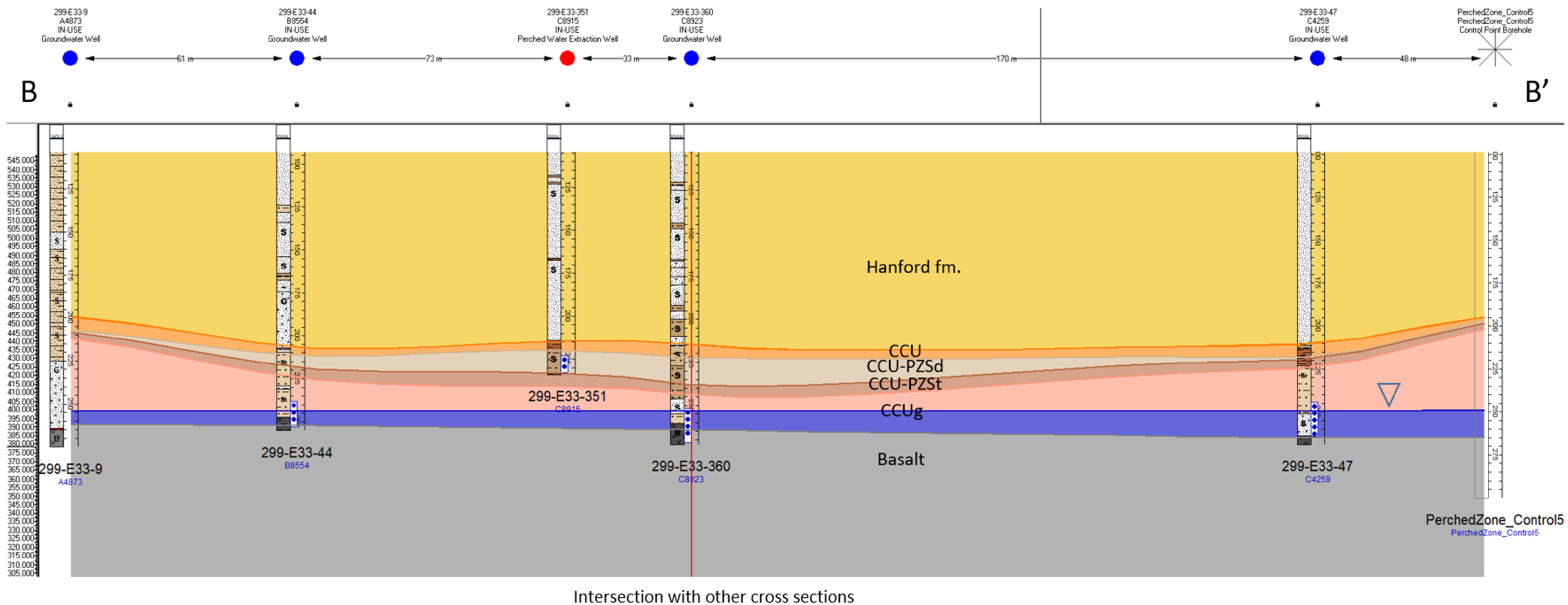


Figure 4-8. B-B’ (NW-SE) Cross Section Through the Perched Zone

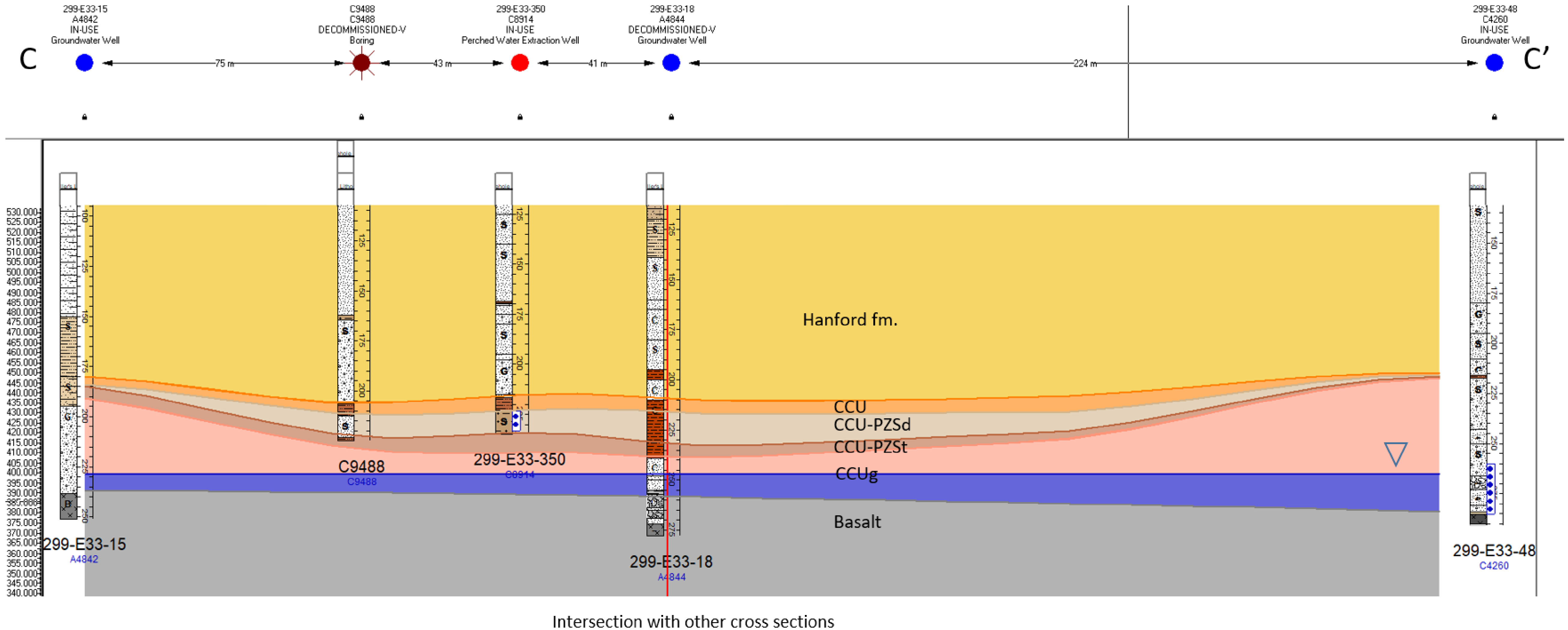


Figure 4-9. C-C' (N-S) Cross Section Through the Perched Zone

The Perched Zone water table is calculated by mapping the barometrically corrected water levels in the three extraction wells (299-E33-344, 299-E33-350, and 299-E33-351) as a gridded surface. The water level values are derived from DOE/RL-2016-69 and PNNL-27846, *Physical and Hydraulic Properties of Sediments from the 200-DV-1 Operable Unit,* and are listed in Table 4-1. There is some uncertainty in these water level measurements as there is not a continuous monitoring record in the Perched Zone and while current extraction activities do not appear to be changing the water levels significantly, there may be some effects unaccounted for since the 2016 measurements.

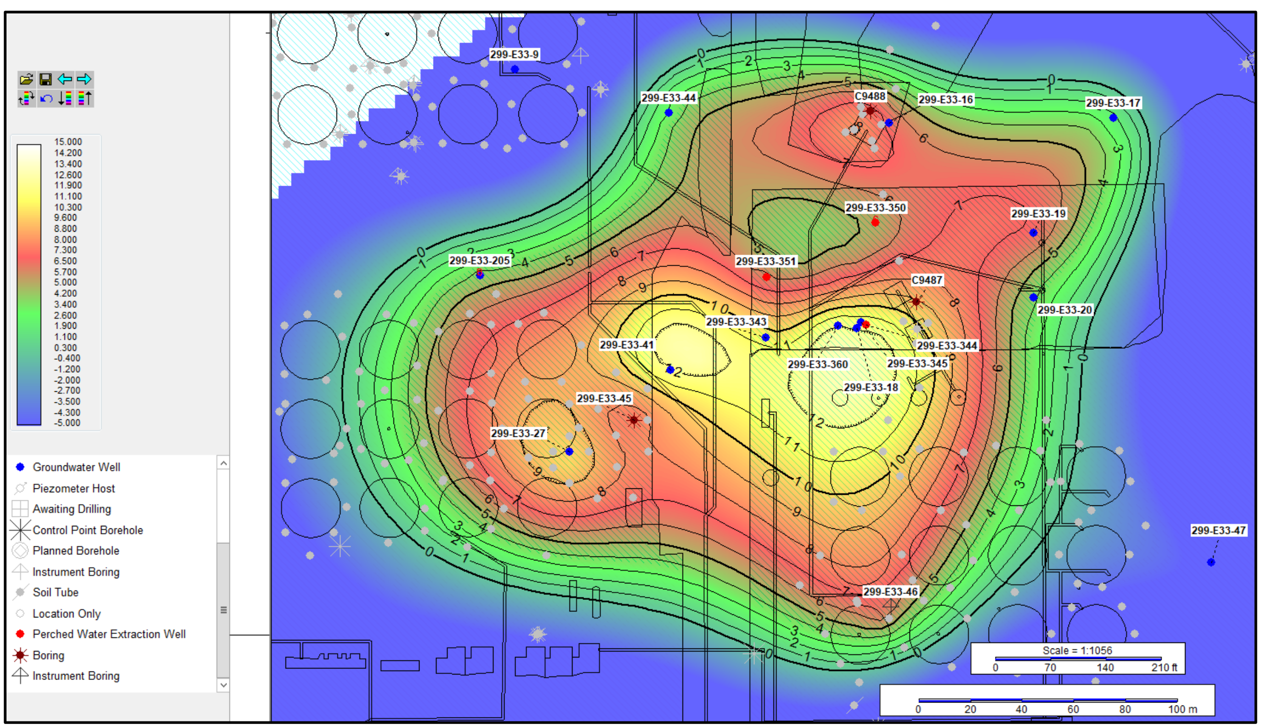
Table 4-1. Perched Zone Water Levels

Well Name	Well ID	Water Level (ft bgs)
299-E33-344	C5859	225.97
299-E33-350	C8914	229.40
299-E33-351	C8915	226.52

bgs = below ground surface

ID = identification

The resulting saturated thickness map can be found in Figure 4-10. The zero-contour value represents the point at which the water level plane intersects the CCU-PZSt at the walls of the Perched Zone bowl structure. The thickest part of the saturated Perched Zone are the 3.4 to 3.7 m (11 to 12 ft) contours between wells 299-E33-41 and 299-E33-344. This map is expected to change over time as extraction proceeds at the Perched Zone.



Note: The water is confined to the CCU-PZSd Unit.

Figure 4-10. Saturated Thickness Map of the Perched Zone

To calculate the static volume of the saturated thickness of the Perched Zone the volumetric calculator was employed. Past evaluations of the Perched Zone volume assumed a constant saturated thickness over an areal extent (PNNL-22499 *Perched-Water Evaluation for the Deep Vadose Zone Beneath the B, BX, and BY Tank Farms Area of the Hanford Site*). The Kingdom Volumetric calculator tool allows a three-dimensional calculation of the volume of the associated saturated thickness grid. With the saturated thickness grid input the results returned an area of 50,908.3 m^2 and 318,586.76 m^2ft. The volume result is in m^2ft because the Kingdom project is set up as meters in the x/y dimension and ft in the z dimension to accommodate drilling reports measured in ft. The following conversion was used to convert to m^3:

$318{,}586.76\ m^2ft \times 0.3048\ m/1\ ft = 97{,}105.25\ m^3$

$97{,}105.25\ m^3 = 9.7 \times 10^7$ L

To find effective volume the 9.7×10^7 L was multiplied by a porosity of 25.2%, which is the porosity assumed in PNNL-22499 for the perched sand. The final calculated static volume of the saturated perched zone is 2.4×10^7 L. This does not account for the balance of water coming into the system or water flux out of the system. The volume is also given to change as new water level or lithology data are collected.

5 Software Applications

Software used for this calculation is applicable in accordance with PRC-PRO-IRM-309, *Controlled Software Management.*

5.1 Approved Software

The software identified in the following sections was used to perform this calculation and was approved and used compliant with PRC-PRO-IRM-309.

5.1.1 Description

The following approved software was used to perform this calculation:

- Software Title: Kingdom-Geology
- Software Version: 2016.1
- Hanford Information Systems Inventory Identification Number: 3899 (Safety Software S3, Level C)
- Workstation type and property number (from which software is run): Hanford Local Area Network Computer Property Number WF34759.

This approved software is managed under the following software quality assurance documents:

- CHPRC-02937, *Kingdom-Geology Software Management Plan*
- CHPRC-02938, *Kingdom-Geology Software Test Plan*

5.1.2 Software Installation and Checkout

A copy of the *Software Installation and Checkout Form* for Kingdom-Geology is provided in Appendix B to this ECF.

5.1.3 Statement of Valid Software Application

The Kingdom-Geology software identified was used consistent with intended use for CH2M HILL Plateau Remediation Company as identified in CHPRC-02937. This software was used within the limitations defined in CHPRC-02937 for CH2M HILL Plateau Remediation Company applications.

5.2 Support Software

The following software was used for limited purposes to support the use of Kingdom-Geology in this calculation:

- Microsoft Excel® – Microsoft Excel was used to perform the calculations and as a spreadsheet tool.
- Microsoft PowerPoint® – Microsoft PowerPoint was used to enhance graphics.

6 References

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PRC-PRO-IRM-309, 2009, *Controlled Software Management*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: https://www.gpo.gov/fdsys/pkg/STATUTE-90/pdf/STATUTE-90-Pg2795.pdf.

Appendix A

Perched Zone Geoframework Interpreted Borehole Profiles

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A1 Introduction

This appendix contains graphic geologic log profiles that illustrate the geologic unit contacts selected for the boreholes used to develop the Perched Zone Geoframework. Geophysical log data are integrated with driller's or borehole log observations to illustrate the basis for the stratigraphic top interpretation. Figure A-1 is a guide to understanding the data and features in these profiles. Graphic displays of logs generally follow the conventions of the geophysical log contractors or align as closely to geologic logging procedures as possible. In general, the colors of units within the lithologic log are selected to highlight the amount of silt observed (the brown color gets darker as the observed percentage of silt increases) or other noteworthy color features of the sediment.

Figure A-2 is a location map that shows where each of these boreholes is in relation to each other.

Figures A-3 through A-33 (need a statement here)

