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Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis

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EXECUTIVE SUMMARY

This model package report documents the development of the three-dimensional geologic framework model for the 241-A and 241-AX Tank Farms, collectively referred to as Waste Management Area A-AX. The three-dimensional geologic framework model forms a primary input in development of numerical models for fate and transport calculations that are integral parts of the ongoing performance assessment studies of residual waste impacts from the single-shell tanks.

This report discusses the approach for the conceptualization of the geologic framework beneath Waste Management Area A-AX including alternative conceptual models, identification of key boreholes within the geologic framework model domain, interpretation of borehole logs (based on geologic descriptions and geophysical logs) to identify the major geologic units and interpolate unit surfaces using Kingdom® Geology[1] modeling software, and employing Tecplot 360®[2] to develop three-dimensional geologic framework models and identify significant potential sources of uncertainty with the construction of three-dimensional geologic framework models.

The geologic model development effort is based on evaluation of 43 deep boreholes (≥150 ft in depth) and provides an estimate of extent and thicknesses of various lithostratigraphic units for Waste Management Area A-AX. Based on the quality of data and information that was available, the development effort identified two geologic alternative conceptual models (ACMs) called ACM 1 and ACM 2. ACM 1 was developed using only the best-quality subsurface geologic data based on 29 of the 43 boreholes, while ACM 2 was developed using subsurface geologic data from all 43 deep boreholes. In addition to using the entire borehole dataset, ACM 2 also considers differentiation of the uppermost Cold Creek Unit by incorporating an estimation of the extent and thickness of Cold Creek silt and sand beds.

[1] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.
[2] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

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TERMS

2D	two-dimensional
3D	three-dimensional
ACM	alternative conceptual model
bgs	below ground surface
BP	Before Present
CCU	Cold Creek Unit
CCUg	Cold Creek Unit gravels
CCUs	Cold Creek Unit sand
CCUu	Cold Creek Unit undifferentiated
CCUz	Cold Creek Unit silt
CHPRC	CH2M HILL Plateau Remediation Company
CPM	Central Plateau Model
DOE	U.S. Department of Energy
EMMA	Environmental Model Management Archive
FEPs	Features, Events, and Processes
GFM	geologic framework model
GL	ground level
HCL	hydrochloric acid
HEIS	Hanford Environmental Information System
HF1	Hanford formation Unit 1
HF2	Hanford formation Unit 2
HF3	Hanford formation Unit 3

HFFACO	Hanford Federal Facility Agreement and Consent Order
HISI	Hanford Information System Inventory
LiDAR	light detection and ranging
Ma	one million years
MPR	model package report
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
PA	performance assessment
PK	probability kriging
PUREX	Plutonium Uranium Extraction (Plant)
RCRA	*Resource Conservation and Recovery Act of 1976*
Rlm	Ringold Formation Wooded Island Lower Mud Unit
Rwia	Ringold Formation Wooded Island Unit A
Rwie	Ringold Formation Wooded Island Unit E
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases©
TFEM	triangular finite element mesh
TOB	top of basalt
WIDS	Waste Information Data System
WMA	Waste Management Area

1.0 PURPOSE

The purpose of this report is to document the information and methods employed to construct two alternative three-dimensional (3D) geologic framework models (GFMs) as a part of the conceptual site model established in the vicinity of Waste Management Area (WMA) A-AX. The GFMs present our best current interpretation of the 3D geometry of the suprabasalt sediment geologic units beneath the WMA A-AX region. The domain of the WMA A-AX GFMs is chosen to extend beyond the WMA A-AX fence line in order to connect to the broader, regional GFMs described in other investigations.

The WMA A-AX GFMs are based on the lithostratigraphic information and geophysical data from selected interpreted boreholes and wells and use this information and data to identify and spatially interpolate distribution and thicknesses of the geologic units in a manner consistent with the Hanford Site stratigraphic nomenclature. These data are used to create the WMA A-AX 3D GFMs by interpolating geologic unit picks at boreholes and wells into two–dimensional (2D) surfaces using Kingdom® Geology[3] software followed by generating geologic unit volumes from those surfaces using Tecplot 360®[4] to construct 3D models.

1.1 NEED

The GFMs developed in this effort are needed to provide a technical basis for the interpretation of the local hydrogeologic conditions represented in flow and transport models that are used at WMA A-AX to assess human health and environmental impacts from waste left at closure. The conceptual model for the site geologic setting is based on local-scale borehole and well data and information. The 3D GFMs are developed in such a manner that they can be implemented directly in a 3D numerical process model used for modeling flow and contaminant transport in the WMA A-AX region.

The flow and transport modeling needs to be carried out as part of a performance assessment (PA) in order to meet the requirements for assessment of radiological impacts of waste residuals in a closed, radioactive waste tank under the U.S. Department of Energy (DOE) O 435.1, *Radioactive Waste Management* and evaluation of hazardous chemical impacts for the same wastes outlined in Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA).

1.2 BACKGROUND

WMA A-AX comprises the 241-A and 241-AX Tank Farms and is located within in the 200 East Area of the Central Plateau of the Hanford Site. The 241-A Tank Farm (A Farm) and 241-AX Tank Farm (AX Farm) were constructed between 1953 and 1955 and between 1963 and 1965, respectively. The WMA A-AX tank farms are surrounded by several other double-shell tank

[3] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.
[4] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

farms within the A Complex, and single-shell tank (SST) Farm 241-C (C Farm) is located nearby to the northwest. WMA A-AX includes catch tanks, diversion boxes, valve pits, pipelines, French drains and unplanned release sites. Numerous liquid discharge facilities used nearby at various times (cribs, trenches, ditches, septic systems, etc.) surround the WMA.

The tanks in both A and AX Farms were designed for the storage of boiling waste generated from irradiated fuel reprocessing at the 202-A Plutonium Uranium Extraction (PUREX) Plant. A Farm contains six 75-ft diameter, nominally 1,000,000-gal capacity SSTs that consist of a carbon steel liner inside a concrete tank. AX Farm contains four such SSTs of a later design. A and AX Farms were placed in service in 1955 and 1965, respectively, and both were used to store and transfer waste until mid-1980.

In brief, as of 2018, plans for the future closure of A and AX Farms call for retrieval of wastes remaining in the SSTs (mostly sludge and saltcake solids) to the maximum extent practicable, grouting the residual wastes and interior volume of the SSTs, and construction of a surficial barrier over the tank farms. The PA uses numerical models to evaluate the ability of the closed WMA to contain the residual waste and prevent unacceptable human exposures due to release and migration of contaminants for at least a period of 1,000 years. The first step in constructing the numerical models, to be discussed in separate model package reports (MPRs), is to develop the GFM representing the natural system in which the WMA resides.

1.3 DATA SOURCES

Hanford Site documents that describe the most current geologic and hydrologic interpretations relevant to WMA A-AX are as follows.

- RPP-ENV-58578, Rev. 1, "*Summary of the Natural System at Waste Management Area A/AX*." Revised in parallel with preparation of this report, this document provides a description of the conceptual site model for the area in the immediate vicinity of WMA A-AX tank farms, including the geologic setting.

- PNNL-15955, Rev. 1, "*Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*." This report provides information on the geologic settings of the various SST farms (including WMA A-AX) of the Central Plateau.

- PNNL-12261, Rev. 0, "*Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*." This report provides information on the geologic setting of the Central Plateau and 200 East Area where WMA A-AX is located.

- ECF-HANFORD-13-0029, Rev. 4, "*Development of the Hanford South Geologic Framework Model, Hanford Site, Washington Fiscal Year 2016 Update*." This report provides data and information related to the most current GFM of the area. Borehole information for interpolating major geologic units beneath WMA A-AX (Hanford South)

is included, and it outlines the detailed method for construction of GFMs using Leapfrog®[5] Geo.

- The Hanford Environmental Information System (HEIS) is the controlled database from which borehole geologic and geophysical logs used in WMA A-AX GFM geologic interpretations were accessed.

1.4 DOCUMENT ORGANIZATION

This MPR is organized into the following sections:

- Section 2 presents the model development objectives
- Section 3 discusses the model conceptualization, including the features, events, and processes (FEPs); the geology of WMA A-AX, along with key assumptions used in WMA A-AX model development; and a brief discussion of alternative conceptual models (ACMs)
- Section 4 describes the model implementation details, including the lateral and vertical extent of the model domain and the technical approach steps of model development and sources of potential error that can lead to uncertainty in the construction of 2D and 3D GFMs
- Section 5 identifies the limitations and uncertainty of the model and the applicability of the results
- Section 6 discusses the use of the Kingdom® Geology and Tecplot 360® software to interpolate geologic-unit volumes and WMA A-AX construction
- Section 7 provides the details related to configuration management of the model inputs and outputs including the software used.

This report documents the WMA A-AX 3D GFMs, their applicability, and the quality-control checks that are necessary to demonstrate the soundness of the GFMs. The usefulness of the model to serve as the environmental setting for the WMA A-AX site fate and transport models is also discussed. Control of all environmental modeling software supporting performance assessment calculations on the Hanford Site is directed by the requirements of PRC-PRO-IRM-309, "Controlled Software Management."