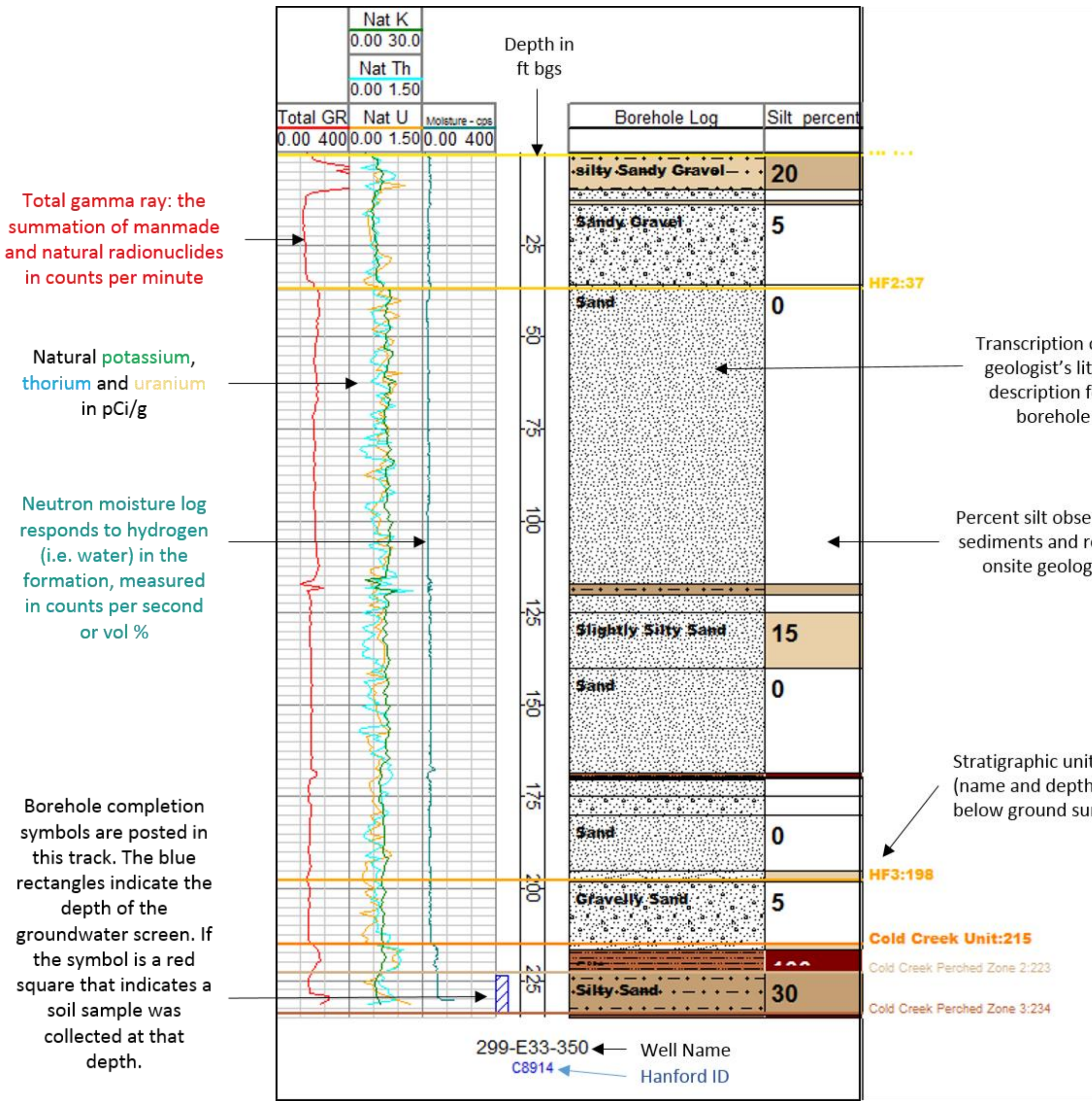


Figure A-1. Guide to Understanding the Elements of a Borehole Profile

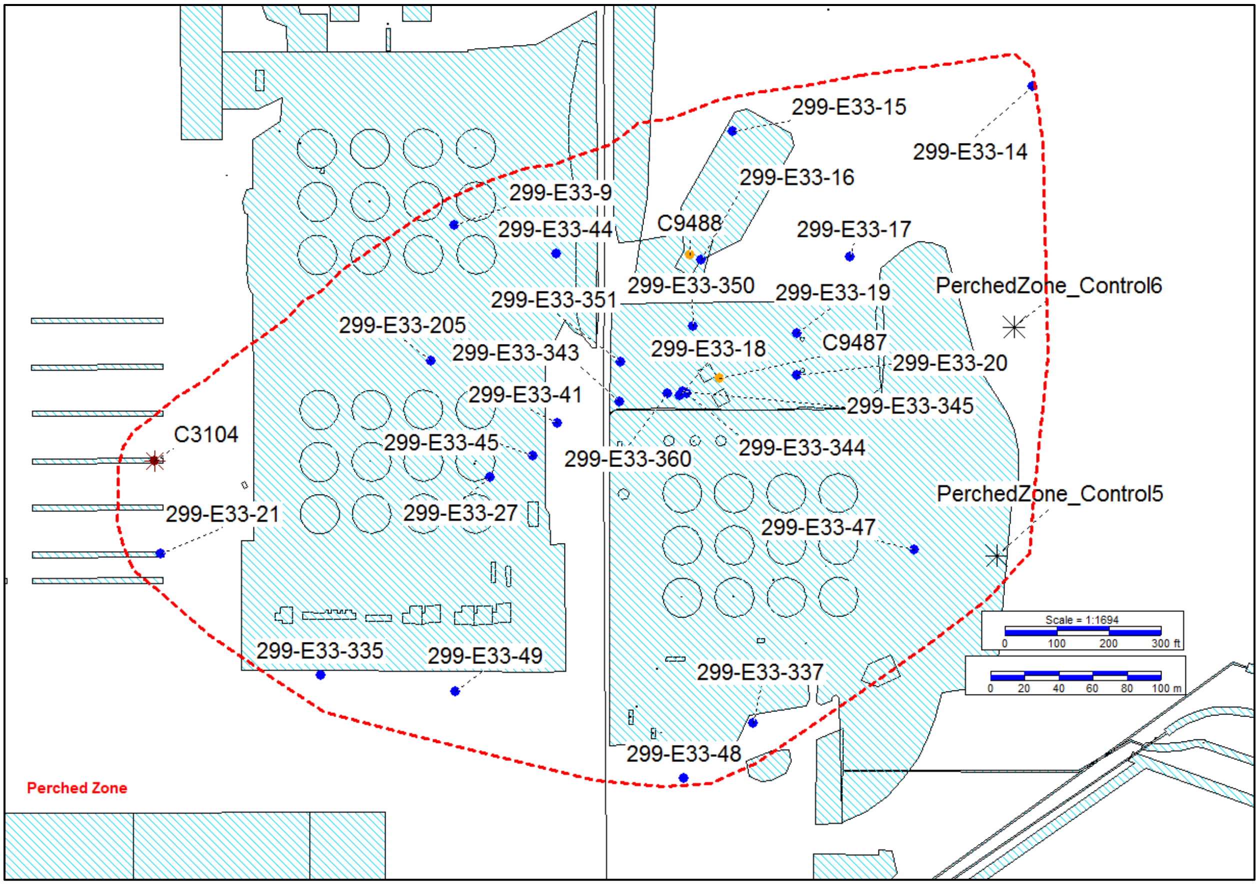


Figure A-2. Location Map of the Perched Zone Area with Borehole Used to Create the Perched Zone GFM

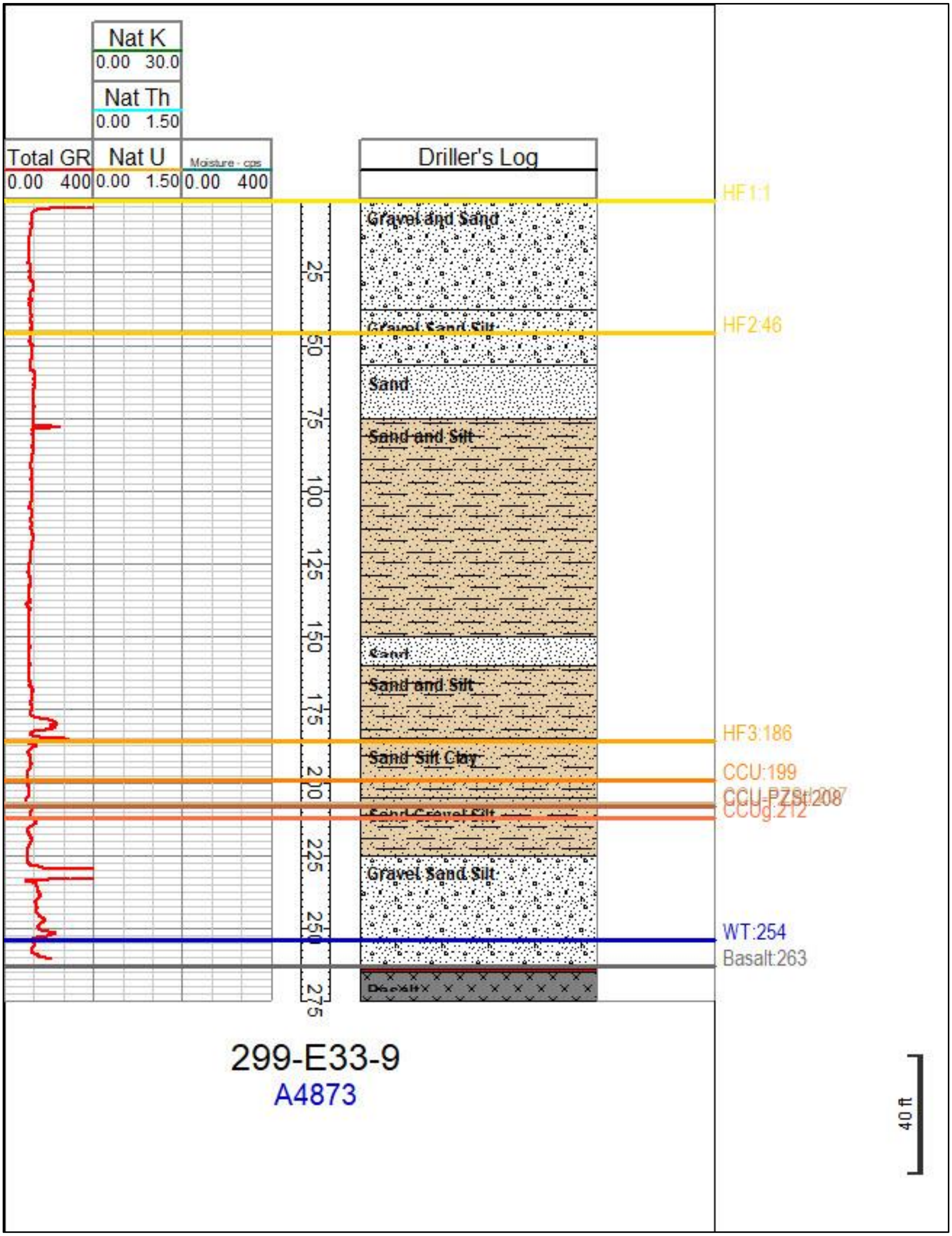


Figure A-3. (Title needs to be added through A-33)

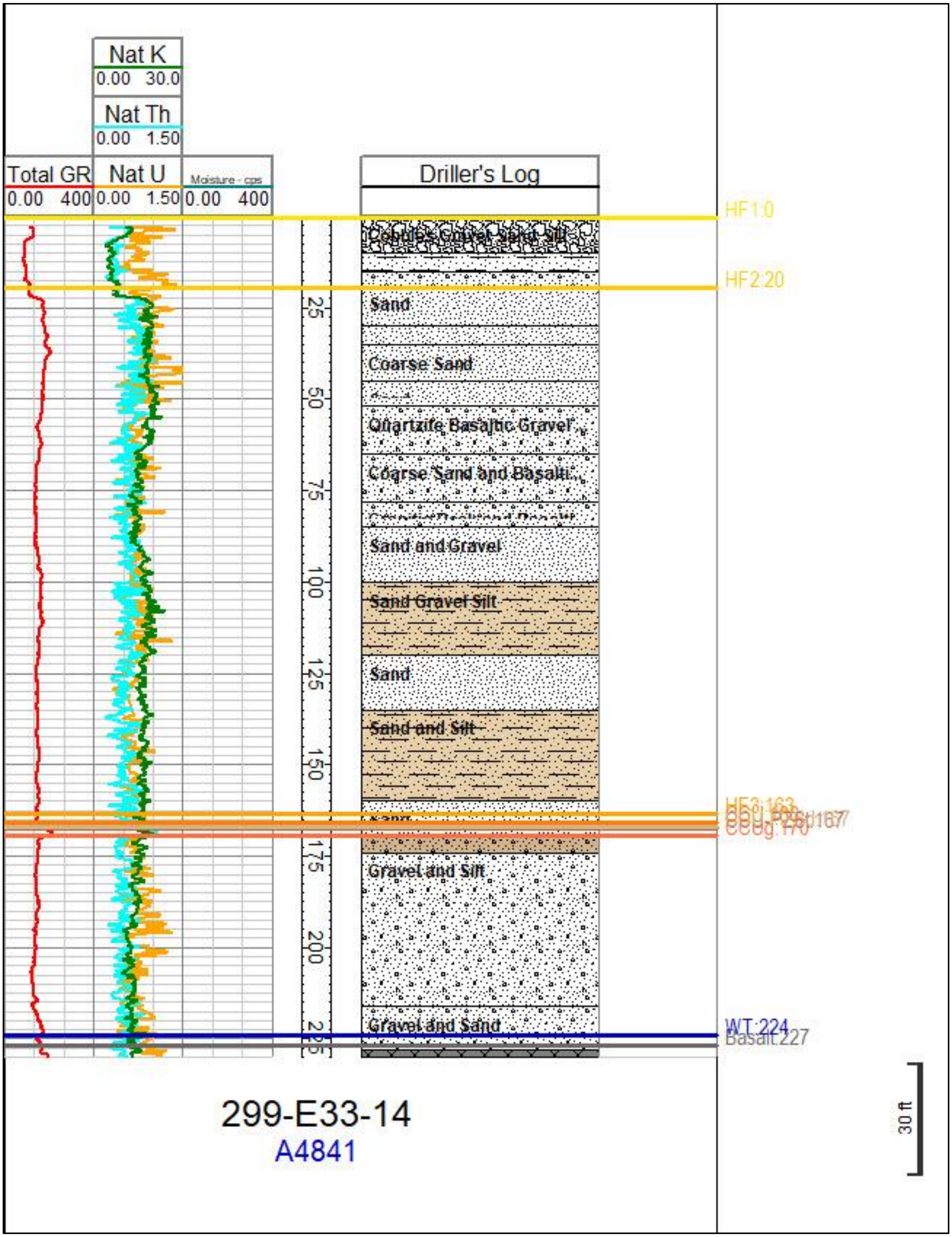

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
HF1:0
HF2:20
Sand
Coarse Sand
Quartzite Basaltic Gravel
Coarse Sand and Basalt
Sand and Gravel
Sand Gravel Silt
Sand
Sand and Silt
Gravel and Silt
Gravel and Sand
25
50
75
100
125
150
175
200
WT:224
Basalt:227
299-E33-14
A4841
30 ft

Figure A-4.

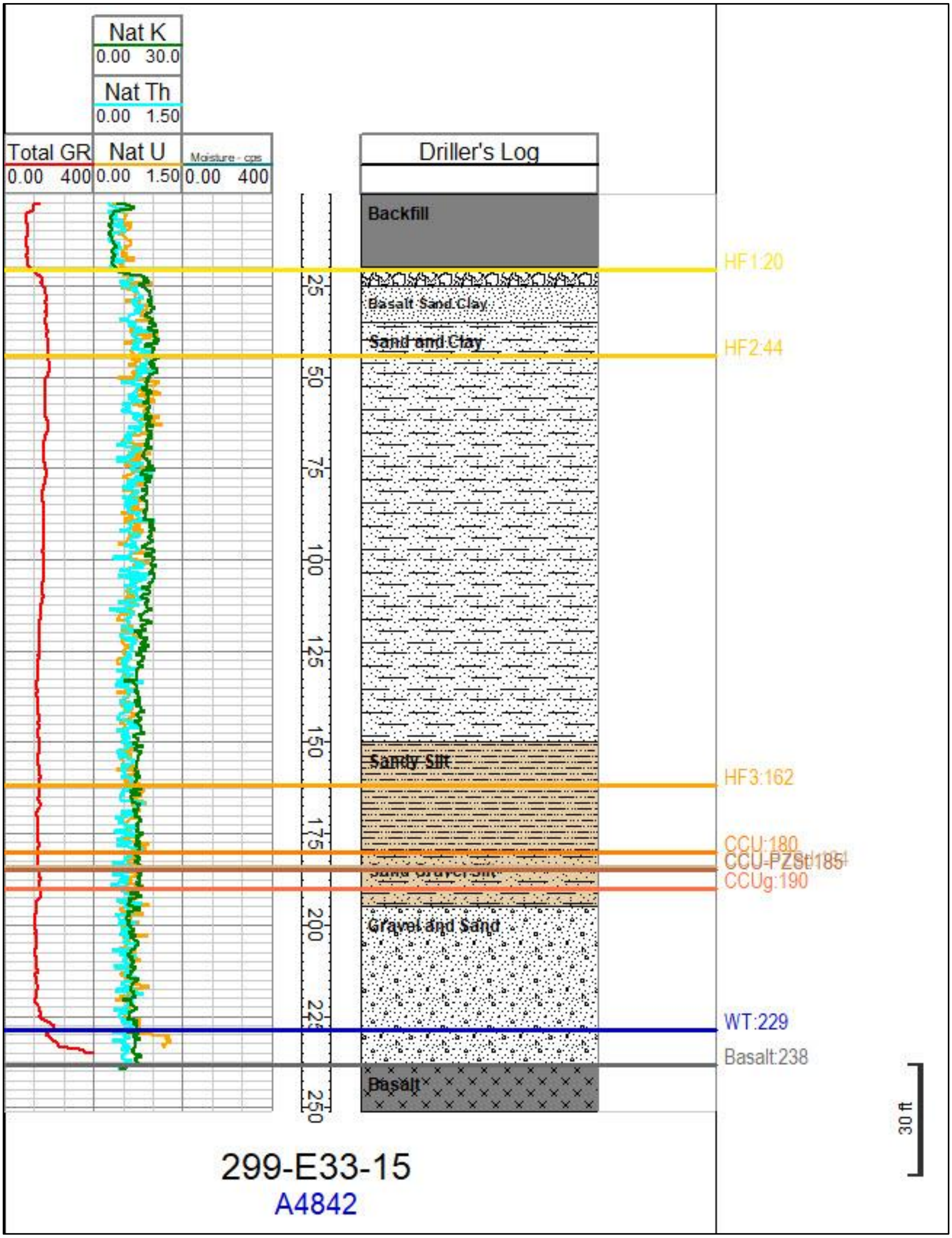

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Backfill
Basalt Sand Clay
Sand and Clay
Sandy Silt
Gravel and Sand
Basalt
25
50
75
100
125
150
175
200
250
HF1:20
HF2:44
HF3:162
CCU:180
CCU-PZSt:185
CCUg:190
WT:229
Basalt:238
30 ft
299-E33-15
A4842

Figure A-5.

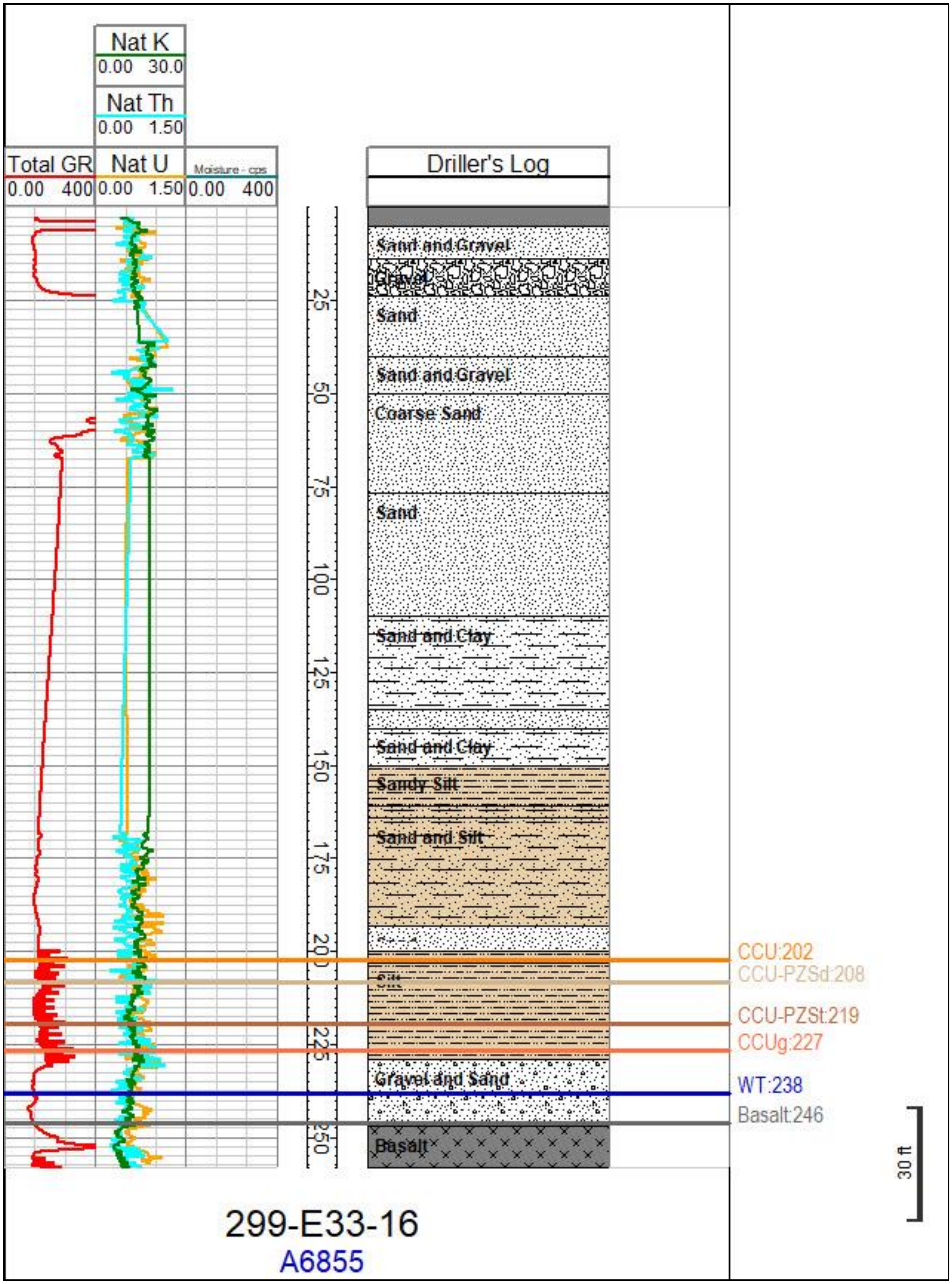

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Sand and Gravel
Gravel
Sand
Sand and Gravel
Coarse Sand
Sand
Sand and Clay
Sand and Clay
Sandy Silt
Sand and Silt
Silt
Gravel and Sand
Basalt
25
50
75
100
125
150
175
200
225
250
CCU:202
CCU-PZSd:208
CCU-PZSt:219
CCUg:227
WT:238
Basalt:246
30 ft
299-E33-16
A6855

Figure A-6.