[5] Leapfrog® is a registered trademark of ARANZ Geo Limited, Christchurch, New Zealand.

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2.0 MODEL DEVELOPMENT OBJECTIVES

The objective of this effort is to develop a 3D GFM for the area encompassing WMA A-AX based on the data and information available in the selected borehole logs. This effort involves establishing a methodology for identifying the tops of various stratigraphic units, documenting the elevations of these contacts, defining a 3D upper surface for each unit based on interpolation among known data points, and translating these surfaces into a 3D GFM where the unit thickness can be assessed along with any unit lateral pinch-outs.

The 3D GFM model is developed with the purpose to provide a technical basis of the hydrogeologic conditions represented in numerical process models used as part of the PA for impacts from waste left at closure at WMA A-AX. As additional geologic and hydrogeologic information becomes available from ongoing site-characterization activities, the 3D GFM will be reexamined and revised as needed.

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3.0 MODEL CONCEPTUALIZATION

This section describes the approach for the conceptualization of the geologic framework beneath WMA A-AX (Figure 3-1) that includes identified geologic units, their interpreted dimensions, their primary sedimentary characteristics and other features (e.g., bedding, crossbedding, clastic dikes), as well as a description of the broader WMA A-AX geologic setting and its pertinent physical characteristics. The FEPs approach to model conceptualization is discussed in this section. Because the GFM represents a 3D framework, only the "features" aspect of the FEPs routine is considered for this report. A summary of this rationale and the basis for selecting one of two alternative conceptual models developed from the borehole logs is also presented.

3.1 FEATURES, EVENTS, AND PROCESSES

The evaluation of FEPs is a well-established approach for developing models that are used in evaluating system performance. Identifying and incorporating relevant FEPs helps provide confidence in the modeling results and improves the traceability and transparency of PA evaluation.

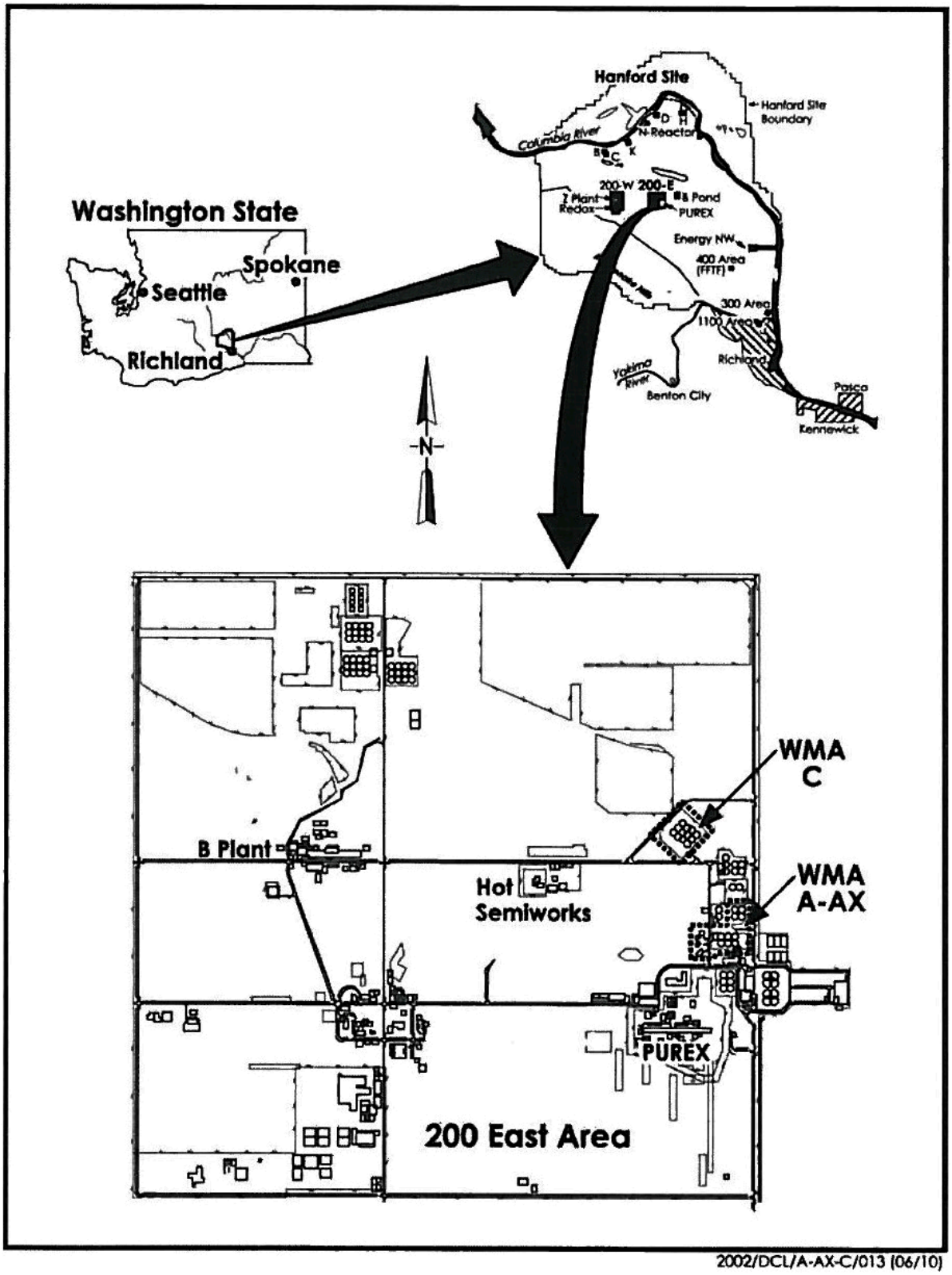
The intent of the use of FEPs is to identify conditions that may affect the ability of the closed WMA system to perform successfully. In general, the process of using FEPs consists of four steps: (1) identifying a comprehensive list of FEPs, (2) screening the comprehensive list to a manageable number, (3) describing the relationships between the FEPs, and (4) arranging them into computational cases, or scenarios, for the safety assessment.

FEP approaches have also been used increasingly within the DOE Environmental Management and Tank Waste programs. Lists of Hanford-relevant FEPs have been developed in the past [BHI-01573, "*Groundwater/Vadose Zone Integration Project – The Application of Feature, Event, and Process Methodology at the Hanford Site*"; WMP-22922, "*Prototype Hanford Features, Events, and Processes (HFEP) Graphical User Interface*"]. The Hanford FEP lists differ in some regards from the international FEP list, mainly in being focused at a very fine level of detail, which has limited their utility in PAs. Attachment A contains a list of FEPs that are deemed relevant to GFM development for the WMA A-AX.

3.2 GEOLOGIC SETTING

The geological setting information presented here is a synthesis of information acquired from prior investigations, including those documented in: HW-79805, "*Geology Underlying the 241-AX Tank Farm*"; ARH-LD-127, *Geology of the 241-A Tank Farm*; PNNL-12261; DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*; RPP-14430, "*Subsurface Conditions Description of the C and A-AX Waste Management Area*"; PNNL-15955; PNNL-19702, "*Hydrogeologic Model for the Gable Gap Area, Hanford Site*"; ARH-LD-128, *Geology of the 241-AX Tank Farm*; BHI-01103, Clastic Injection Dikes of the Pasco Basin and Vicinity – Geologic Atlas Series; and RPP-ENV-58578.