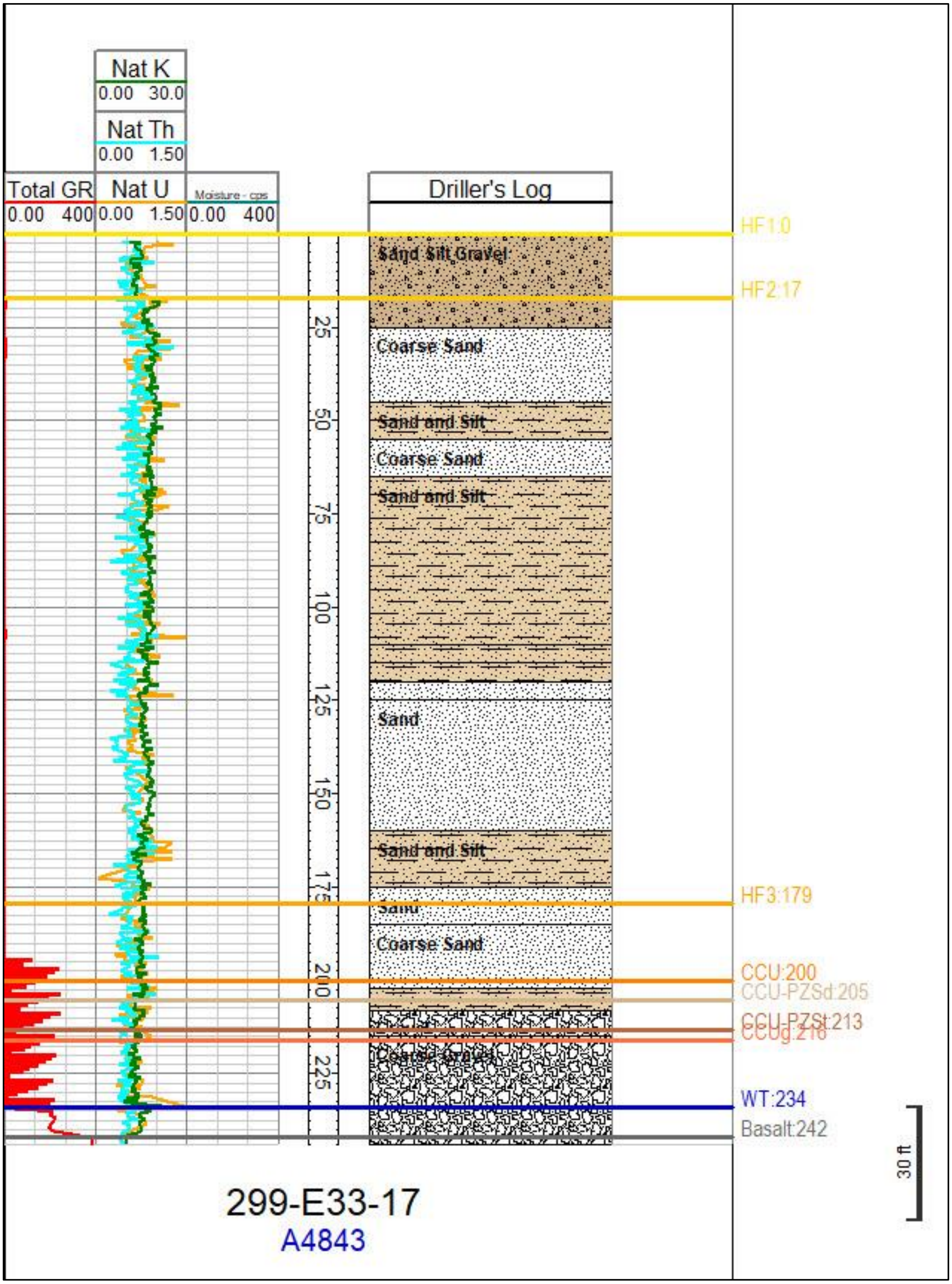
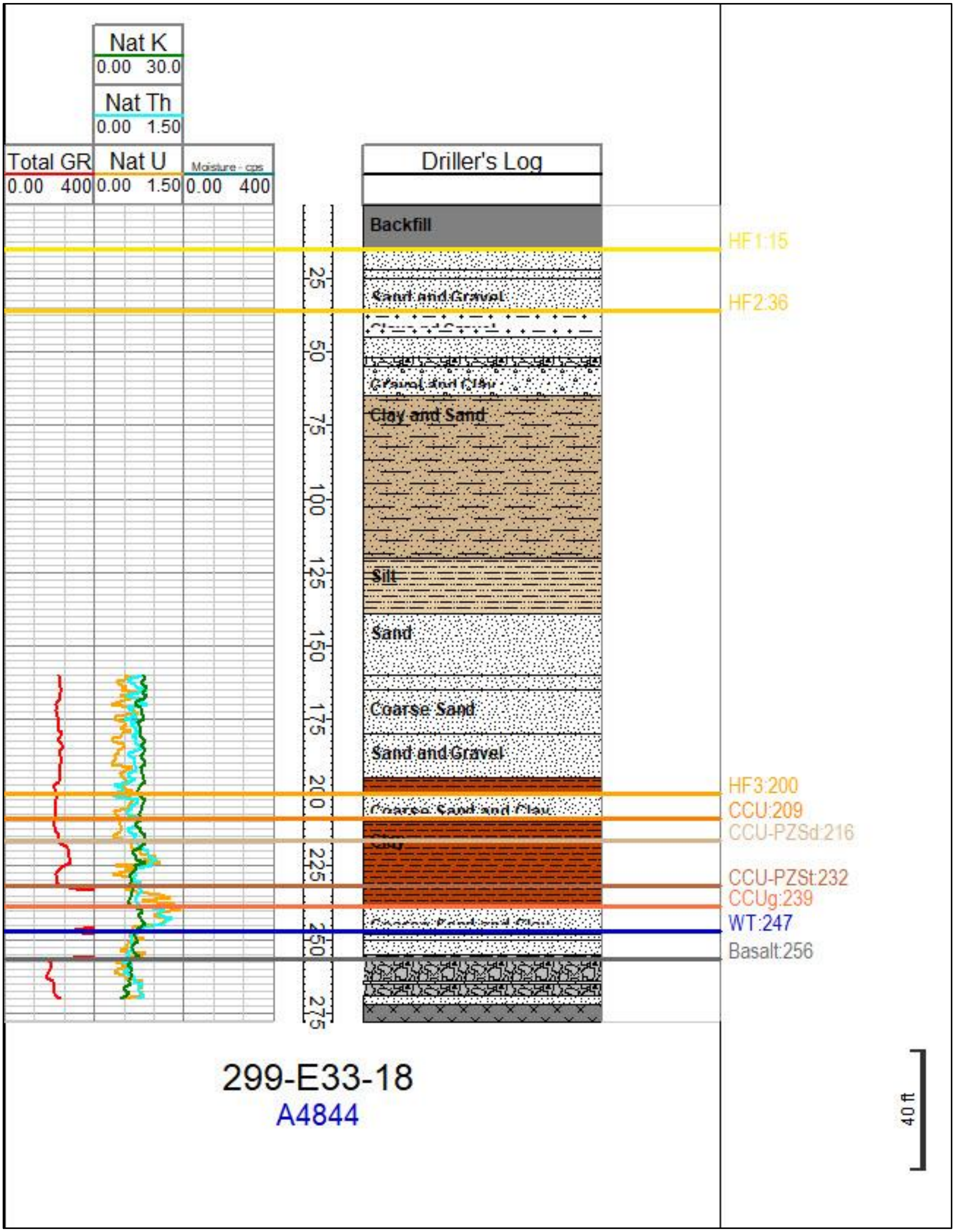
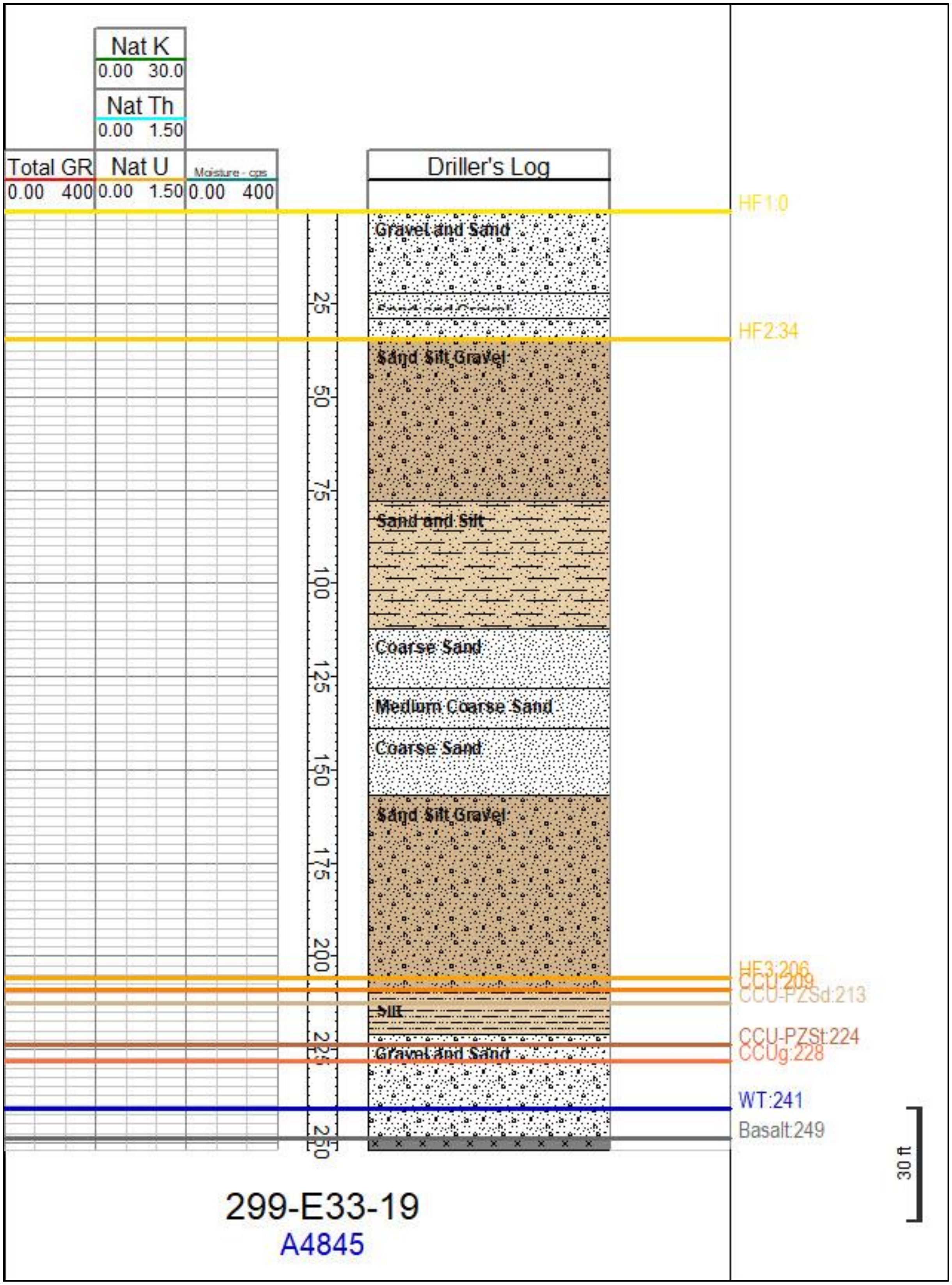

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Sand Silt Gravel
Coarse Sand
Sand and Silt
Coarse Sand
Sand and Silt
Sand
Sand and Silt
Sand
Coarse Sand
Coarse Gravel
25
50
75
100
125
150
175
200
225
HF1:0
HF2:17
HF3:179
CCU:200
CCU-PZSd:205
CCU-PZSt:213
CCUg:216
WT:234
Basalt:242
30 ft
299-E33-17
A4843

Figure A-7.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Backfill
Sand and Gravel
Gravel and Clay
Clay and Sand
Silt
Sand
Coarse Sand
Sand and Gravel
Coarse Sand and Clay
25
50
75
100
125
150
175
200
225
250
275
HF1:15
HF2:36
HF3:200
CCU:209
CCU-PZSd:216
CCU-PZSt:232
CCUg:239
WT:247
Basalt:256
299-E33-18
A4844
40 ft

Figure A-8.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Gravel and Sand
Sand and Gravel
Sand Silt Gravel
Sand and Silt
Coarse Sand
Medium Coarse Sand
Coarse Sand
Sand Silt Gravel
Silt
Gravel and Sand
25
50
75
100
125
150
175
200
250
HF1:0
HF2:34
HF3:206
CCU:209
CCU-PZSd:213
CCU-PZSt:224
CCUg:228
WT:241
Basalt:249
30 ft
299-E33-19
A4845

Figure A-9.

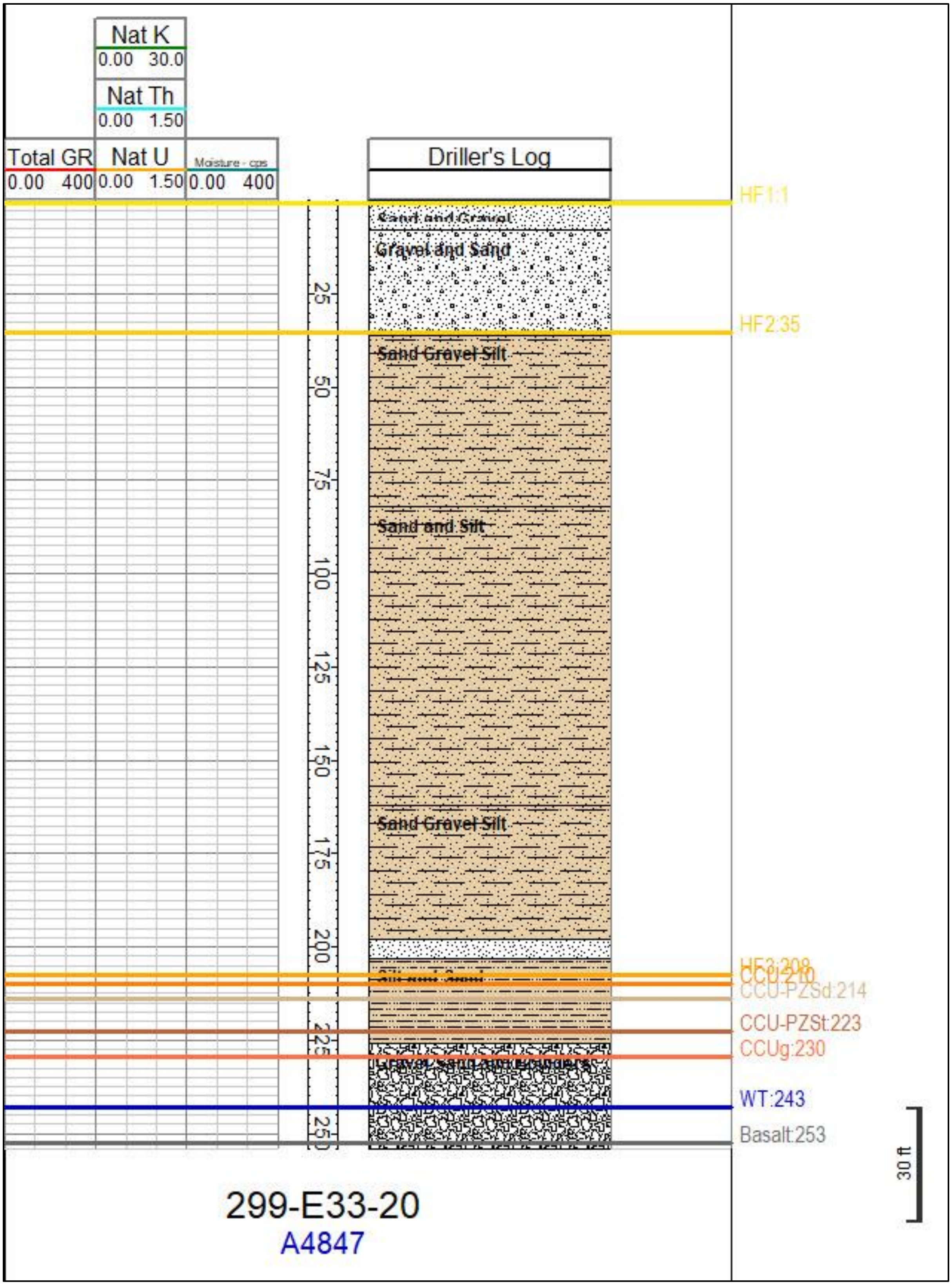

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
HF1:1
Gravel and Sand
HF2:35
Sand Gravel Silt
Sand and Silt
Sand Gravel Silt
HF3:208
CCU:210
CCU-PZSd:214
CCU-PZSt:223
CCUg:230
WT:243
Basalt:253
30 ft
299-E33-20
A4847

Figure A-10.