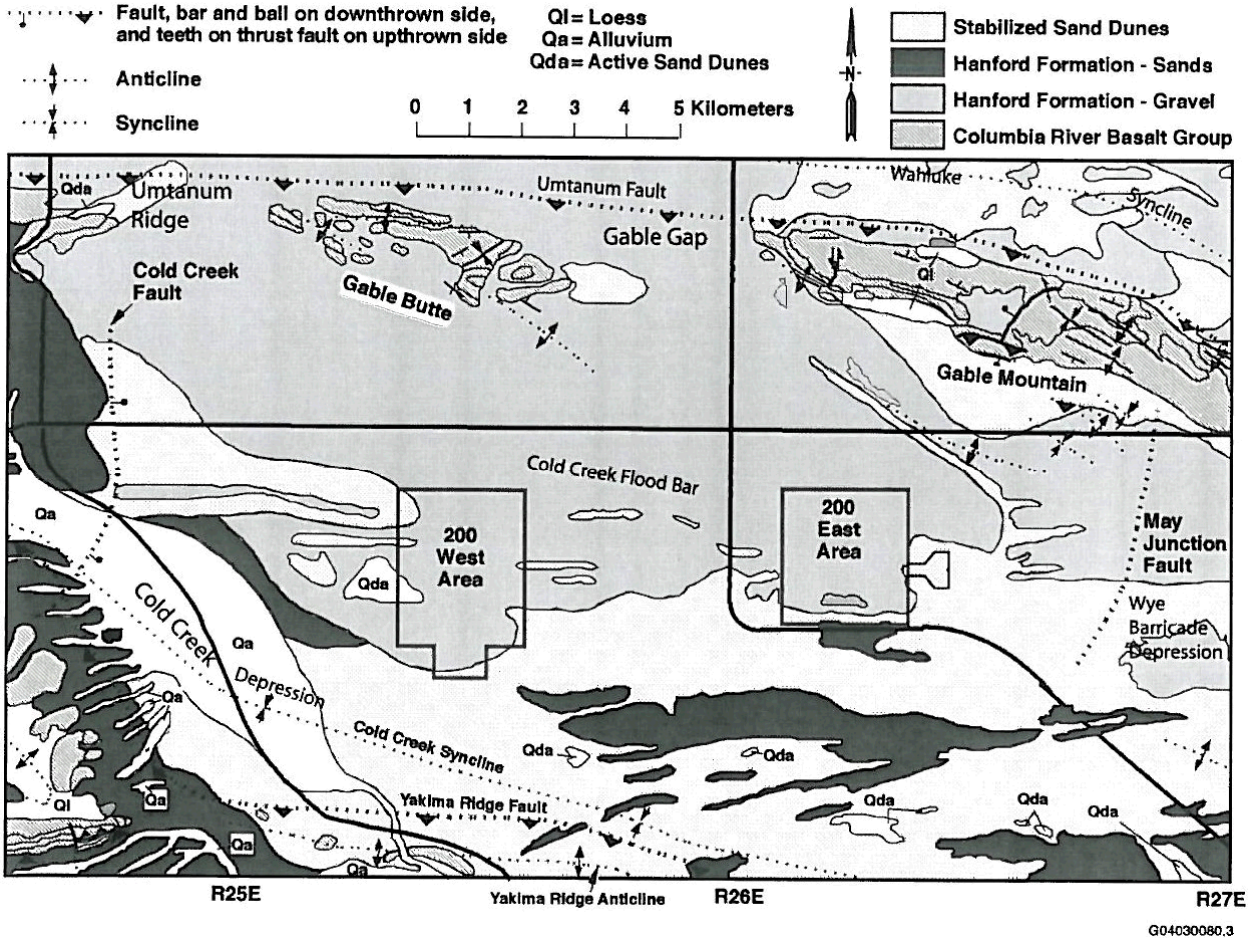
Figure 3-1. Map Showing the Location of the Waste Management Area A-AX.



FFTF = Fast Flux Test Facility
PUREX = Plutonium Uranium Extraction (Plant)
REDOX = Reduction-Oxidation (S Plant)
WMA = Waste Management Area

WMA A-AX is underlain by the Cold Creek Bar, a geomorphic construct of the Pleistocene Ice-Age cataclysmic floods, which is commonly referred to as the "200 Areas Central Plateau" (see Figure 3-1 and Figure 3-2). The upper surface of the bar in the 200 East Area forms a broad plain extending westward for several miles. The northern boundary of the bar (see Figure 3-2) is defined by a series of northwest-southeast trending flood channels (RPP-14430; PNNL-14586, "*Geologic Data Package for 2005 Integrated Disposal Facility Waste Performance Assessment*"; PNNL-19702). WMA A-AX is located near the apex of the Cold Creek Bar at an elevation of about 690 ft (210 m) on the North American Vertical Datum of 1988 (NAVD88). At depth, WMA A-AX is located along the edge of a buried Pleistocene-age, cataclysmic-flood paleochannel that eroded much, or all, of the older Miocene-Pliocene Ringold Formation and Pliocene-Pleistocene Cold Creek Unit (CCU).

Figure 3-2. Geologic and Geomorphic Map of the 200 Areas and Vicinity.



Note: Waste Management Area A-AX is in the 200 East Area (see Figure 3-1).
Source: PNNL-15955, "*Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*."

The following sections describe the 12 stratigraphic units currently recognized and defined within the WMA A-AX model domain. Within the boundaries of the WMA A-AX model domain, 43 "deep" (penetrated ≥ 150 ft below ground surface [bgs]) boreholes or wells were identified that had geologic logs or geophysical logs, or both, from which subsurface geologic

unit picks have previously been made (Table 3-1 and Table 3-2). The geologic logs (and geophysical logs, if available) for each of these deep boreholes were reviewed by multiple experienced Hanford geologists, a consensus on the geologic interpretation of each well/borehole was reached, and the overall quality of the geologic and geophysical logs was judged. The methodology used for the identification, interpretation, and extrapolation of these geologic units for the 43 deep boreholes/wells used in this MPR is outlined in Section 3.3 and Section 4.0 and presented in Table 3-1 and Table 3-2. Examples of the 2D extrapolation of these geologic surfaces are illustrated in three geologic cross-sections through WMA A-AX (Figure 3-3) which are presented in Figure 3-4, Figure 3-5, and Figure 3-6.

3.2.1 Recent Backfill Material

Excavation related to WMA A-AX construction (e.g., Figure 3-7 and Figure 3-8) removed Holocene dune sand and the uppermost portion of the Pleistocene Hanford formation HF1 (at the A Farm site; see ARH-LD-127, p. 8, Table V) and Holocene dune sand and the uppermost portion of the Pleistocene Hanford formation HF2[6] (at AX Farm site; see ARH-LD-128, p. 8, Table V) units (Figure 3-9). During and after building the tanks, the volume between the tanks was backfilled. Backfill differs from the undisturbed Hanford formation sediments, however, in that stratification of contrasting textures is disrupted and compaction of these backfill sediments occurred from driving tracked vehicles throughout the excavations and applying water.

3.2.2 Recent (Holocene) Eolian (Dune) Sand

A relatively thin (typically < 5 to 10 ft thick), well sorted, fine- to medium-grained, massive to weakly-laminated eolian sand to silty sand caps the suprabasalt sediment sequence (Figure 3-9). These eolian deposits are derived from the reworking of the uppermost cataclysmic flood deposits by winds since the last Pleistocene cataclysmic flood (approximately 13,000 years Before Present [BP]). Most of the eolian deposits beneath WMA A-AX were removed during excavation and construction activities related to WMA A-AX.

[6] In related literature by other authors, the Hanford formation may be represented simply by “H” instead of “HF”; therefore HF2 and H2 mentioned in other literature refer to the same unit.

Table 3-1. Borehole Locations and Suprabasalt Sediment Units Tops Elevations and Depths Used for Alternative Conceptual Model 1.