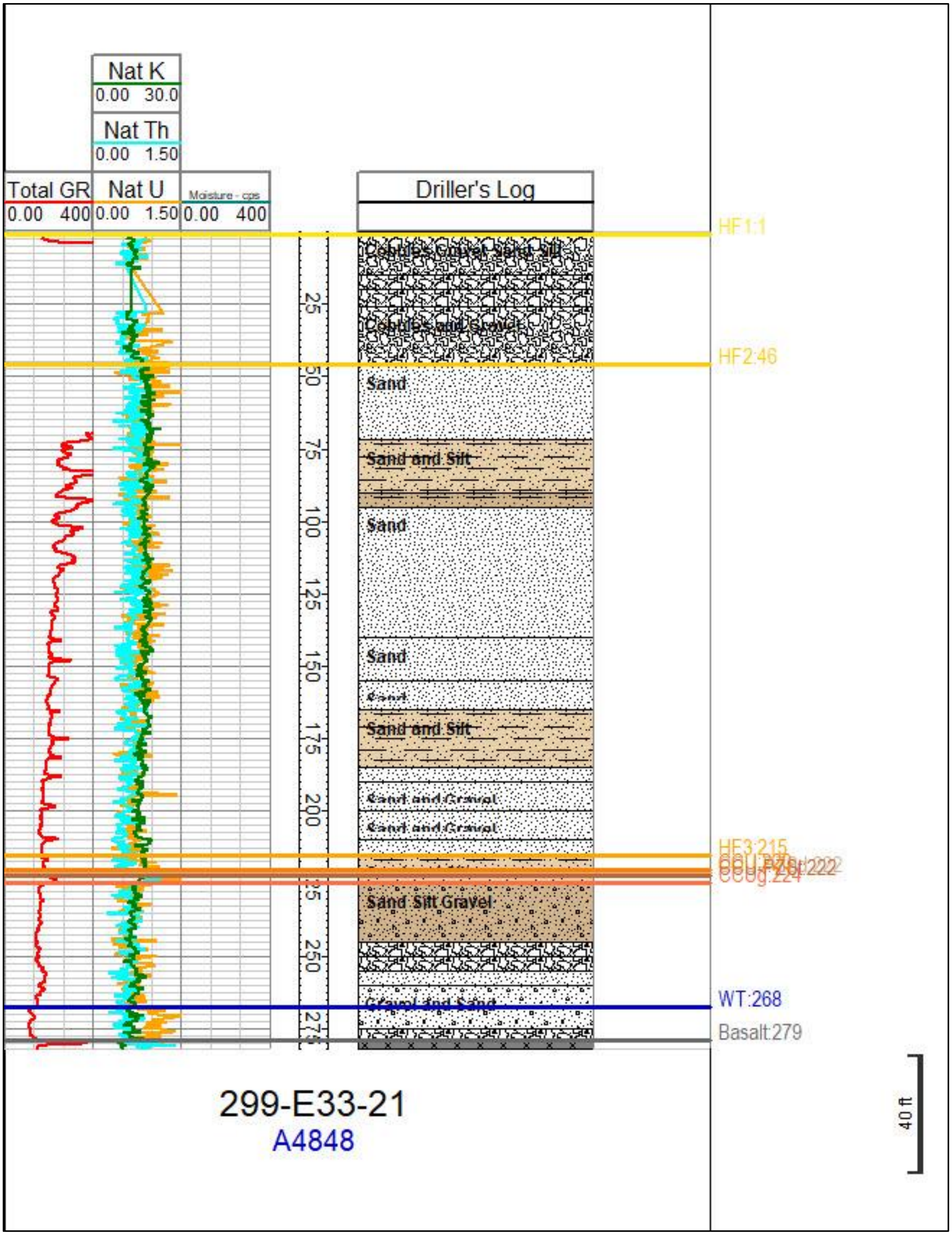

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
Cobbles Gravel Sand Silt
Cobbles and Gravel
Sand
Sand and Silt
Sand
Sand
Sand and Silt
Sand and Gravel
Sand and Gravel
Sand Silt Gravel
Gravel and Sand
25
50
75
100
125
150
175
200
250
HF1:1
HF2:46
HF3:215
WT:268
Basalt:279
299-E33-21
A4848
40 ft

Figure A-11.

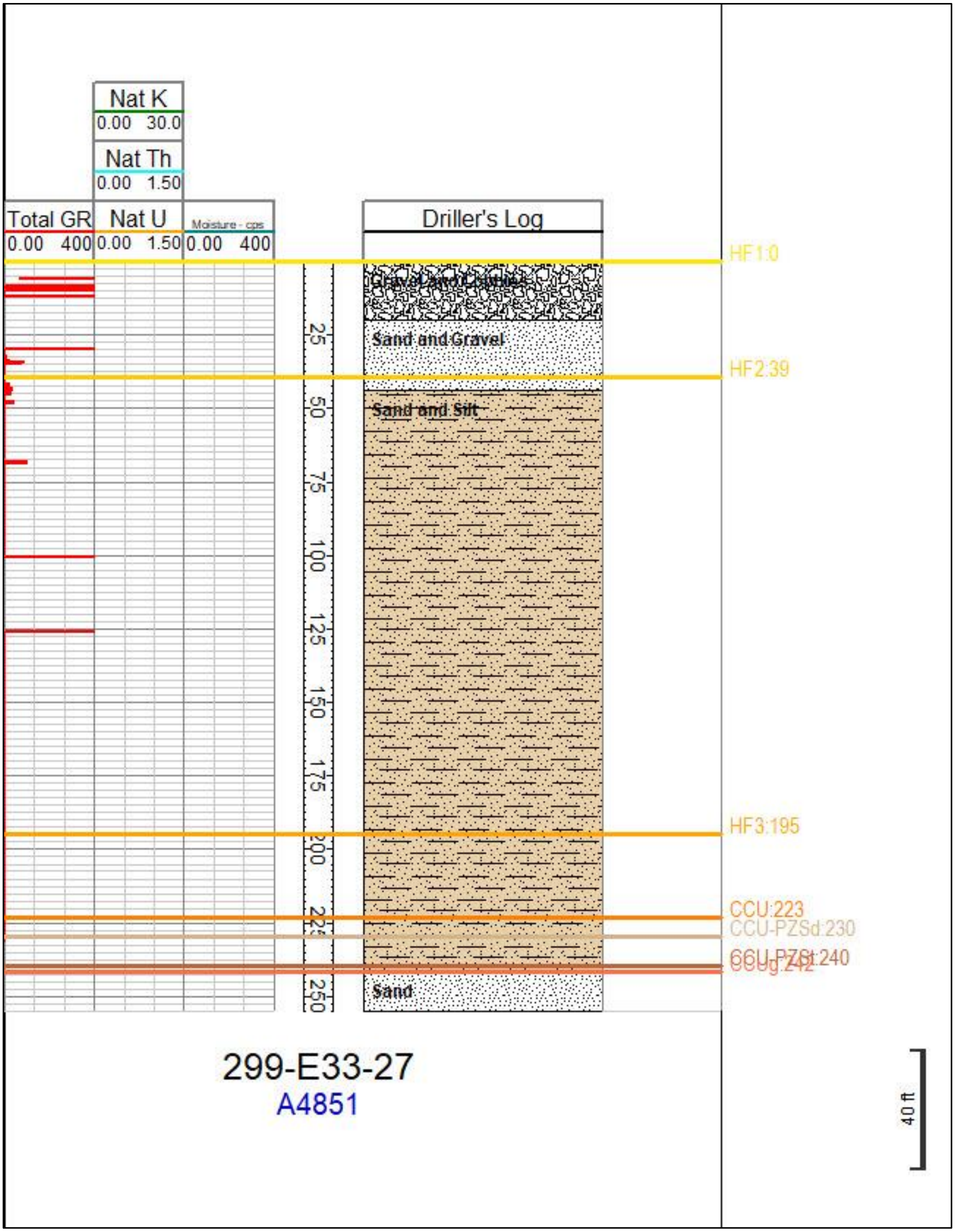
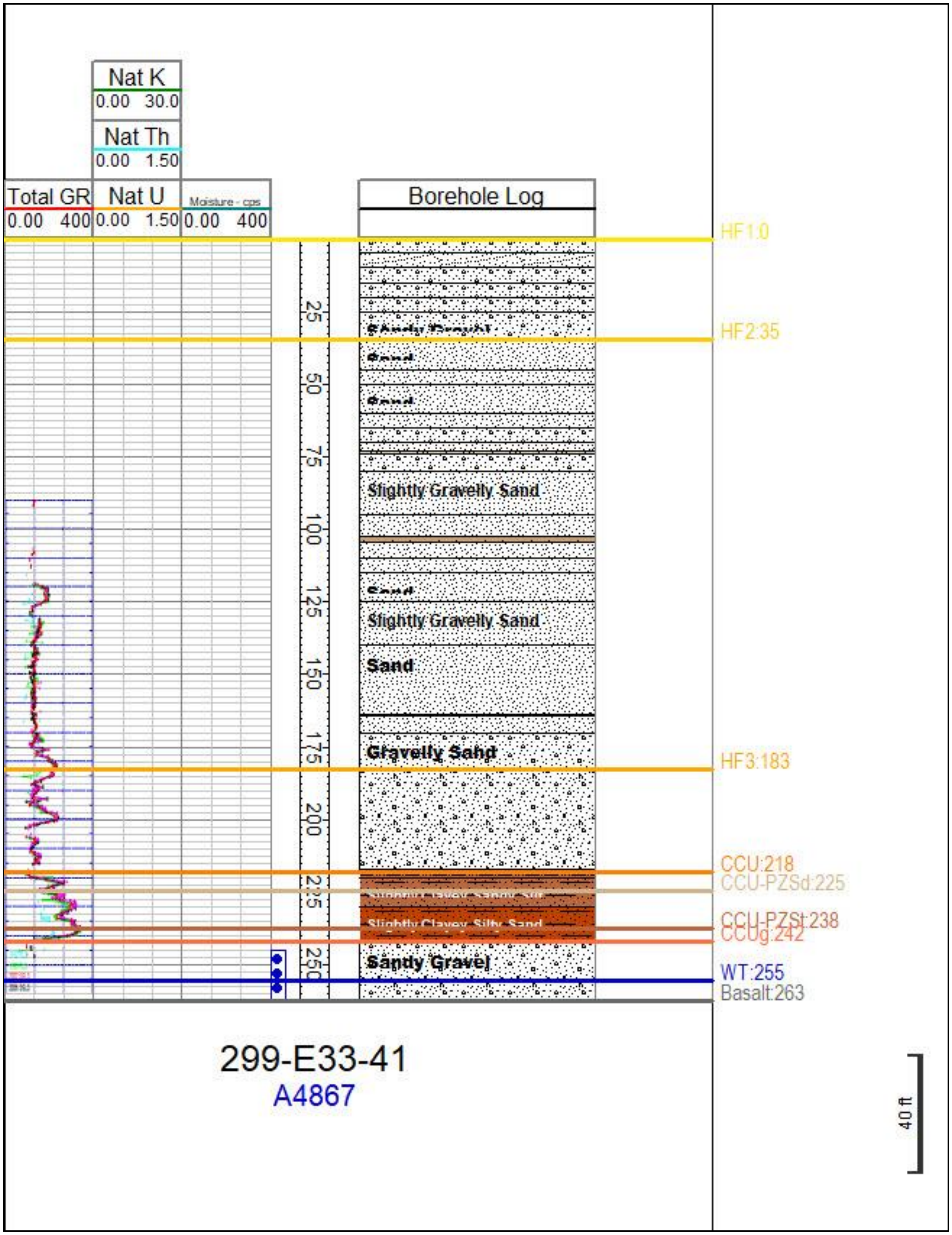

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Driller's Log
25
50
75
100
125
150
175
200
250
Sand and Gravel
Sand and Silt
Sand
HF1:0
HF2:39
HF3:195
CCU:223
CCU-PZSd:230
299-E33-27
A4851
40 ft

Figure A-12.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
HF1:0
HF2:35
Slightly Gravelly Sand
Sand
Slightly Gravelly Sand
Sand
Gravelly Sand
HF3:183
CCU:218
CCU-PZSd:225
CCU-PZSt:238
CCUg:242
Sandy Gravel
WT:255
Basalt:263
25
50
75
100
125
150
175
200
225
250
299-E33-41
A4867
40 ft

Figure A-13.

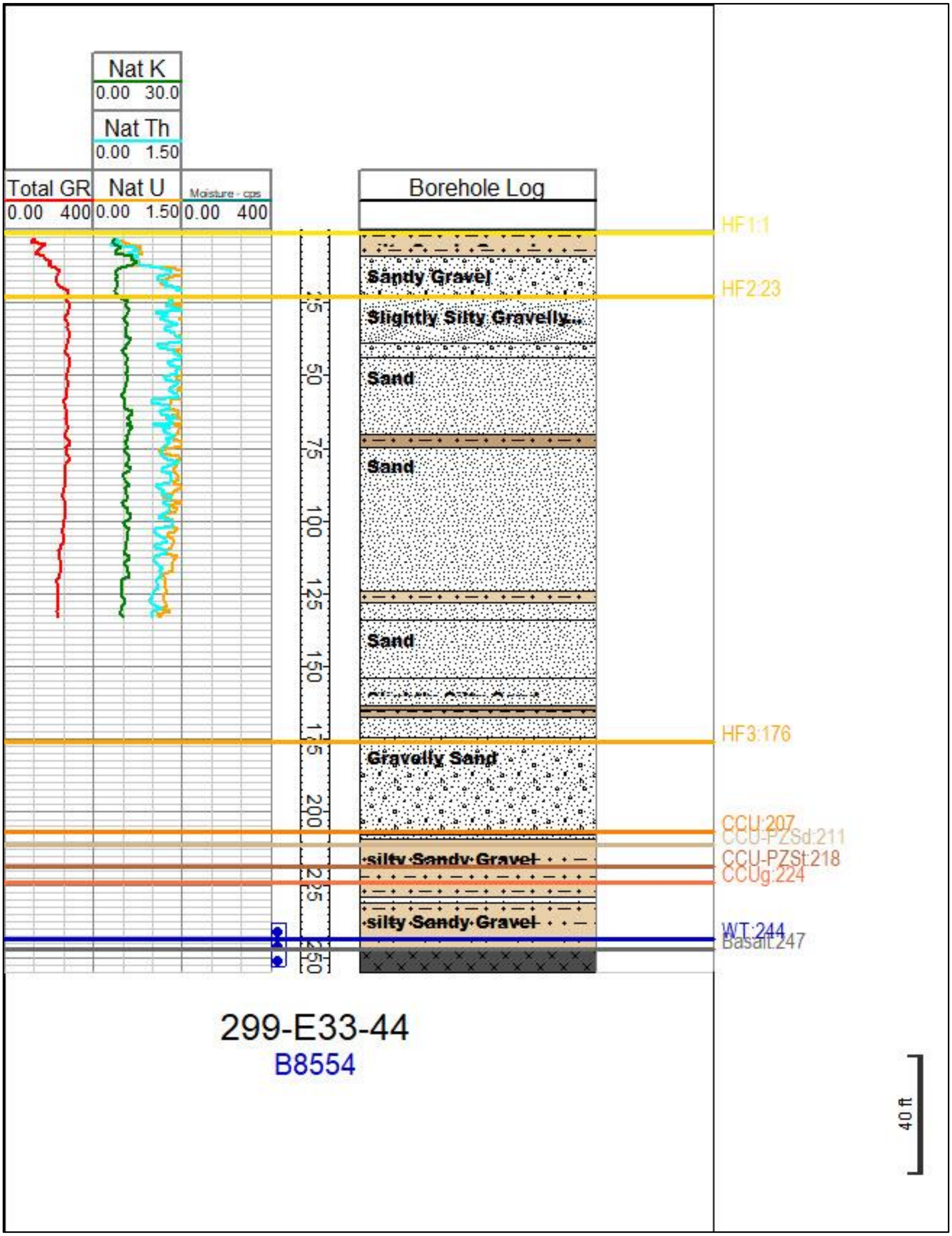

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Sandy Gravel
Slightly Silty Gravelly...
Sand
Sand
Sand
Gravelly Sand
silty Sandy Gravel
silty Sandy Gravel
25
50
75
100
125
150
175
200
225
250
HF1:1
HF2:23
HF3:176
CCU:207
CCU-PZSd:211
CCU-PZSt:218
CCUg:224
WT:244
Basalt:247
299-E33-44
B8554
40 ft

Figure A-14.

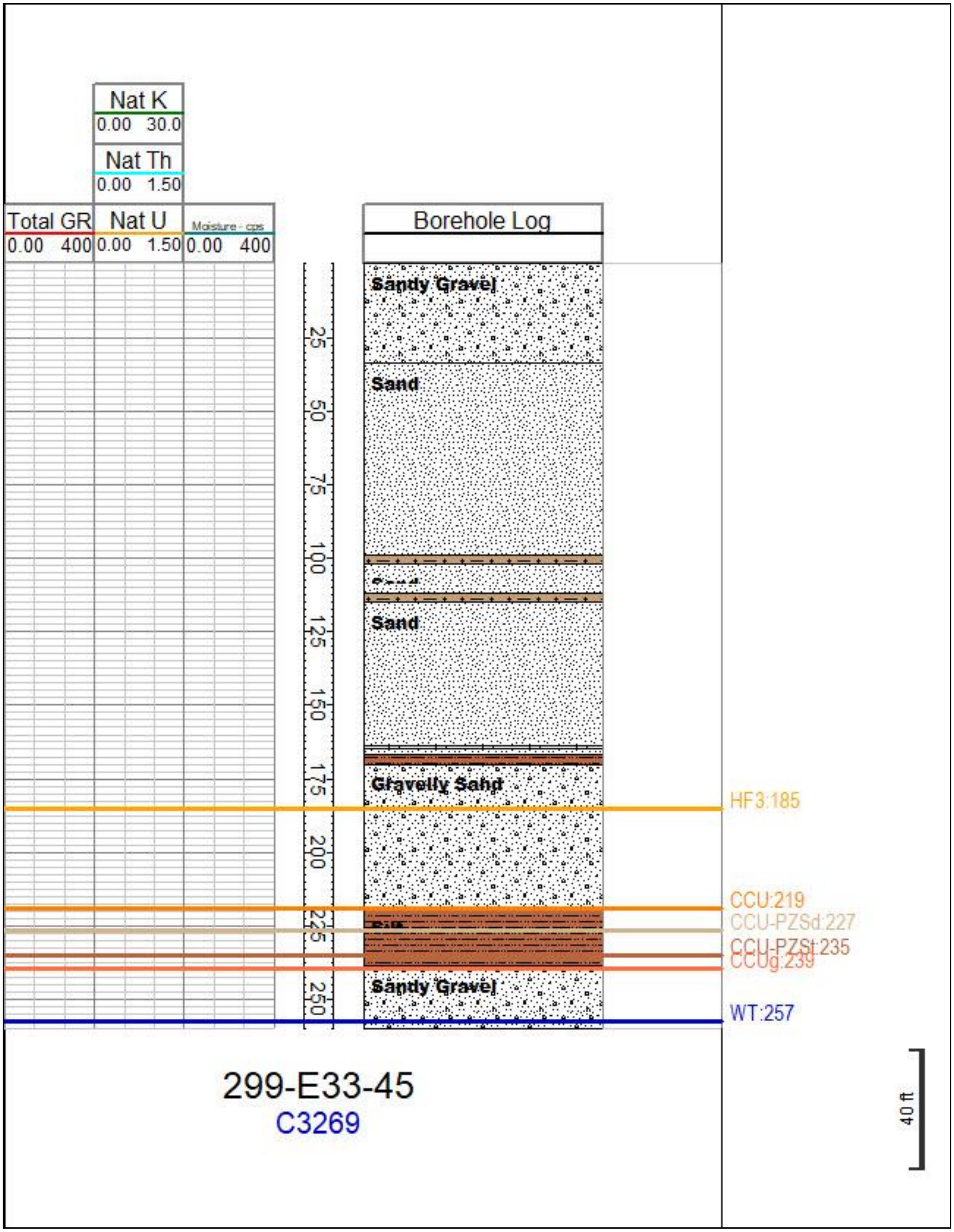

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Sandy Gravel
Sand
Sand
Gravelly Sand
Sandy Gravel
25
50
75
100
125
150
175
200
225
250
HF3:185
CCU:219
CCU-PZSd:227
CCU-PZSt:235
CCUg:239
WT:257
299-E33-45
C3269
40 ft

Figure A-15.

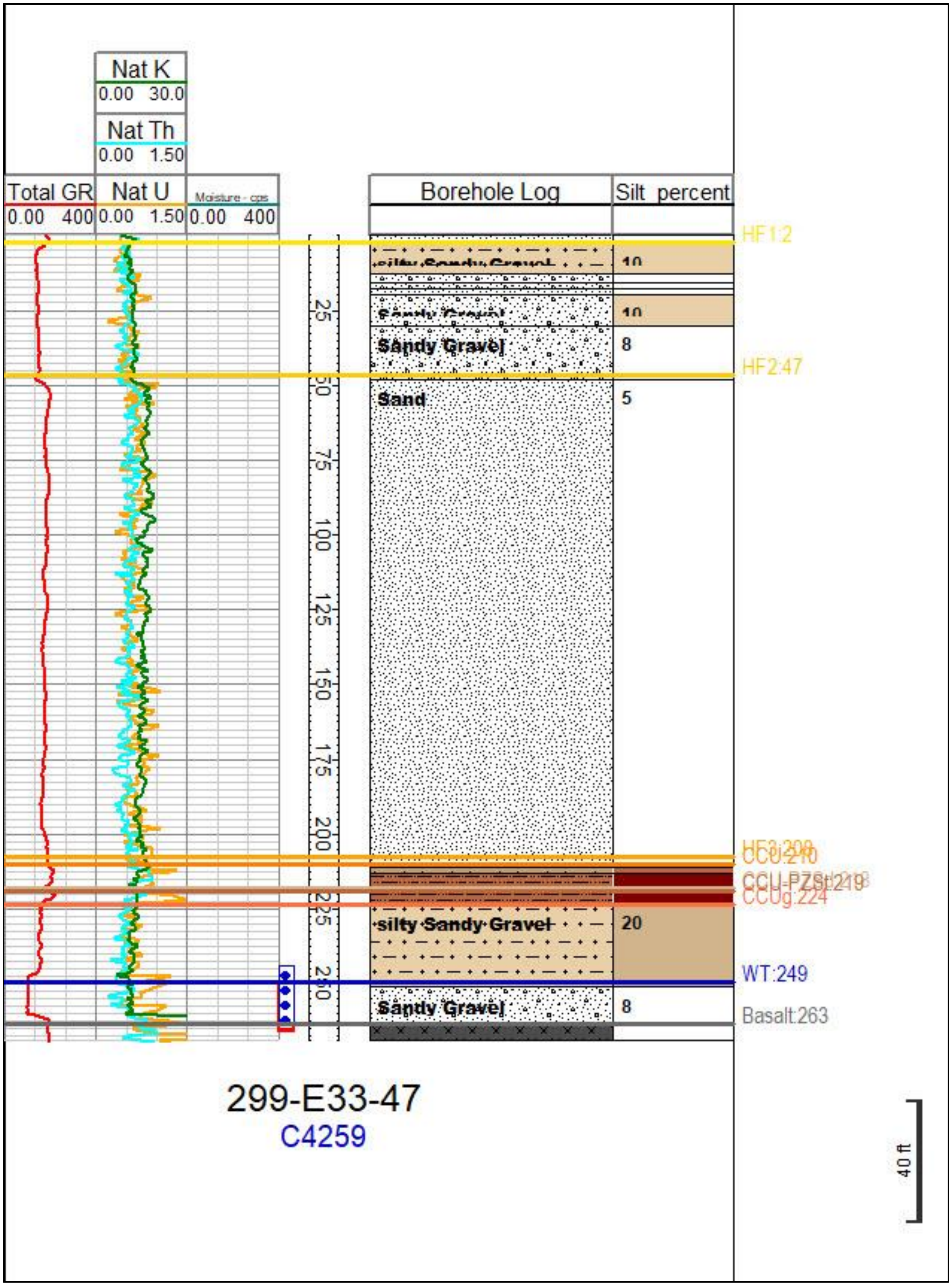

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:2
silty Sandy Gravel
10
Sandy Gravel
10
Sandy Gravel
8
HF2:47
Sand
5
25
50
75
100
125
150
175
200
225
250
HF3:209
CCU:210
CCU-PZSt:219
CCUg:224
silty Sandy Gravel
20
WT:249
Sandy Gravel
8
Basalt:263
299-E33-47
C4259
40 ft

Figure A-16.

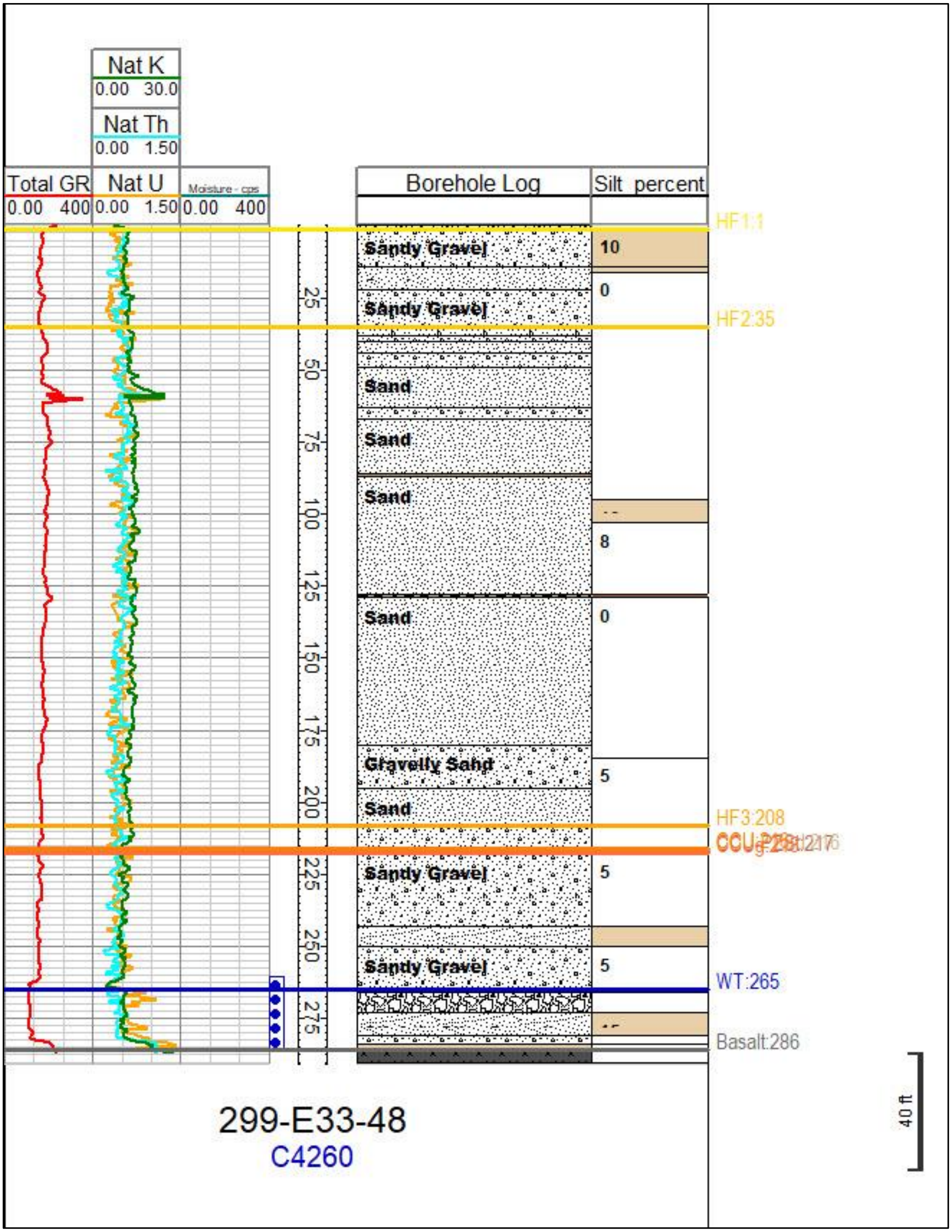
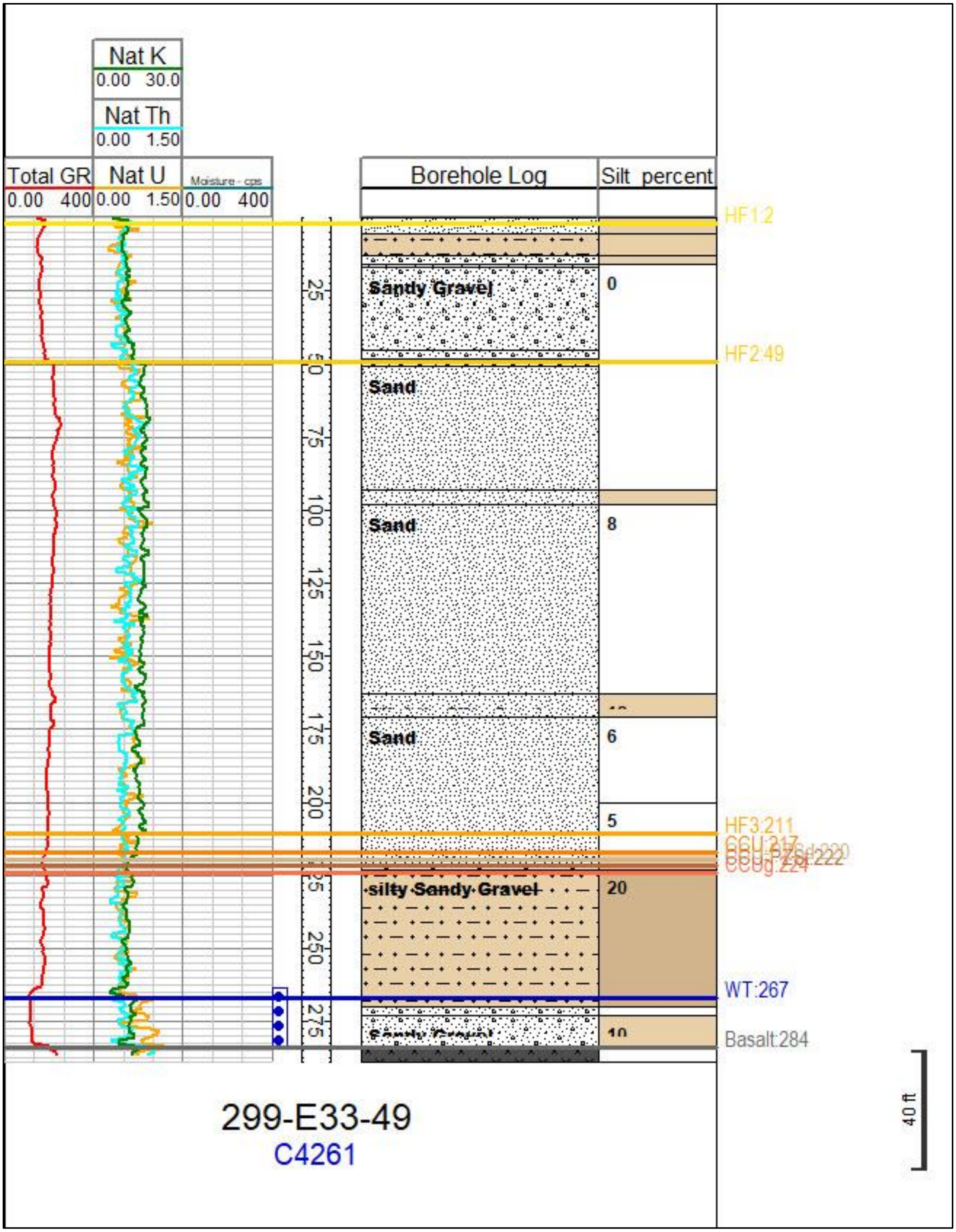
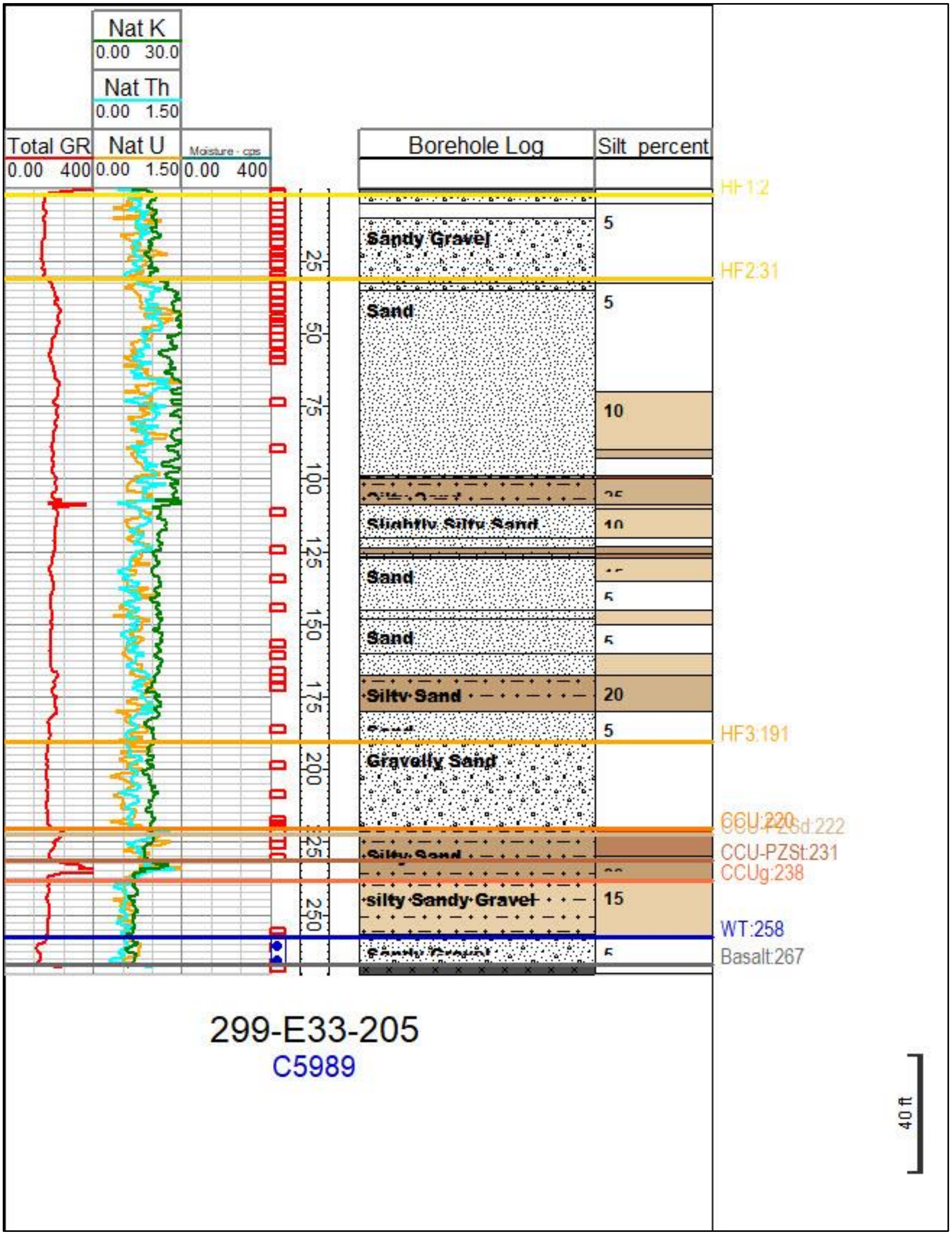

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:1
Sandy Gravel
10
0
Sandy Gravel
HF2:35
Sand
Sand
Sand
8
Sand
0
Gravelly Sand
5
Sand
HF3:208
Sandy Gravel
5
Sandy Gravel
5
WT:265
Basalt:286
25
50
75
100
125
150
175
200
225
250
275
299-E33-48
C4260
40 ft

Figure A-17.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:2
Sandy Gravel
0
HF2:49
Sand
Sand
8
Sand
6
5
HF3:211
silty Sandy Gravel
20
WT:267
Basalt:284
25
50
75
100
125
150
175
200
225
250
275
40 ft
299-E33-49
C4261

Figure A-18.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:2
Sandy Gravel
5
25
HF2:31
Sand
5
50
75
10
100
Slightly Silty Sand
125
Sand
5
150
Sand
5
175
Silty Sand
20
Gravelly Sand
200
HF3:191
CCU:220
CCU-PZSd:222
CCU-PZSt:231
CCUg:238
silty Sandy Gravel
15
250
WT:258
Basalt:267
299-E33-205
C5989
40 ft

Figure A-19.