Well Name	HWI	X (m)	Y (m)	Total Depth (m)	Status	Elevation GL (m)	Latest Completion Date	HF1 (m bgs)	HF1 (elev m)	HF2 (m bgs)	HF2 (elev m)	HF3 (m bgs)	HF3 (elev m)	CCUz/s (m bgs)	CCUz/s (elev m)	CCUz_ thickness (m)	CCUg (m bgs)	CCUg (elev m)	Rwie (m bgs)	Rwie (elev m)	Rlm (m bgs)	Rlm (elev m)	Rwia (m bgs)	Rwia (elev m)
299-E24-20	A4756	575251.1	136049.4	92.66	Groundwater Well	210.11	3/14/1991	0.82	209.28	1.33	208.78	83.02	127.09	83.81	126.29	1.73	85.54	124.57						
299-E24-22	C4123	575262.68	136142.82	98.66	Groundwater Well	209.55	7/10/2003	0.30	209.24	0.47	209.07	80.25	129.30	82.07	127.48	0.84	82.91	126.64	NP	NP	NP	NP	94.59	114.96
299-E24-33	C4257	575325.4	136251.45	96.13	Groundwater Well	206.03	5/25/2004	0.74	205.29	2.19	203.84	77.51	128.51	78.08	127.95	3.68	81.76	124.27	NP	NP	NP	NP	95.17	110.86
299-E25-13	A4762	575362.87	136140.43	96.62	Groundwater Well	208.99	10/31/2000	NP	NP	1.52	207.46	NP	NP	79.25	129.74	4.57	83.82	125.17	NP	NP	NP	NP	96.50	112.49
299-E25-14	A6029	575667.76	136166.55	63.40	Vadose Zone	202.75	1/31/1966	0.18	202.57	4.91	197.84	59.21	143.54											
299-E25-16	A6030	575323.66	136018.54	103.63	Groundwater Well	211.68	7/31/1969	4.29	207.39	18.11	193.57	83.98	127.69	84.50	127.17	2.31	86.82	124.86	NP	NP	NP	NP	101.47	110.20
299-E25-2	A4766	575513.76	136061.87	114.30	Groundwater Well	206.22	3/31/1955	1.52	204.69	37.19	169.03	NP	NP	79.25	126.97	3.05	82.30	123.92	NP	NP	NP	NP	100.58	105.63
299-E25-236	C6542	575327.99	135965.34	100.19	Groundwater Well	211.77	8/26/2008	NP	NP	37.88	173.89	84.15	127.62	84.14	127.63	1.19	85.33	126.44						
299-E25-237	C8922	575323.84	135965.27	114.23	Groundwater Well	211.87	11/10/2014	0.29	211.58	37.72	174.15	84.35	127.52	84.50	127.37	0.93	85.43	126.44	NP	NP	NP	NP	100.39	111.48
299-E25-35	A4783	575708.34	135864.69	86.87	Groundwater Well	205.60	8/27/1988	NP	NP	3.19	202.41	53.54	152.05	67.17	138.43	0.35	67.52	138.08	79.95	125.65	80.76	124.84	83.68	121.92
299-E25-36	A4784	575403.61	135566.37	97.23	Groundwater Well	215.81	4/30/2000	0.14	215.66	26.84	188.96	82.35	133.46	83.33	132.48	0.28	83.61	132.19	NP	NP	NP	NP	95.70	120.10
299-E25-4	A4788	575648.83	136169.12	88.09	Groundwater Well	202.02	4/30/1956	2.76	199.26	5.92	196.09	61.30	140.72	71.28	130.74	0.64	71.92	130.10	NP	NP	NP	NP	84.97	117.05
299-E25-40	A4789	575464.68	136212.32	83.52	Groundwater Well	203.11	9/18/1989	NP	NP	1.57	201.54	60.85	142.26	77.50	125.61	3.40	80.91	122.20						
299-E25-41	A4790	575466.06	136145.92	85.04	Groundwater Well	204.73	9/22/1989	NP	NP	4.52	200.21	62.46	142.27	77.16	127.57	2.68	79.84	124.89						
299-E25-42	A4791	575622.8	135887.6	89.82	Groundwater Well	208.24	8/26/1991	5.74	202.50	6.46	201.78	67.14	141.09	74.88	133.36	2.72	77.60	130.64	87.73	120.51	87.79	120.45	87.84	120.39
299-E25-46	A4793	575359.73	135963.5	94.58	Groundwater Well	211.88	9/30/2000	NP	NP	0.68	211.20	81.76	130.12	83.10	128.77	1.89	84.99	126.89						
299-E25-48	A4795	575623.85	135815.69	90.68	Groundwater Well	208.18	12/31/1999	5.43	202.75	6.39	201.79	66.10	142.08	76.57	131.61	1.12	77.70	130.48	85.81	122.37	NP	NP	86.05	122.13
299-E25-56	A6045	575337.65	136066.77	46.02	Vadose Zone	210.11	6/30/1955	14.56	195.55	24.98	185.13													
299-E25-6	A4796	575683.76	136163.97	88.39	Groundwater Well	201.87	4/30/1956	0.33	201.54	5.95	195.92	53.94	147.93	69.59	132.28	1.41	70.99	130.88	NP	NP	NP	NP	84.10	117.77
299-E25-9	A4797	575914.15	136219.64	88.09	Groundwater Well	200.91	5/31/1956	1.65	199.26	6.23	194.68	45.72	155.19	67.91	132.99	1.41	69.32	131.59						
299-E25-93	C4122	575471.51	136022.09	99.06	Groundwater Well	207.27	7/1/2003	0.97	206.30	3.03	204.23	80.69	126.57	80.92	126.34	0.12	81.05	126.22	NP	NP	NP	NP	96.50	110.76
299-E25-94	C4665	575409.17	136012.43	101.50	Groundwater Well	211.31	9/17/2004	0.47	210.84	1.17	210.14	81.85	129.46	82.49	128.82	3.54	86.02	125.28						
299-E26-3	A6640	575853.55	136384.34	83.52	Groundwater Well	195.81	7/31/1958	0.98	194.83	2.88	192.93	43.94	151.87	60.61	135.19	NP	60.61	135.19	NP	NP	NP	NP	81.68	114.13
299-E26-4	A4804	575733.96	136360.88	86.26	Groundwater Well	197.96	6/27/1958	0.24	197.71	6.33	191.62	54.68	143.28	62.61	135.34	0.14	62.76	135.20	NP	NP	NP	NP	84.54	113.42
299-E26-5	A6641	575614.42	136337.77	89.00	Groundwater Well	198.63	4/23/1958	1.49	197.14	6.26	192.37	56.40	142.23	74.09	124.54	0.09	74.18	124.45	NP	NP	NP	NP	88.00	110.63
299-E27-24	C7570	575212.03	136436.28	96.87	Groundwater Well	202.84	5/4/2010	0.32	202.52	11.18	191.66	72.74	130.09	73.45	129.39	1.83	75.29	127.55	NP	NP	NP	NP	91.56	111.27
299-E27-3	A6671	575108.94	136284.23	109.73	Piezometer Host	208.90	12/18/1958	1.58	207.32	21.32	187.58	72.83	136.07	85.02	123.88	0.37	85.39	123.51	NP	NP	NP	NP	102.45	106.45
299-E27-6	A6673	575245.06	136332.48	107.59	Vadose Zone	204.87	11/30/1976	3.00	201.87	25.73	179.14	77.86	127.00	78.44	126.42	2.44	80.88	123.99	NP	NP	NP	NP	98.85	106.02
C3245	C3245	575660.99	136269.73	78.94	Boring	200.28	4/4/2003	NP	NP	4.96	195.32	58.68	141.59	71.34	128.94	0.34	71.68	128.60						

Note: All elevations are on the North American Vertical Datum of 1988.

bgs = below ground surface
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GL = ground level
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
HWI = Hanford Well Identification
NP = not present
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Table 3-2. Borehole Locations and Suprabasalt Sediment Units Tops Elevations and Depths Used for Alternative Conceptual Model 2. (2 sheets)

Well Name	HWI	X (m)	Y (m)	Total Depth (m)	Status	Elevation GL (m)	Latest Completion Date	HF1 (m bgs)	HF1 (elev m)	HF2 (m bgs)	HF2 (elev m)	HF3 (m bgs)	HF3 (elev m)	CCUz/s (m bgs)	CCUz/s (elev m)	CCUz_ thickness (m)	CCUg (m bgs)	CCUg (elev. m)	Rwie (m bgs)	Rwie (elev m)	Rlm (m bgs)	Rlm (elev m)	Rwia (m bgs)	Rwia (elev m)
299-E24-13	A4749	575300.61	136037.32	103.63	Groundwater Well	211.63	9/30/2000	NP	NP	1.52	210.10	NP	NP	81.99	129.64	5.49	87.48	124.15						
299-E24-14	A4750	575323.85	136018.81	103.63	Groundwater Well	211.65	12/31/1999	NP	NP	1.52	210.12	NP	NP	84.43	127.22	3.96	88.39	123.26						
299-E24-20	A4756	575251.1	136049.4	92.66	Groundwater Well	210.11	3/14/1991	0.82	209.28	1.33	208.78	83.02	127.09	83.81	126.29	1.73	85.54	124.57						
299-E24-22	C4123	575262.68	136142.82	98.66	Groundwater Well	209.55	7/10/2003	0.30	209.24	0.47	209.07	80.25	129.30	82.07	127.48	0.84	82.91	126.64	NP	NP	NP	NP	94.59	114.96
299-E24-3	A5897	575165.15	135983.2	101.50	Groundwater Well	213.46	6/30/1956	NP	NP	4.57	208.89	86.87	126.59											
299-E24-33	C4257	575325.4	136251.45	96.13	Groundwater Well	206.03	5/25/2004	0.74	205.29	2.19	203.84	77.51	128.51	78.08	127.95	3.68	81.76	124.27	NP	NP	NP	NP	95.17	110.86
299-E24-4	A5898	575112.42	136035.2	100.58	Groundwater Well	213.03	6/14/1956	NP	NP	6.10	206.93	83.82	129.21											
299-E24-5	A5899	575037.9	136063.46	100.28	Groundwater Well	212.91	6/30/1956	NP	NP	3.05	209.86	81.99	130.92											
299-E25-1	A4759	575336.03	136030.88	98.15	Groundwater Well	211.46	2/28/1955	NP	NP	9.14	202.31	NP	NP	82.30	129.16	3.66	85.95	125.50						
299-E25-13	A4762	575362.87	136140.43	96.62	Groundwater Well	208.99	10/31/2000	NP	NP	1.52	207.46	NP	NP	79.25	129.74	4.57	83.82	125.17	NP	NP	NP	NP	96.50	112.49
299-E25-14	A6029	575667.76	136166.55	63.40	Vadose Zone	202.75	1/31/1966	0.18	202.57	4.91	197.84	59.21	143.54											
299-E25-15	A4763	575368.82	136018.65	103.63	Groundwater Well	211.19	7/31/1969	NP	NP	4.57	206.61	NP	NP	83.82	127.37	1.52	85.34	125.84						
299-E25-16	A6030	575323.66	136018.54	103.63	Groundwater Well	211.68	7/31/1969	4.29	207.39	18.11	193.57	83.98	127.69	84.50	127.17	2.31	86.82	124.86	NP	NP	NP	NP	101.47	110.20
299-E25-2	A4766	575513.76	136061.87	114.30	Groundwater Well	206.22	3/31/1955	1.52	204.69	37.19	169.03	NP	NP	79.25	126.97	3.05	82.30	123.92	NP	NP	NP	NP	100.58	105.63
299-E25-236	C6542	575327.99	135965.34	100.19	Groundwater Well	211.77	8/26/2008	NP	NP	37.88	173.89	84.15	127.62	84.14	127.63	1.19	85.33	126.44						
299-E25-237	C8922	575323.84	135965.27	114.23	Groundwater Well	211.87	11/10/2014	0.29	211.58	37.72	174.15	84.35	127.52	84.50	127.37	0.93	85.43	126.44	NP	NP	NP	NP	100.39	111.48
299-E25-35	A4783	575708.34	135864.69	86.87	Groundwater Well	205.60	8/27/1988	NP	NP	3.19	202.41	53.54	152.05	67.17	138.43	0.35	67.52	138.08	79.95	125.65	80.76	124.84	83.68	121.92
299-E25-36	A4784	575403.61	135566.37	97.23	Groundwater Well	215.81	4/30/2000	0.14	215.66	26.84	188.96	82.35	133.46	83.33	132.48	0.28	83.61	132.19	NP	NP	NP	NP	95.70	120.10
299-E25-4	A4788	575648.83	136169.12	88.09	Groundwater Well	202.02	4/30/1956	2.76	199.26	5.92	196.09	61.30	140.72	71.28	130.74	0.64	71.92	130.10	NP	NP	NP	NP	84.97	117.05
299-E25-40	A4789	575464.68	136212.32	83.52	Groundwater Well	203.11	9/18/1989	NP	NP	1.57	201.54	60.85	142.26	77.50	125.61	3.40	80.91	122.20						
299-E25-41	A4790	575466.06	136145.92	85.04	Groundwater Well	204.73	9/22/1989	NP	NP	4.52	200.21	62.46	142.27	77.16	127.57	2.68	79.84	124.89						
299-E25-42	A4791	575622.8	135887.6	89.82	Groundwater Well	208.24	8/26/1991	5.74	202.50	6.46	201.78	67.14	141.09	74.88	133.36	2.72	77.60	130.64	87.73	120.51	87.79	120.45	87.84	120.39
299-E25-46	A4793	575359.73	135963.5	94.58	Groundwater Well	211.88	9/30/2000	NP	NP	0.68	211.20	81.76	130.12	83.10	128.77	1.89	84.99	126.89						
299-E25-48	A4795	575623.85	135815.69	90.68	Groundwater Well	208.18	12/31/1999	5.43	202.75	6.39	201.79	66.10	142.08	76.57	131.61	1.12	77.70	130.48	85.81	122.37	NP	NP	86.05	122.13
299-E25-54	A6043	575512.44	136043.48	47.24	Vadose Zone	206.35	3/31/1955	NP	NP	6.10	200.25													
299-E25-55	A6044	575369.18	136050.83	46.02	Vadose Zone	210.95	5/31/1955	7.62	203.33	21.34	189.61													
299-E25-56	A6045	575337.65	136066.77	46.02	Vadose Zone	210.11	6/30/1955	14.56	195.55	24.98	185.13													
299-E25-58	A6047	575402.68	136029.42	46.02	Vadose Zone	210.66	6/30/1955	9.14	201.51	41.15	169.51													
299-E25-6	A4796	575683.76	136163.97	88.39	Groundwater Well	201.87	4/30/1956	0.33	201.54	5.95	195.92	53.94	147.93	69.59	132.28	1.41	70.99	130.88	NP	NP	NP	NP	84.10	117.77
299-E25-9	A4797	575914.15	136219.64	88.09	Groundwater Well	200.91	5/31/1956	1.65	199.26	6.23	194.68	45.72	155.19	67.91	132.99	1.41	69.32	131.59						
299-E25-93	C4122	575471.51	136022.09	99.06	Groundwater Well	207.27	7/1/2003	0.97	206.30	3.03	204.23	80.69	126.57	80.92	126.34	0.12	81.05	126.22	NP	NP	NP	NP	96.50	110.76
299-E25-94	C4665	575409.17	136012.43	101.50	Groundwater Well	211.31	9/17/2004	0.47	210.84	1.17	210.14	81.85	129.46	82.49	128.82	3.54	86.02	125.28						