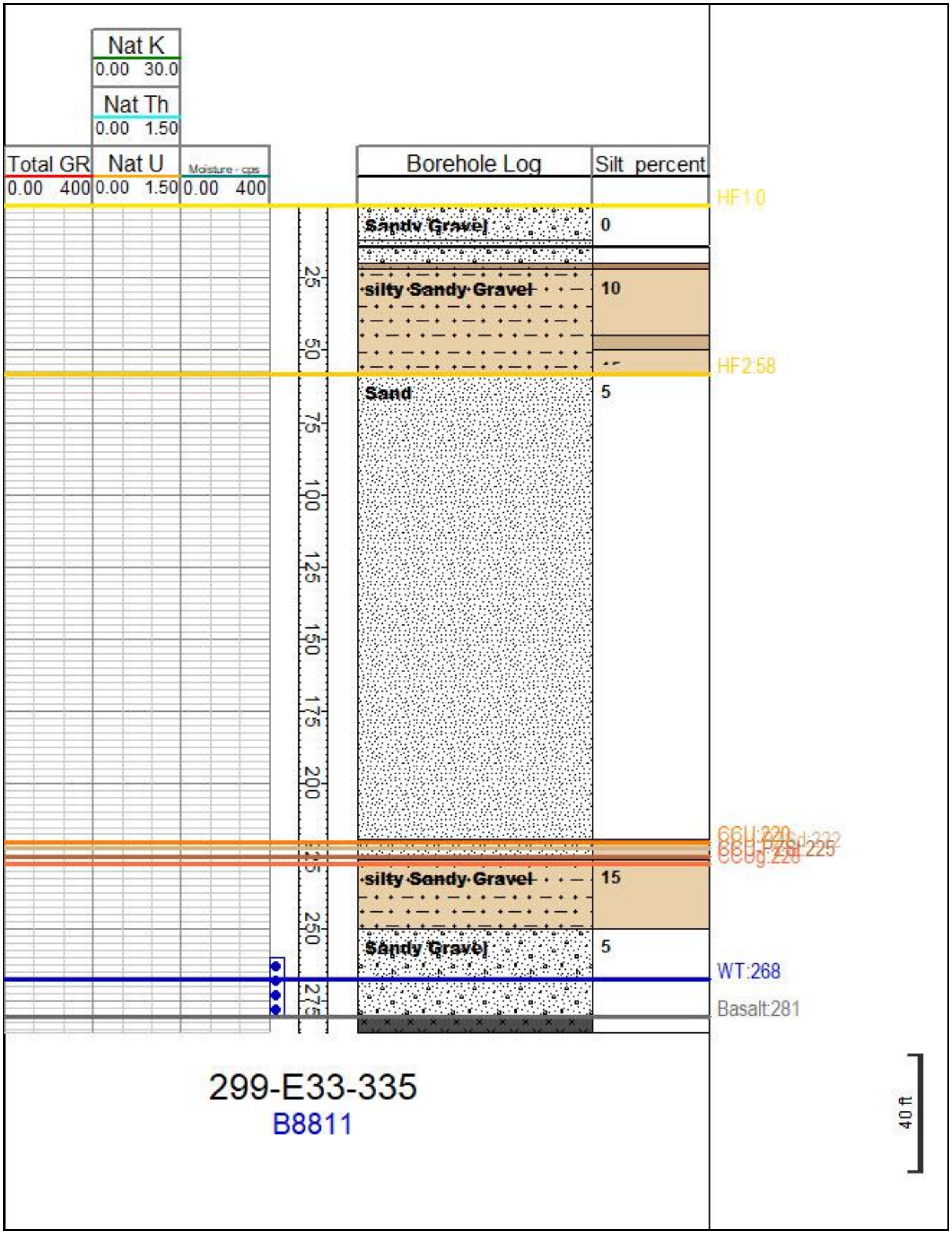

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:0
Sandy Gravel
0
silty Sandy Gravel
10
HF2:58
Sand
5
25
50
75
100
125
150
175
200
250
275
silty Sandy Gravel
15
Sandy Gravel
5
WT:268
Basalt:281
299-E33-335
B8811
40 ft

Figure A-20.

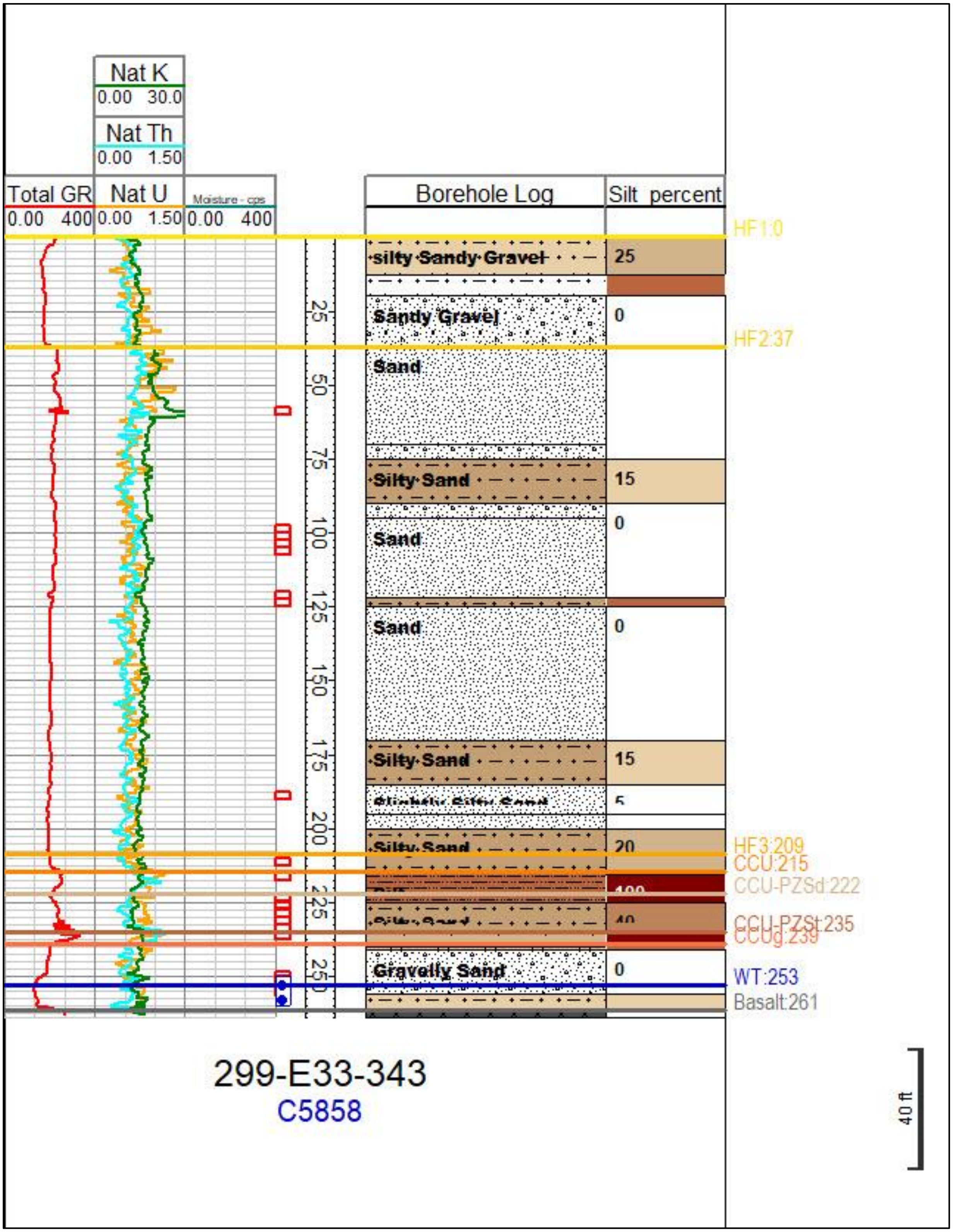
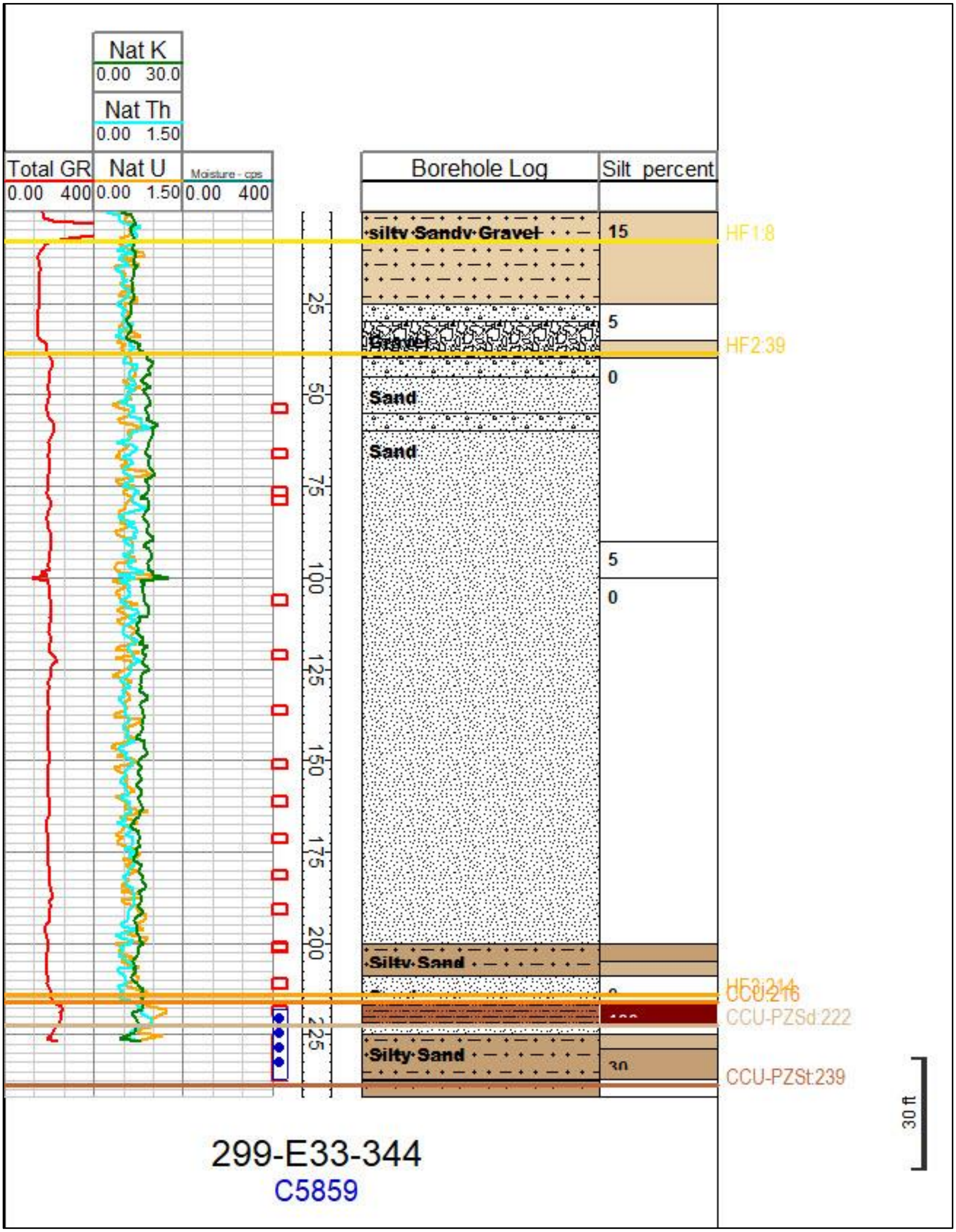

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
silty Sandy Gravel
25
Sandy Gravel
0
Sand
Silty Sand
15
0
Sand
Sand
0
Silty Sand
15
5
Silty Sand
20
Gravelly Sand
0
HF1:0
HF2:37
HF3:209
CCU:215
CCU-PZSd:222
CCU-PZSt:235
CCUg:239
WT:253
Basalt:261
25
50
75
100
125
150
175
200
225
250
299-E33-343
C5858
40 ft

Figure A-21.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
silty Sandy Gravel
15
HF1:8
25
Gravel
5
HF2:39
0
50
Sand
Sand
75
100
5
0
125
150
175
200
Silty Sand
HF3:214
CCU:216
CCU-PZSd:222
225
Silty Sand
CCU-PZSt:239
30 ft
299-E33-344
C5859

Figure A-22.

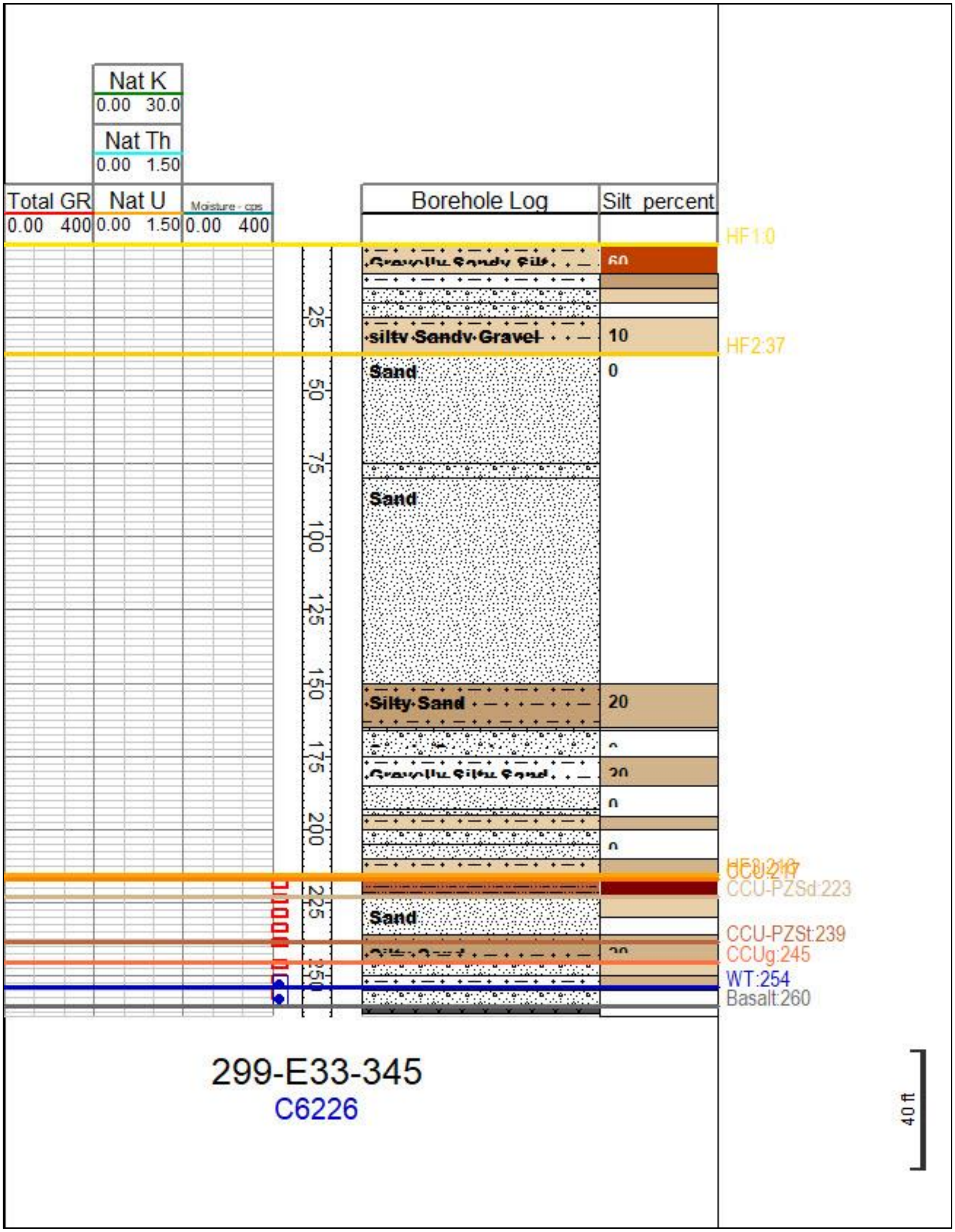

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:0
Gravelly Sandy Silt
60
silty Sandy Gravel
10
HF2:37
Sand
0
Sand
Silty Sand
20
Gravelly Silty Sand
20
Sand
CCU-PZSd:223
CCU-PZSt:239
CCUg:245
WT:254
Basalt:260
25
50
75
100
125
150
175
200
225
250
299-E33-345
C6226
40 ft

Figure A-23.

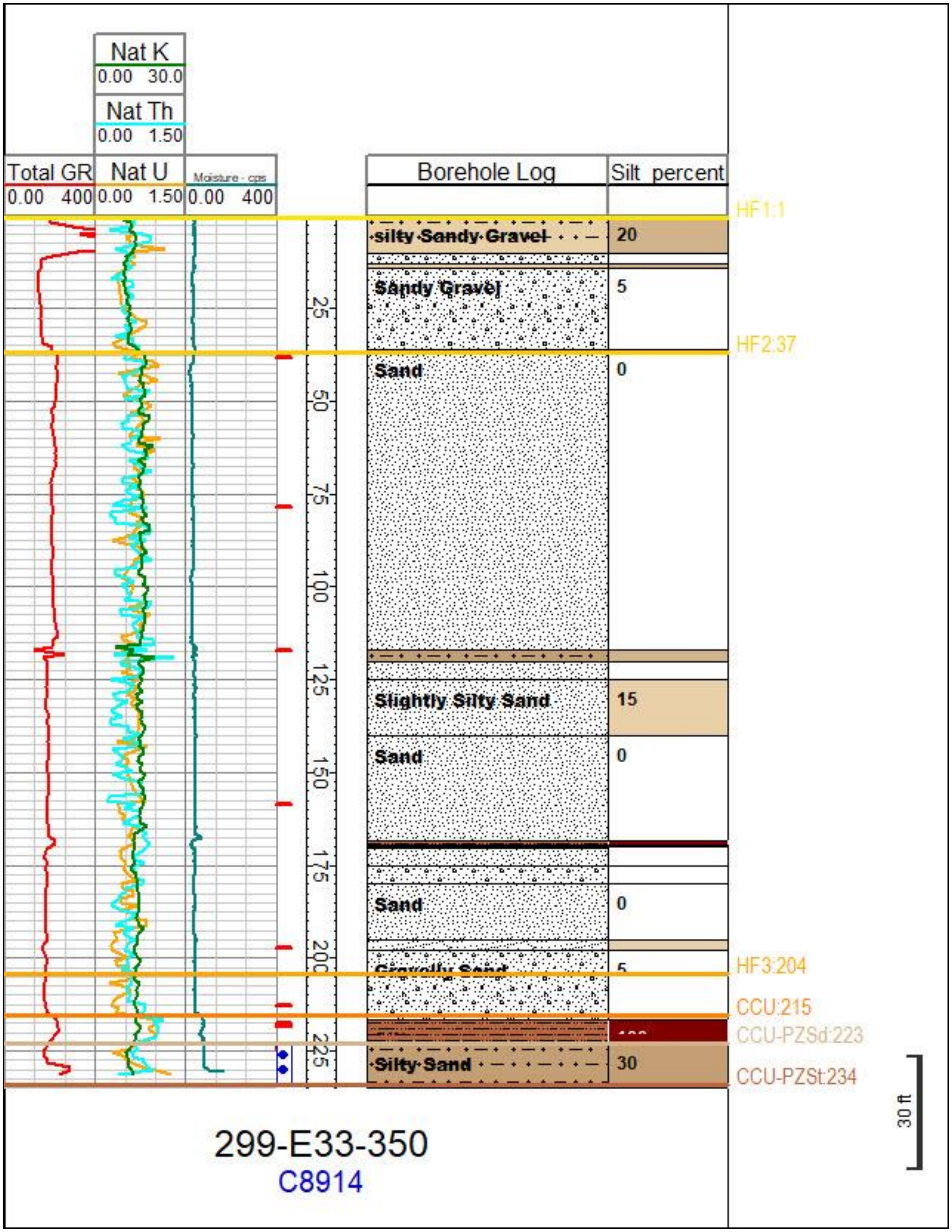
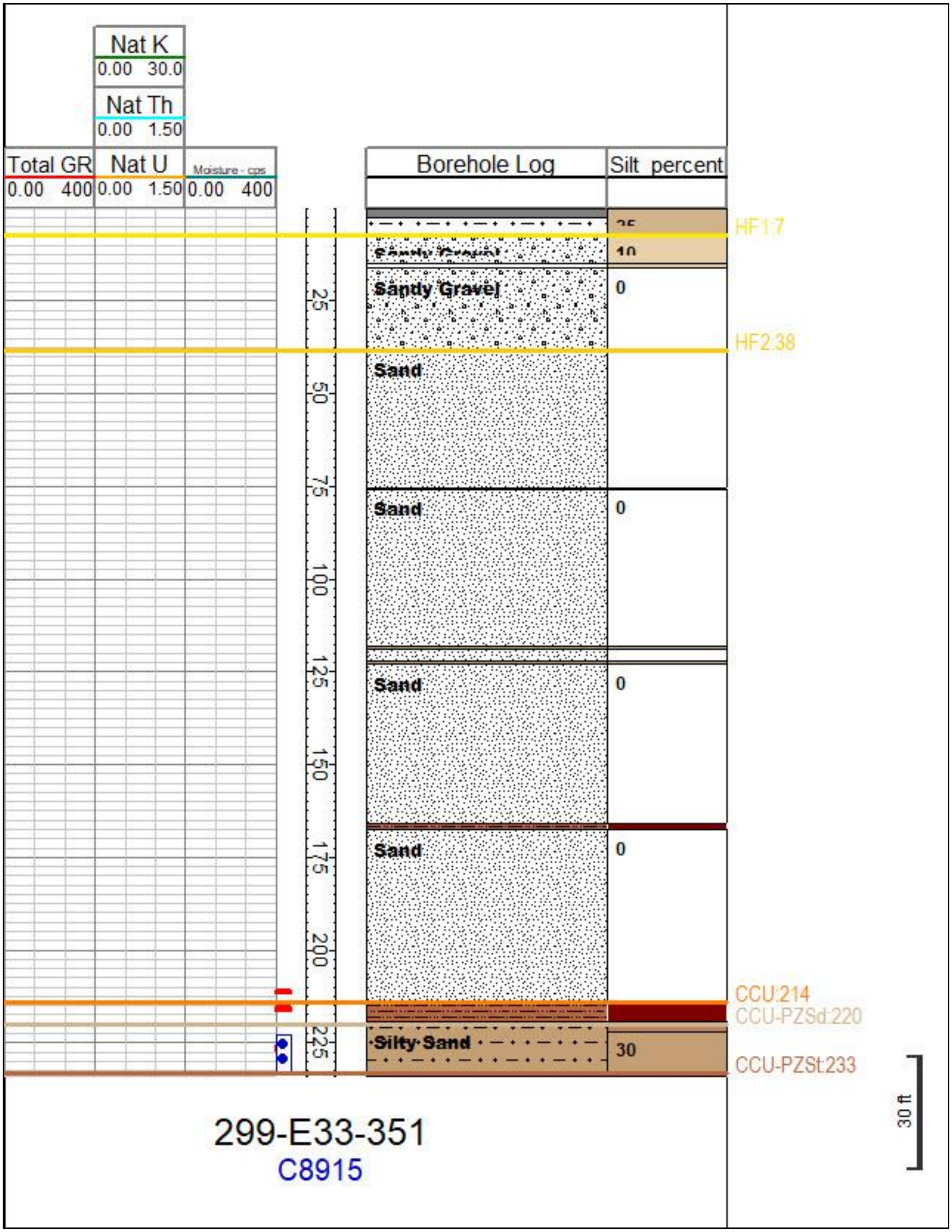