Table 3-2. Borehole Locations and Suprabasalt Sediment Units Tops Elevations and Depths Used for Alternative Conceptual Model 2. (2 sheets)

Well Name	HWI	X (m)	Y (m)	Total Depth (m)	Status	Elevation GL (m)	Latest Completion Date	HF1 (m bgs)	HF1 (elev m)	HF2 (m bgs)	HF2 (elev m)	HF3 (m bgs)	HF3 (elev m)	CCUz/s (m bgs)	CCUz/s (elev m)	CCUz_ thickness (m)	CCUg (m bgs)	CCUg (elev. m)	Rwie (m bgs)	Rwie (elev m)	Rlm (m bgs)	Rlm (elev m)	Rwia (m bgs)	Rwia (elev m)
299-E26-3	A6640	575853.55	136384.34	83.52	Groundwater Well	195.81	7/31/1958	0.98	194.83	2.88	192.93	43.94	151.87	60.61	135.19	NP	60.61	135.19	NP	NP	NP	NP	81.68	114.13
299-E26-4	A4804	575733.96	136360.88	86.26	Groundwater Well	197.96	6/27/1958	0.24	197.71	6.33	191.62	54.68	143.28	62.61	135.34	0.14	62.76	135.20	NP	NP	NP	NP	84.54	113.42
299-E26-5	A6641	575614.42	136337.77	89.00	Groundwater Well	198.63	4/23/1958	1.49	197.14	6.26	192.37	56.40	142.23	74.09	124.54	0.09	74.18	124.45	NP	NP	NP	NP	88.00	110.63
299-E26-6	A6642	575459.83	136397.86	88.39	Groundwater Well	199.04	7/31/2000	NP	NP	4.88	194.16	56.39	142.65	74.07	124.97	1.22	75.29	123.75						
299-E26-7	A6643	575673.17	136373.3	74.68	Groundwater Well	197.51	10/31/2000	NP	NP	4.27	193.24	48.77	148.74											
299-E27-2	A6670	575254.18	136341.95	95.10	Groundwater Well	203.39	8/31/2000	NP	NP	6.10	197.29	NP	NP	77.72	125.66	2.74	80.47	122.92						
299-E27-24	C7570	575212.03	136436.28	96.87	Groundwater Well	202.84	5/4/2010	0.32	202.52	11.18	191.66	72.74	130.09	73.45	129.39	1.83	75.29	127.55	NP	NP	NP	NP	91.56	111.27
299-E27-3	A6671	575108.94	136284.23	109.73	Piezometer Host	208.90	12/18/1958	1.58	207.32	21.32	187.58	72.83	136.07	85.02	123.88	0.37	85.39	123.51	NP	NP	NP	NP	102.45	106.45
299-E27-6	A6673	575245.06	136332.48	107.59	Vadose Zone	204.87	11/30/1976	3.00	201.87	25.73	179.14	77.86	127.00	78.44	126.42	2.44	80.88	123.99	NP	NP	NP	NP	98.85	106.02
C3245	C3245	575660.99	136269.73	78.94	Boring	200.28	4/4/2003	NP	NP	4.96	195.32	58.68	141.59	71.34	128.94	0.34	71.68	128.60						
C4545	C4545	575682.46	136176.35	80.62	Unclassified	201.78	6/6/2005	NP	NP	5.79	195.99	53.04	148.74	72.54	129.24	NP	72.54	129.24						

Note: All elevations are on the North American Vertical Datum of 1988.
bgs = below ground surface
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GL = ground level
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
HWI = Hanford Well Identification
NP = not present
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