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
silty Sandy Gravel
20
Sandy Gravel
5
Sand
0
Slightly Silty Sand
15
Sand
0
Sand
0
5
Silty Sand
30
25
50
75
100
125
150
175
200
225
HF1:1
HF2:37
HF3:204
CCU:215
CCU-PZSd:223
CCU-PZSt:234
30 ft
299-E33-350
C8914

Figure A-24.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:7
Sandy Gravel
10
Sandy Gravel
0
HF2:38
Sand
Sand
0
Sand
0
Sand
0
CCU:214
CCU-PZSd:220
Silty Sand
30
CCU-PZSt:233
25
50
75
100
125
150
175
200
225
30 ft
299-E33-351
C8915

Figure A-25.

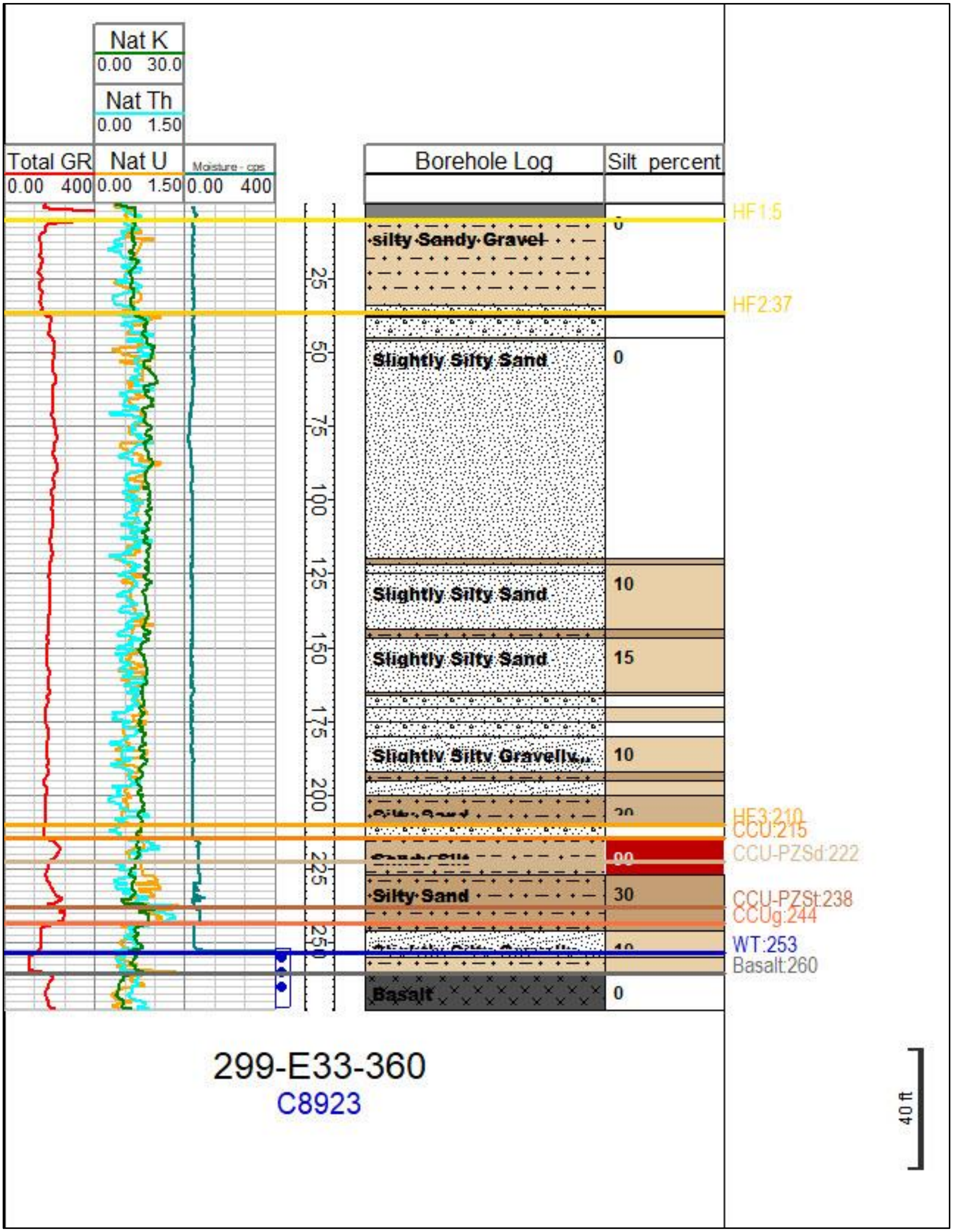
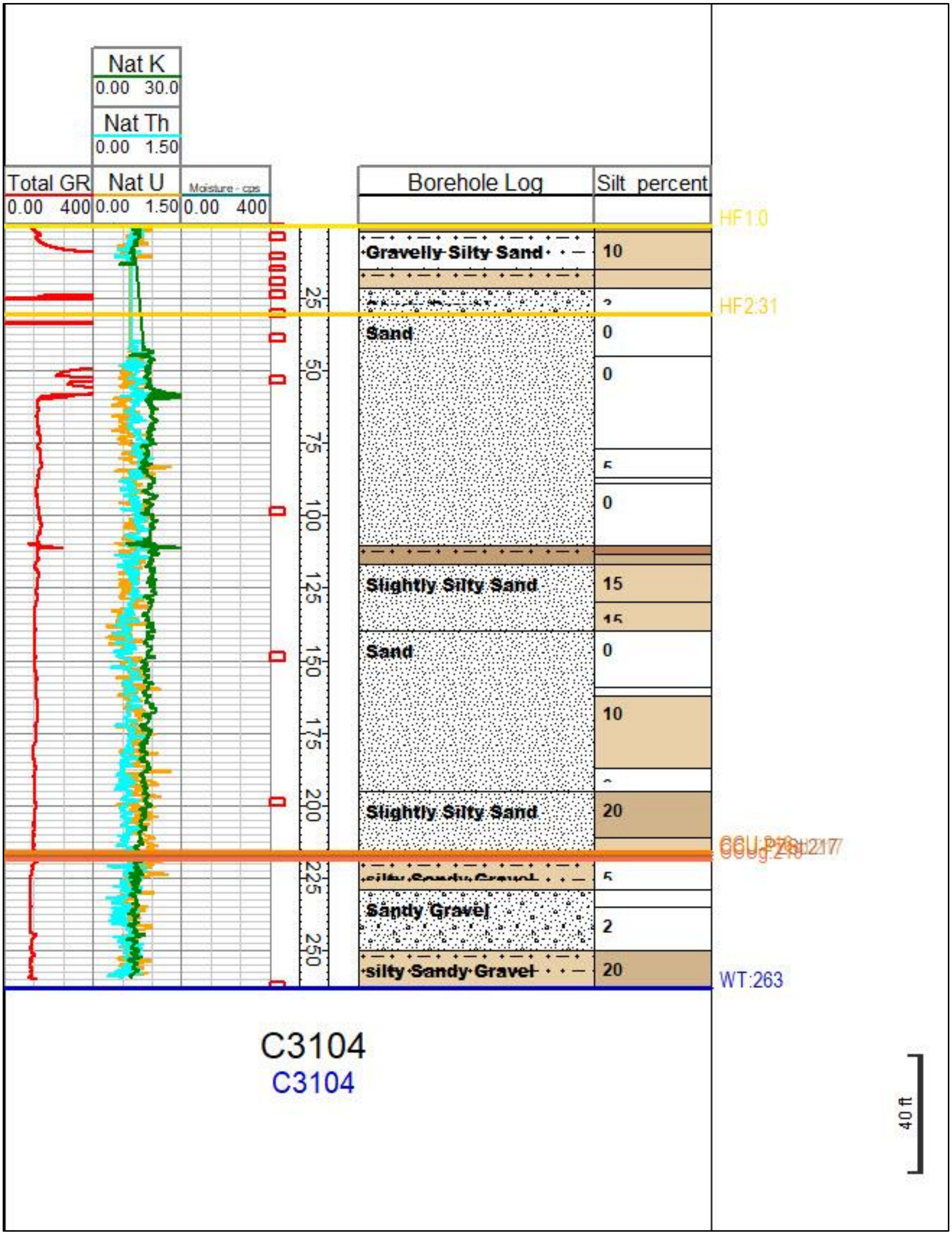

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:5
silty Sandy Gravel
0
HF2:37
Slightly Silty Sand
0
Slightly Silty Sand
10
Slightly Silty Sand
15
Slightly Silty Gravelly...
10
HF3:210
CCU:215
CCU-PZSd:222
Silty Sand
30
CCU-PZSt:238
CCUg:244
WT:253
Basalt:260
Basalt
0
25
50
75
100
125
150
175
200
225
250
299-E33-360
C8923
40 ft

Figure A-26.



Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Borehole Log
Silt percent
HF1:0
HF2:31
Gravelly Silty Sand
10
Sand
0
0
0
Slightly Silty Sand
15
Sand
0
10
Slightly Silty Sand
20
5
Sandy Gravel
2
silty Sandy Gravel
20
WT:263
25
50
75
100
125
150
175
200
225
250
C3104
C3104
40 ft

Figure A-27.

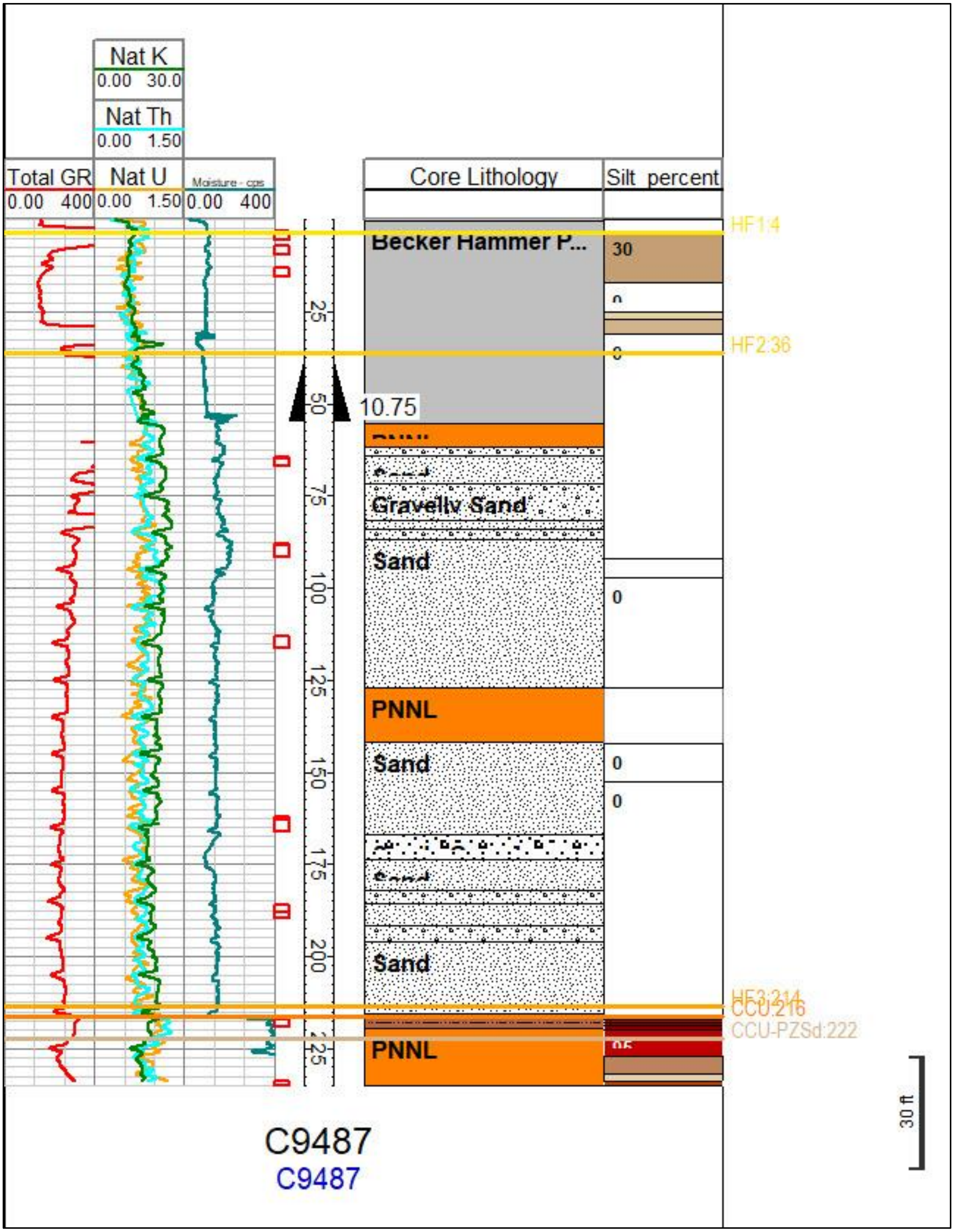

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Core Lithology
Silt percent
Becker Hammer P...
PNNL
Gravelly Sand
Sand
HF1:4
HF2:36
HF3:214
CCU:216
CCU-PZSd:222
10.75
30
0
25
50
75
100
125
150
175
200
225
30 ft
C9487
C9487

Figure A-28.

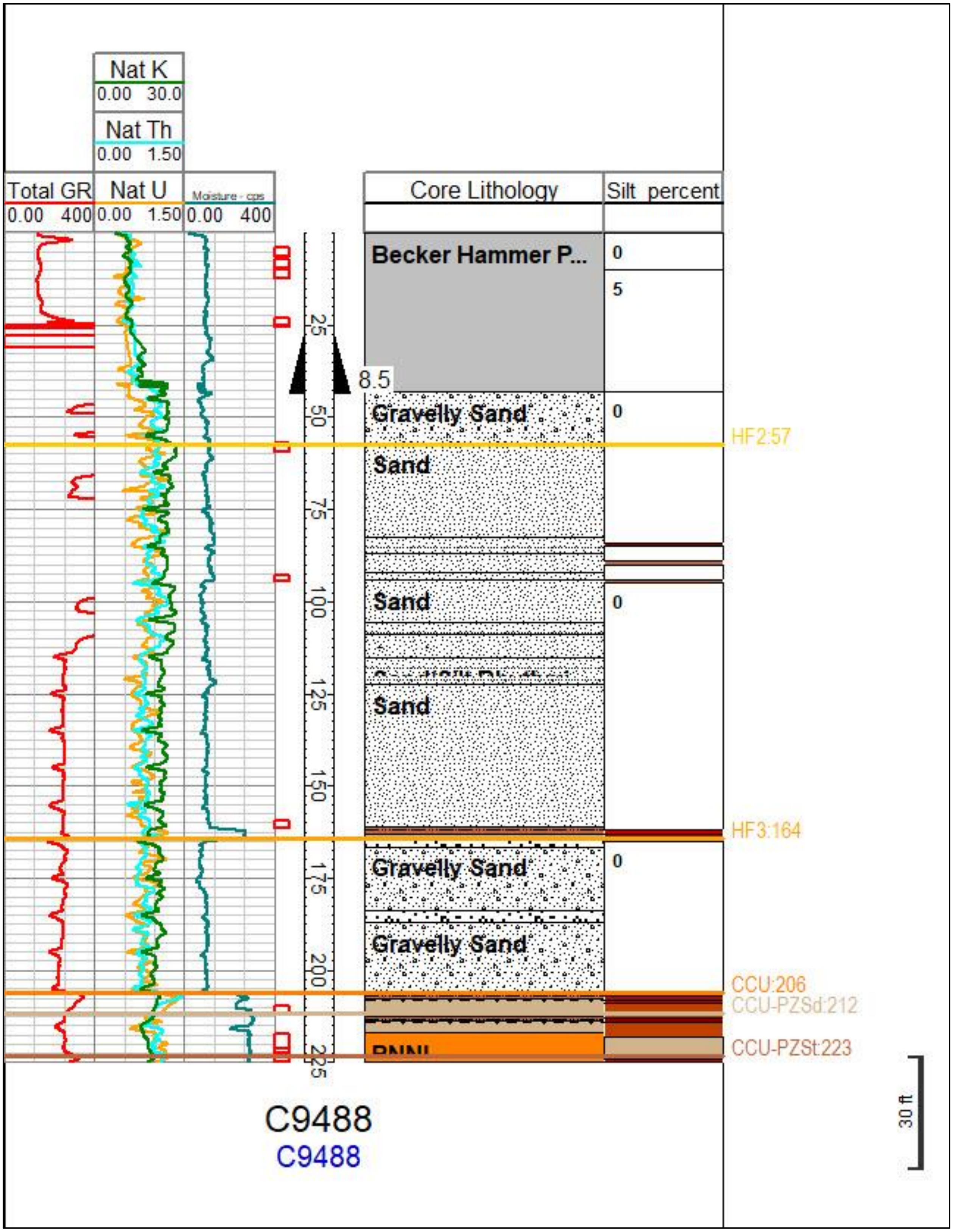

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
Core Lithology
Silt percent
Becker Hammer P...
0
5
8.5
Gravelly Sand
0
HF2:57
Sand
Sand
0
Sand
HF3:164
Gravelly Sand
0
Gravelly Sand
CCU:206
CCU-PZSd:212
CCU-PZSt:223
25
50
75
100
125
150
175
200
225
C9488
C9488
30 ft

Figure A-29.

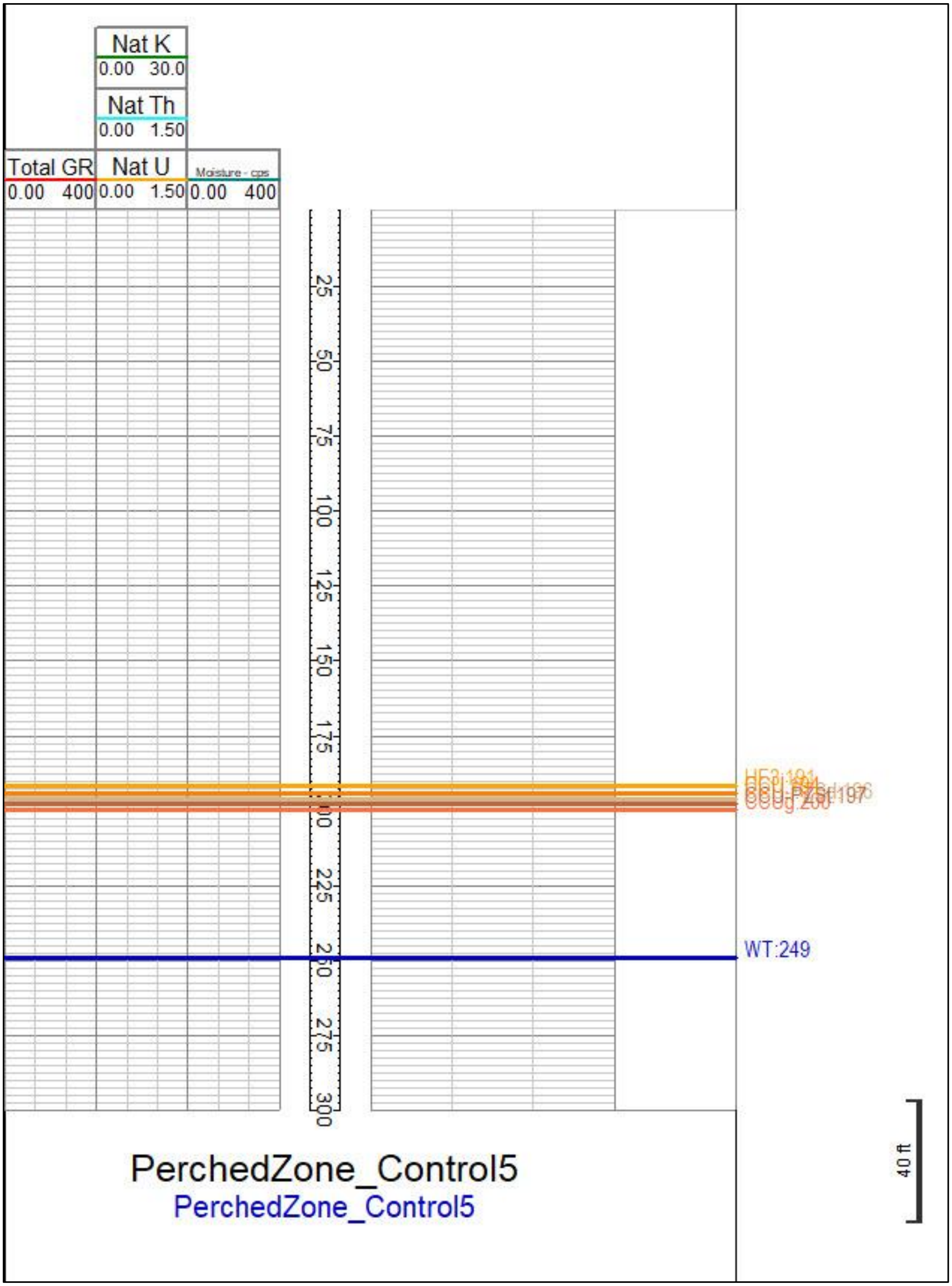

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
25
50
75
100
125
150
175
225
250
275
300
WT:249
40 ft
PerchedZone_Control5
PerchedZone_Control5

Figure A-30.

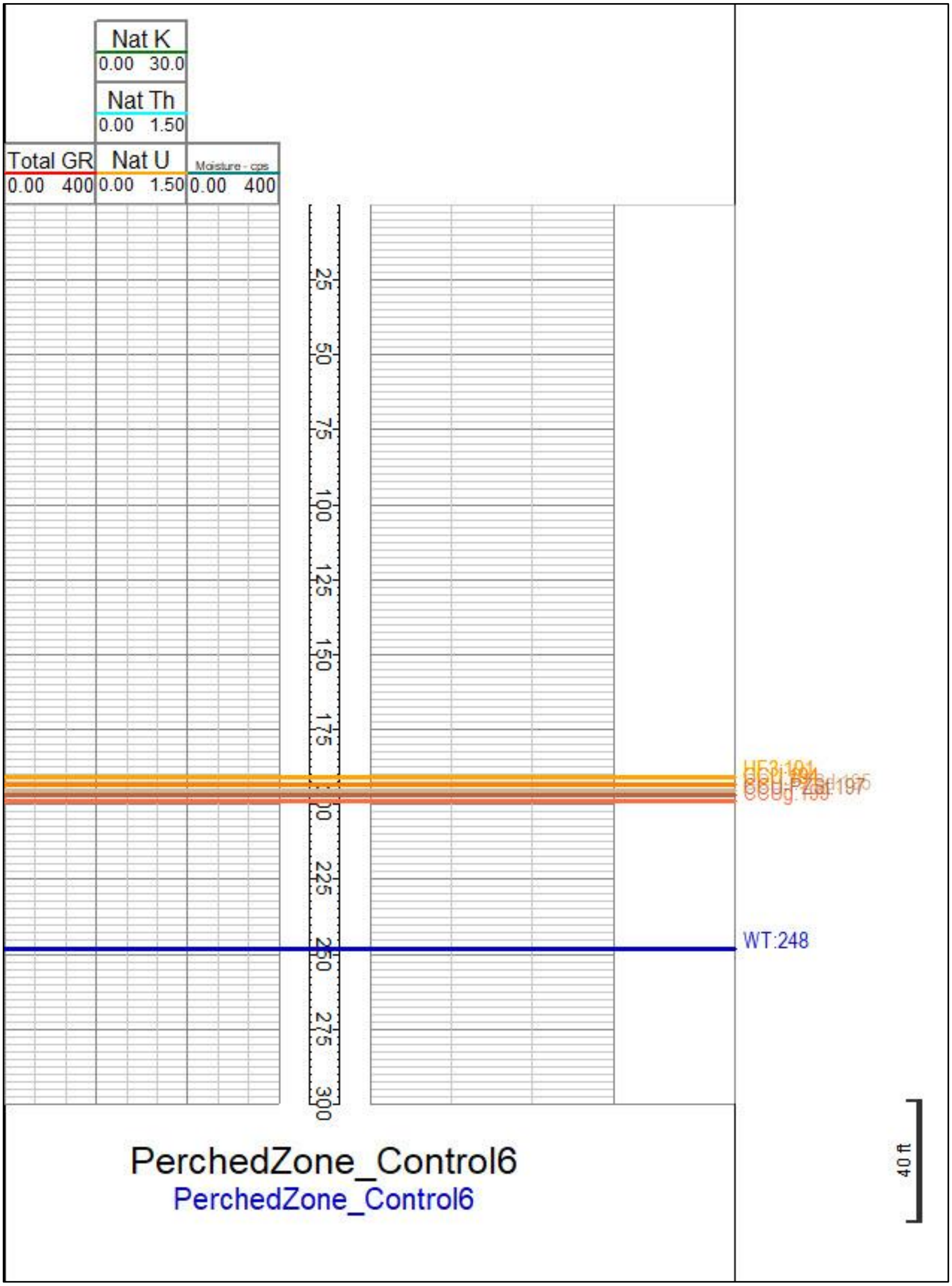

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
25
50
75
100
125
150
175
225
250
275
300
WT:248
40 ft
PerchedZone_Control6
PerchedZone_Control6

Figure A-31.

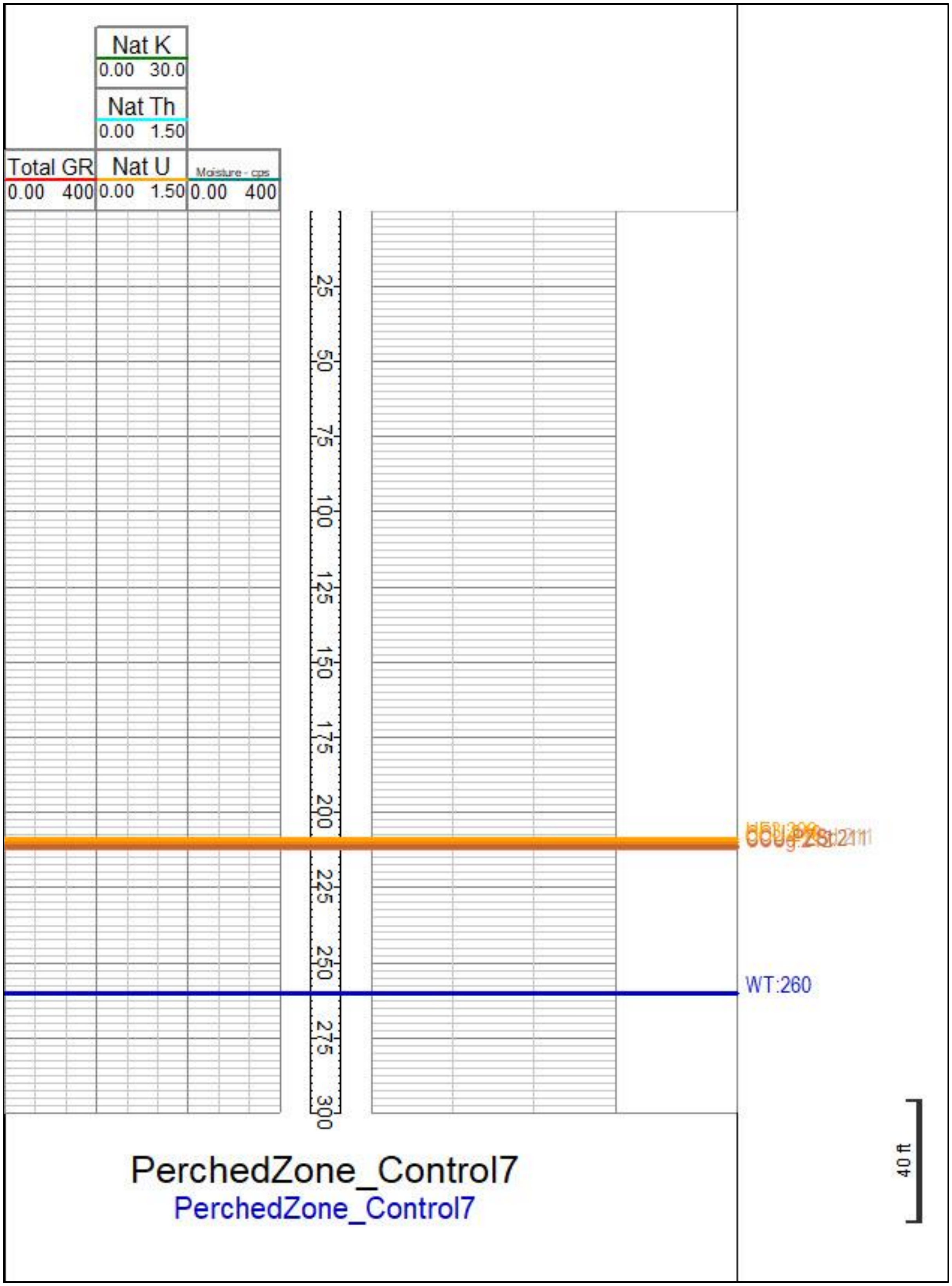

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
25
50
75
100
125
150
175
200
225
250
275
300
WT:260
PerchedZone_Control7
PerchedZone_Control7
40 ft

Figure A-32.

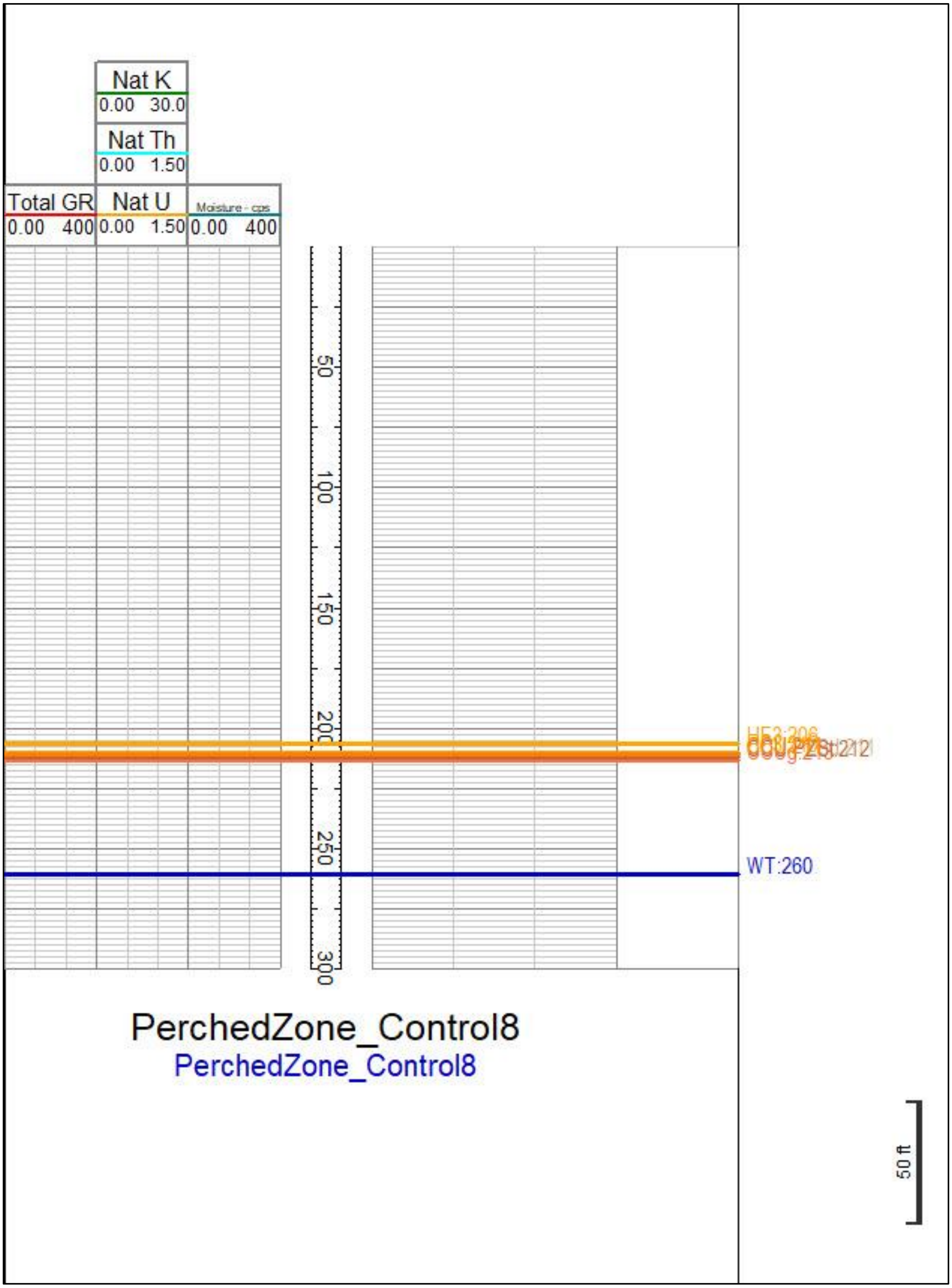

Nat K
0.00 30.0
Nat Th
0.00 1.50
Total GR
0.00 400
Nat U
0.00 1.50
Moisture - cps
0.00 400
50
100
150
200
250
300
WT:260
PerchedZone_Control8
PerchedZone_Control8
50 ft

Figure A-33.

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Appendix B

Software Installation and Checkout Form

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: Kingdom Geology Software Version No.: 2016.1

EXECUTABLE INFORMATION:

2. Executable Name (include path):
   C:\Program Files\IHS Markit\KingdomSuite\TKS 2018\Kingdom.exe
3. Executable Size (bytes): 824 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Vendor supplied
5. Operating System (include version number):
   Windows (Vendor supplied)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   WF34759
7. Operating System (include version number):
   Windows 10
8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:
   U:\Kingdom\Kingdom Evaluation\Quality Assurance\ITC 06112019
10. Procedure(s):
    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan
11. Libraries:
    N/A
12. Input Files:
    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan
13. Output Files:
    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan
14. Test Cases:
    ITC-1
15. Test Case Results:
    Pass
16. Test Performed By: Sarah Springer
17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory
18. Disposition (include HISI update):
    Accepted; installation added to Hanford Off-Site user list

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Kingdom Geology — Software Version No.: 2016.1

Prepared By:

	Software Owner (Signature)	Print	Date
19.	[signature]	WE Nichols	11-Jun 2019

20. Test Personnel:

Sign	Print	Date
[signature]	SD Springer	06-11-2019

Approved By:

	Software SME (Signature)	Print	Date
21.		N/R per SMP	