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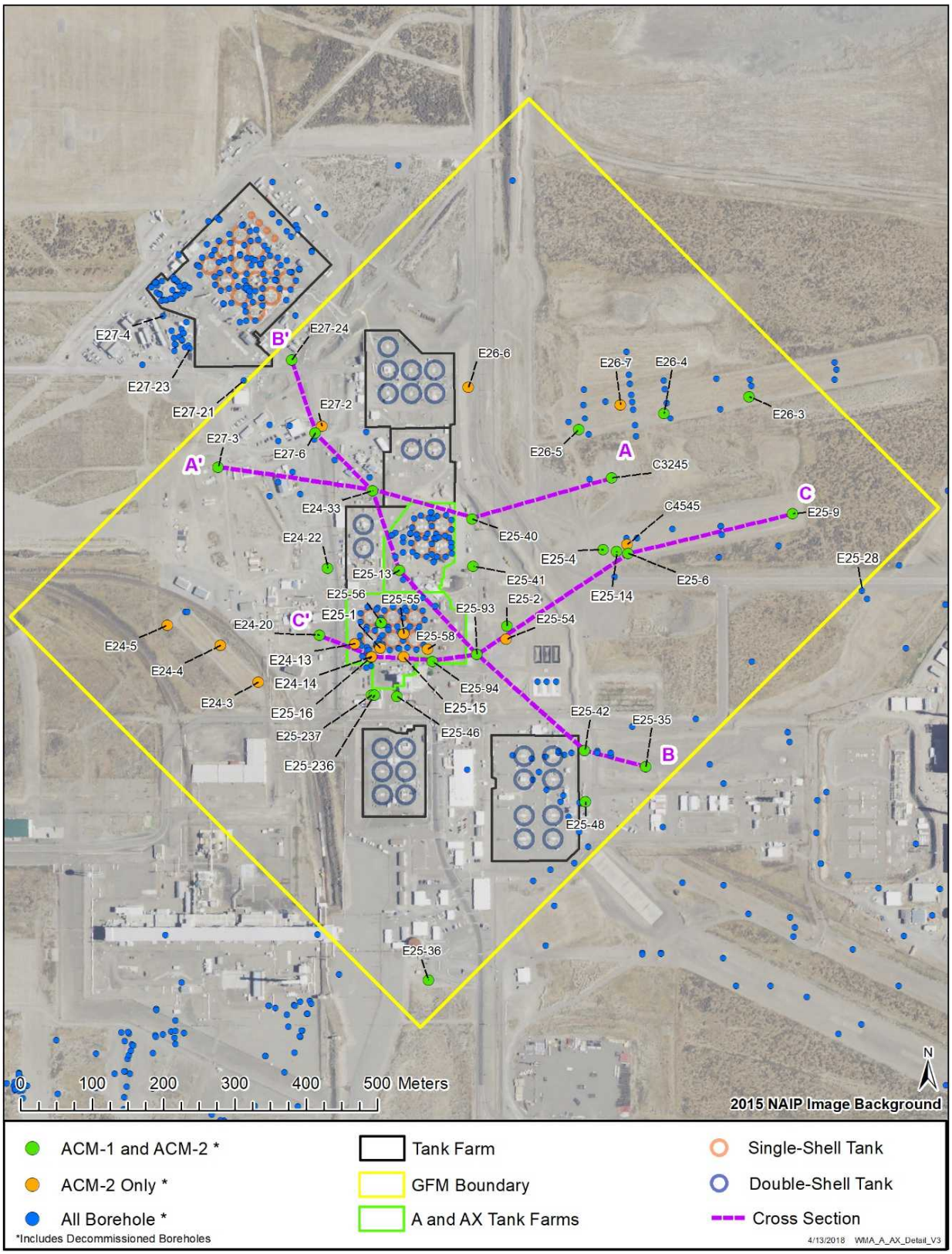
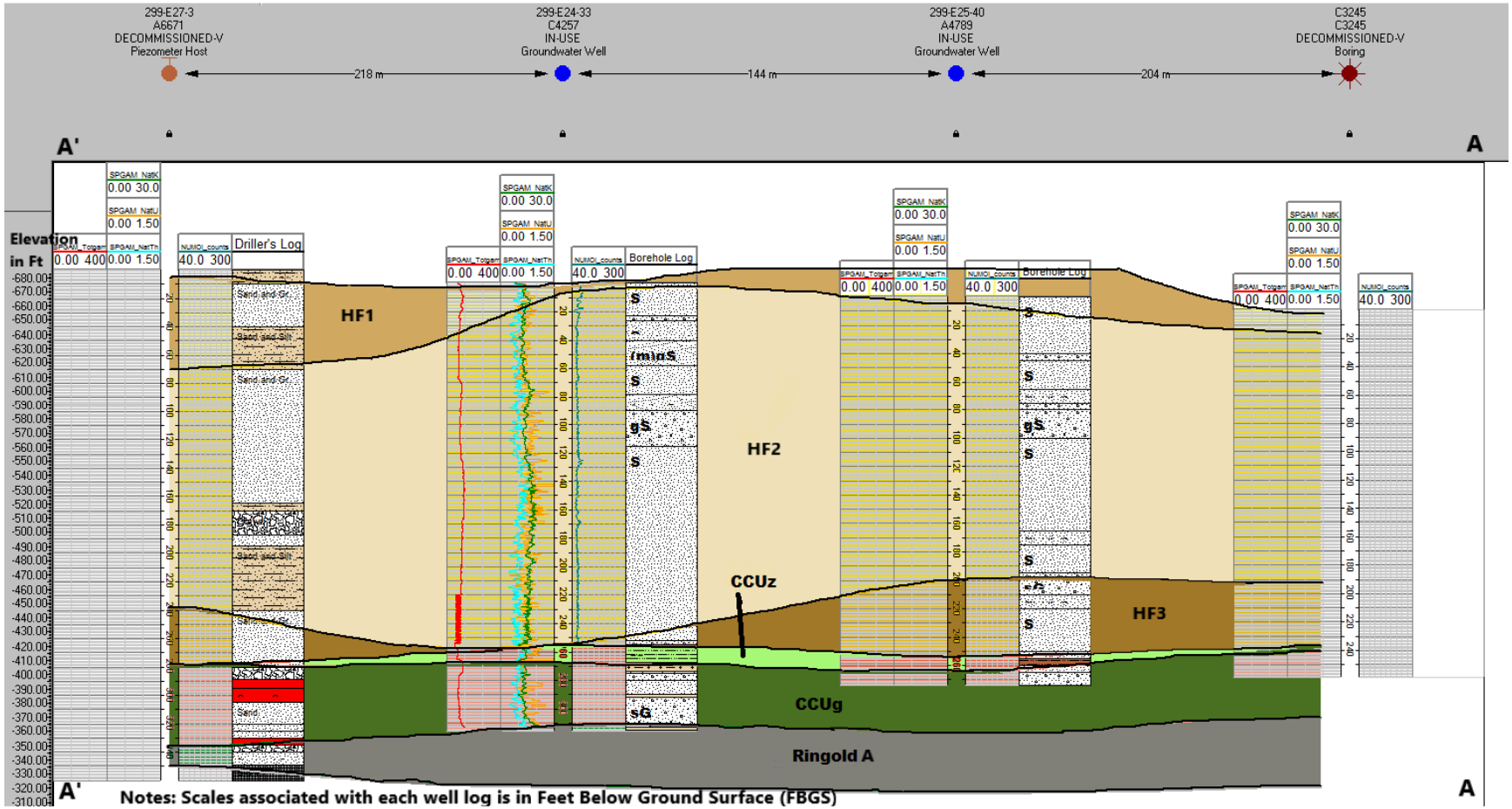
Figure 3-3. Map Showing the Locations of Cross-Sections and Borehole Locations.



ACM = alternative conceptual model GFM = geologic framework model

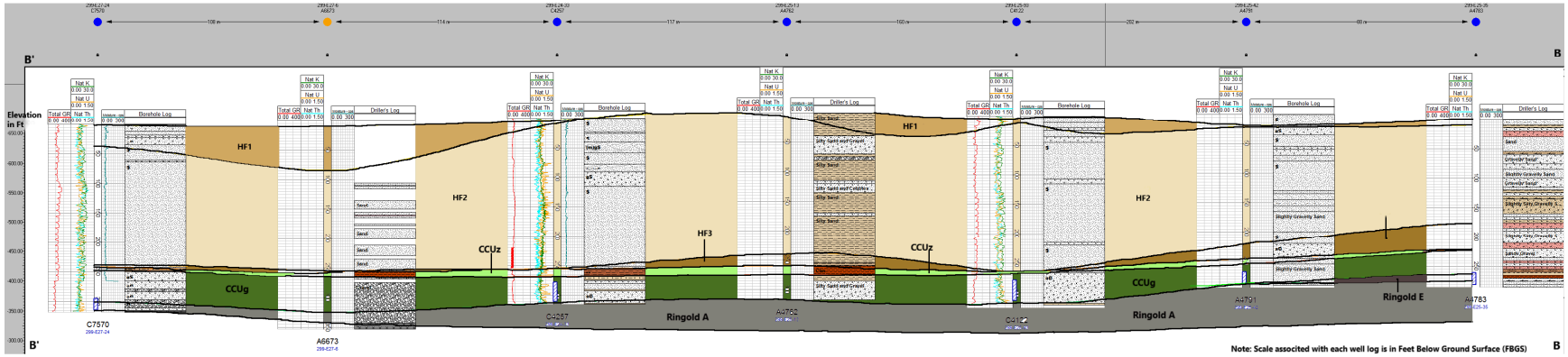
Figure 3-4. Cross-Section A-A' Illustrating the Suprabasalt Sediment Stratigraphy beneath Waste Management Area A-AX.



Note: See Figure 3-3 for well locations and location of the cross-section line.

CCUg = Cold Creek unit gravels
CCUz = Cold Creek unit silt
HF1 = Hanford formation unit 1
HF2 = Hanford formation unit 2
HF3 = Hanford formation unit 3
Ringold = Ringold formation

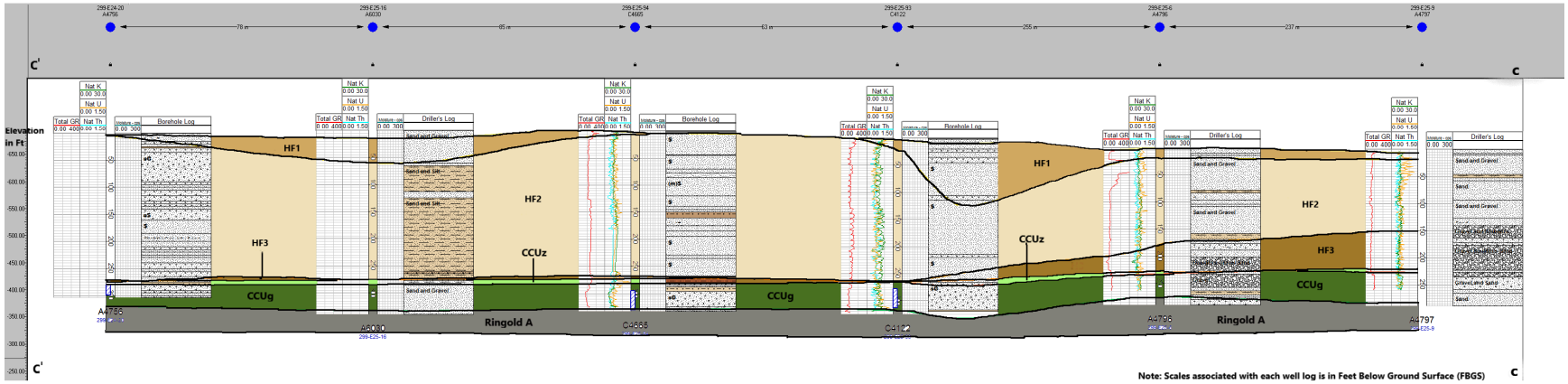
Figure 3-5. Cross-Section B-B' Illustrating the Suprabasalt Sediment Stratigraphy beneath Waste Management Area A-AX.



Note: See Figure 3-3 for well locations and location of the cross-section line.

CCUg = Cold Creek unit gravels
CCUz = Cold Creek unit silt
HF1 = Hanford formation unit 1
HF2 = Hanford formation unit 2
HF3 = Hanford formation unit 3
Ringold = Ringold formation

Figure 3-6. Cross-Section C-C' Illustrating the Suprabasalt Sediment Stratigraphy beneath Waste Management Area A-AX.



Note: See Figure 3-3 for well locations and location of the cross-section line.

CCUg = Cold Creek unit gravels
CCUz = Cold Creek unit silt
HF1 = Hanford formation unit 1
HF2 = Hanford formation unit 2
HF3 = Hanford formation unit 3
Ringold = Ringold formation

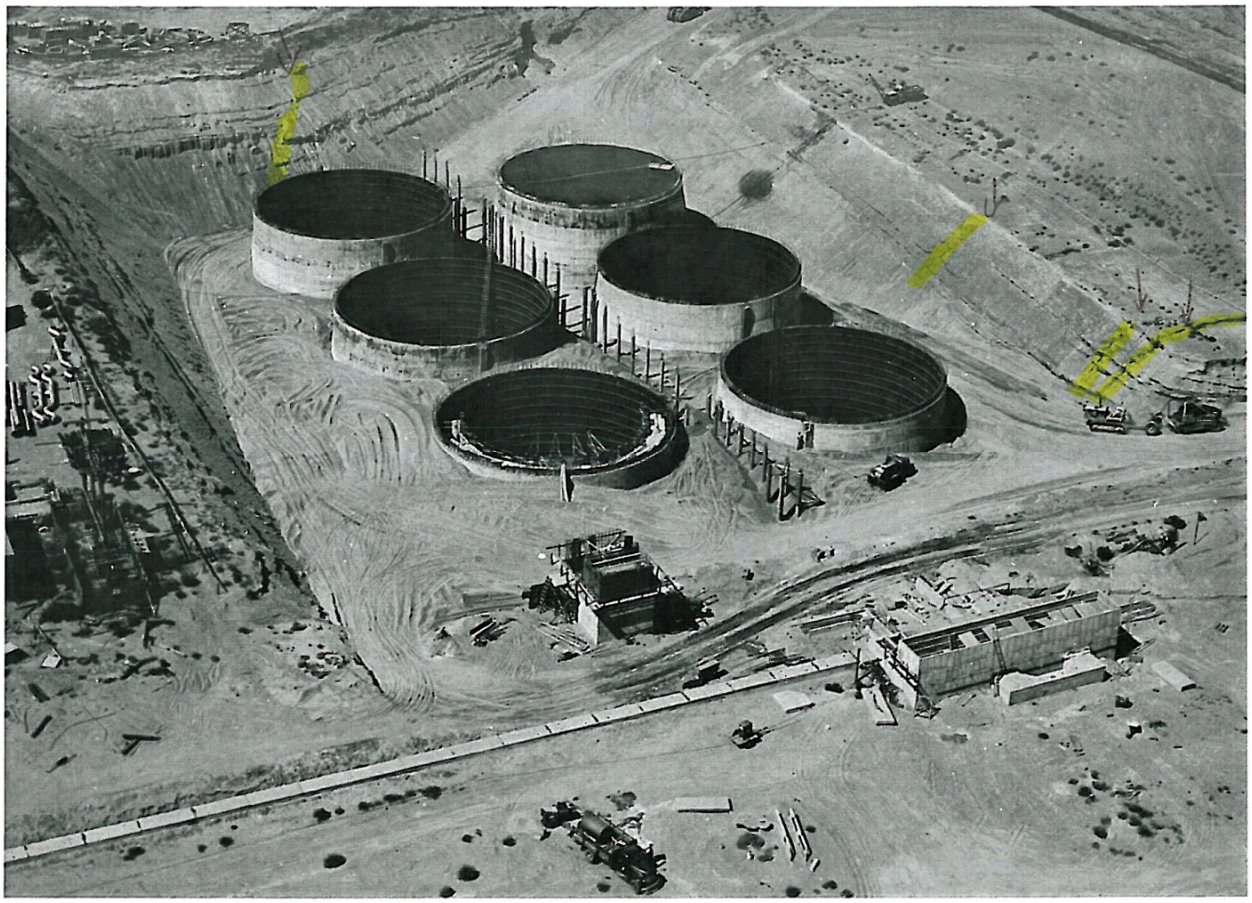
Figure 3-7. Photograph of the 241-A Tank Farm Excavation with a View to the West Showing Completed Tank Steel Liners Prior to Backfill.

Note: Red arrows and yellow highlights on excavation walls denote potential locations of clastic dikes.

3.2.3 Pleistocene Hanford Formation General

Hanford formation is the informal name that has been applied to the Pleistocene Ice-Age, cataclysmic-flood ("Missoula floods") deposits in the Pasco Basin (RHO-BWI-ST-4, "*Geologic Studies of the Columbia Plateau—A Status Report*"; DOE/RL-2002-39). The Hanford formation consists predominately of unconsolidated sediments that range from pebble-boulder gravel to sand to silt. Multiple cataclysmic-flood events, perhaps as many as one hundred separate floods ("*Many monstrous Missoula floods down Channeled Scabland and Columbia Valley*" [Waitt et al. 2009]), may have occurred from 2 Ma to 13,000 years BP ("*Age of the last major scabland flood of the Columbia Plateau in eastern Washington*" [Mullineaux et al. 1978]; "*Magnetostratigraphic evidence from the Cold Creek Bar for onset of ice-age cataclysmic floods in eastern Washington during the Early Pleistocene*" [Pluhar et al. 2006]). Deposition of cataclysmic-flood gravel, sand, and silt "lithofacies" was directly dependent on floodwater "energy," so gravel-dominated deposits represent high-energy floodwaters in, or immediately adjacent to, main-flood channels; sand-dominated deposits represent lower-energy floodwaters away from the main-flood channels or during the waning stages of flooding; silt-dominated deposits represent deposition under slackwater conditions or back-flooded areas.

Figure 3-8. Photograph of 241-A Tank Farm Excavation, View to the West, Showing Partial Backfill of the Excavation.



Note: Red arrows and yellow highlights on excavation walls denote potential locations of clastic dikes.

For the 200 Areas Central Plateau region on the Hanford Site, the Hanford formation has been informally divided into three "lithofacies dominated" units (Figure 3-9). These units are, from upper to lower, HF1 Unit (gravel-dominated), HF2 Unit (sand-dominated), and HF3 Unit (gravel-dominated) (BHI-00184, "*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*"; PNNL-12261; DOE/RL-2002-39; RPP-14430; PNNL-15955; PNNL-17913, "*Hydrogeology of the Hanford Site Central Plateau – A Status Report for the 200 West Area"*; PNNL-19702). As pointed out in PNNL-15955, the three informal Hanford formation units are defined solely on the basis of lithofacies (gravel-dominated versus sand-dominated) in relation to relative stratigraphic position. There are no unique sedimentological criteria used to define each unit; therefore, it is essentially impossible to correlate these units for any distance with any certainty. Paleomagnetic studies of the Hanford formation in the Central Plateau region by Pluhar et al. (2006) have demonstrated that the Hanford formation sediments in the 200 West Area are much younger in age than those that underlie the 200 East Area. This confirms that the HF1, HF2, and HF3 units in the 200 East and 200 West Areas are not time-stratigraphically equivalent deposits and are not correlative. However, for this effort, the informal Hanford unit "lithofacies" designations of HF1, HF2, and

HF3 (Figure 3-9) will be used to assist in identifying physical characteristics of flood-sediment deposits that determine hydrogeologic properties.

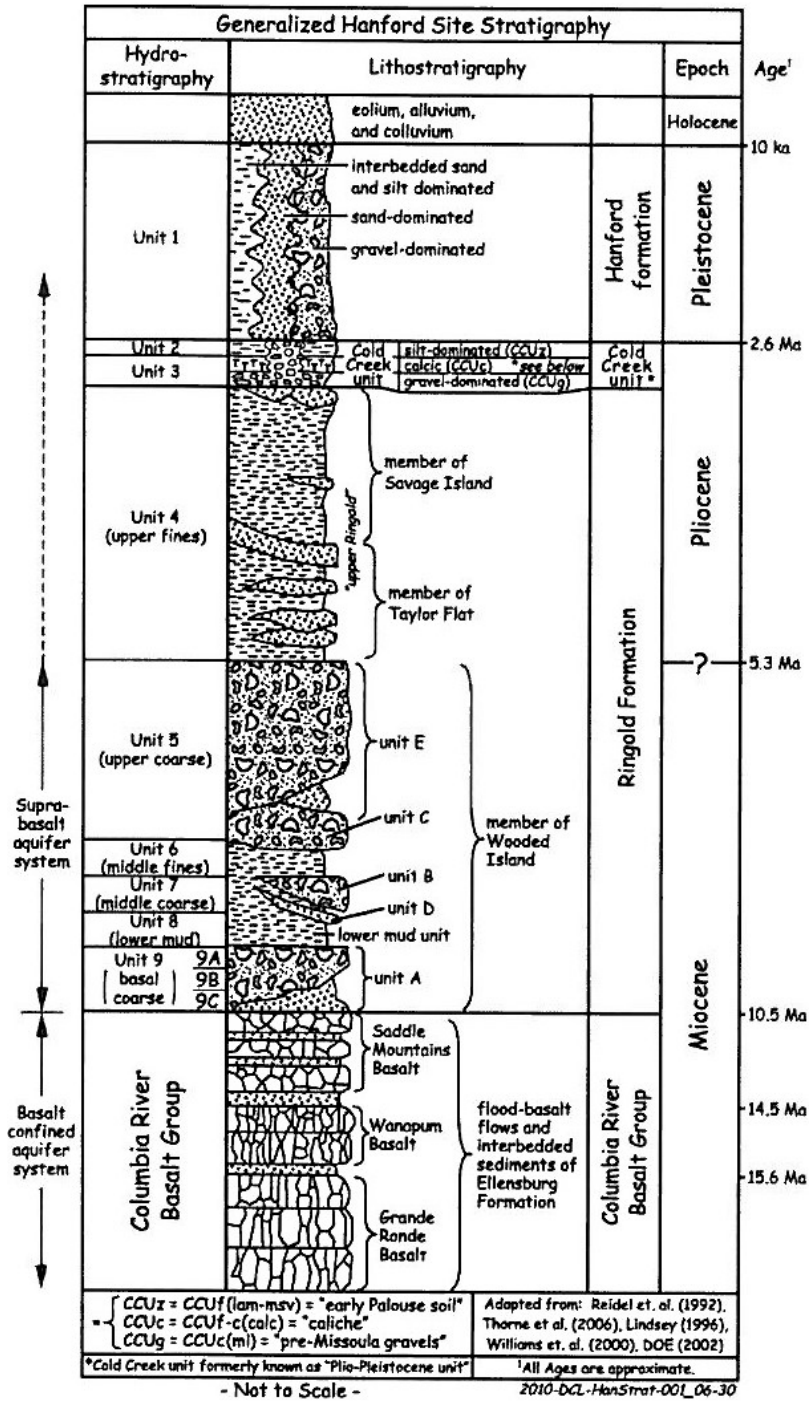
3.2.3.1 Pleistocene Hanford Formation Unit HF1

Ice-Age, cataclysmic-flood deposits that consist predominately of poorly consolidated and sorted basalt pebble to cobble sandy gravel to gravelly sand, with discontinuous minor interbeds of sand to silty sand that occur within the uppermost portion of the Hanford formation, have been informally designated as the "HF1 Unit" (DOE/RL-2002-39; Figure 3-9). HF1 gravel deposits typically have an open-frame fabric characterized by clast-supported, basalt-dominated gravel with little, or no, matrix filling sand or silt. The gravel clasts can be coated, to varying degrees, with calcium carbonate (caliche) which, when tested with dilute hydrochloric acid (HCl), display a diverse range of reactions, from no reaction to a strong reaction. These gravel-dominated, cataclysmic-flood deposits typically display massive bedding to horizontal-low angle bedding or large-scale, planar-tabular cross bedding. Locally, rip-up clasts consisting of cemented Ringold Formation blocks or caliche may be present. Previously, the gravel-dominated HF1 Unit (facies) was defined by DOE/RL-2002-39 as consisting of >50% gravel-dominated lithofacies, but some previous interpretations of the HF1 Unit beneath WMA A-AX (e.g., RPP-14430, PNNL-15955) lowered the definition of "gravel-dominated" HF1 Unit to much less than 50% (in some cases, less than 10%) gravel-dominated lithofacies in some wells (e.g., 299-E24-22, 299-E25-1, 299-E25-40, 299-E25-46, 299-E25-93). Existing log data for the wells used in this investigation (see Attachment B), were re-interpreted to determine the presence, absence, and thickness of the HF1 Unit. In doing so, the definition of "gravel-dominated" was lowered from >50 to >25% gravel-dominated lithofacies for this study. The lowering of the "gravel-dominated" threshold definition is more in keeping with previous WMA A-AX geologic studies (e.g., RPP-14430, PNNL-15955). It should be noted that thin beds of sand and, much less commonly, minor silty sand to silt beds are found throughout the HF1 gravel-dominated sequence. When present, these minor silty sand and silt beds typically comprise less than 15% of the total thickness of the HF1 Unit. Sands within the HF1 Unit, when tested with dilute HCl, typically exhibited moderate-to-strong reactions. The HF1 Unit represents deposition by high-energy, cataclysmic floodwaters in, or immediately adjacent to, the main cataclysmic-flood channels. The thickness of the HF1 Unit varies on a northeast-southwest trend across WMA A-AX, pinching out toward the southwest (Figure 3-4, Figure 3-5, and Figure 3-6). Due to the relative thinness of the HF1 Unit at WMA A-AX, it is likely that significant portions of the HF1 Unit were removed during excavation for tank construction (ARH-LD-127, ARH-LD-128).

3.2.3.2 Pleistocene Hanford Formation Unit HF2

The HF2 Unit consists of predominately fine- to coarse-grained sand sequence with minor interbeds of matrix-supported, pebble gravelly sand to pebble gravel, and sandy silt to silt layers (Figure 3-9). The sand-dominated HF2 Unit (facies) was previously defined by DOE/RL-2002-39 as consisting of greater than 50% sand-dominated lithofacies, but, for this effort, the definition of "sand-dominated lithofacies" was raised to >75%.

Figure 3-9. Regional Stratigraphy Chart for the Pasco Basin and the Hanford Site.



Source: PNNL-19702, "*Hydrogeologic Model for the Gable Gap Area, Hanford Site*," Figure 3.1.

DOE (2002)	=	DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments Within the Central Pasco Basin*.
Lindsey (1996)	=	Open File Report 96-8, *The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-Central Washington and North-Central Oregon*.
Reidel et. al. (1992)	=	WHC-MR-0391, "*Field Trip Guide to the Hanford Site*."
Thorne et al. (2006)	=	PNNL-14753, "*Groundwater Data Package for Hanford Assessments*."
Williams et al. (2000)	=	PNNL-12261, "*Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*."

HF2 Unit sand lithofacies typically consist of relatively thin beds that are usually less than 3 ft thick and display normally graded bedding (DOE/RL-2002-39, RPP-14430, PNNL-15955) and have relatively high basalt content (30 to 70%), giving these deposits a characteristic black, gray, or "salt-and-pepper" appearance. The presence of silty sand to silt beds within the HF2 Unit is highly variable, ranging from absent to comprising less than 20% of the unit's total thickness. Where the silt content is low to absent, the sands are clean and well sorted. The HF2 Unit sands and silts exhibited a wide range of responses when tested with dilute HCl, ranging from no reaction to very strong reactions. The HF2 Unit represents sand-dominated deposition by moderate-energy, cataclysmic floodwaters adjacent to main cataclysmic-flood channels during the waning stages of flooding. With the reinterpretation of borehole logs for this report, the thickness of the HF2 Unit beneath WMA A-AX (e.g., Figure 3-4, Figure 3-5, and Figure 3-6) is much greater than previously depicted (e.g., RPP-14430, PNNL-15955).

3.2.3.3 Pleistocene Hanford Formation Unit HF3

The HF3 Hanford formation Unit is essentially the same as the HF1 Unit (described in Figure 3-9) in that it is a gravel-dominated (>25% gravel) unit that consists of mainly poorly-consolidated and poorly-sorted, basalt pebble to cobble gravel to gravelly sand, with discontinuous minor interbeds of sand to silty sand. The HF3 Unit gravels and sands, when tested with dilute HCl, typically exhibited weak to moderate reactions. HF3 Unit gravel deposits typically display an open-frame fabric characterized by clast-supported gravel with little, or no, matrix filling sand or silt. The HF3 Unit, like the HF1 Unit, represents gravel-dominated deposition by high-energy cataclysmic floodwaters in, or immediately adjacent to, the main cataclysmic-flood channels. The HF3 Unit is inferred to be generally absent beneath much of WMA A-AX (e.g., Figure 3-4, Figure 3-5, and Figure 3-6).

3.2.4 Plio-Pleistocene Cold Creek Unit General

The informal CCU consists of post-Ringold Formation and pre-cataclysmic-flood deposits composed of fluvial (ancestral Columbia River and alluvial side stream) eolian, as well as pedogenic sediment deposits (BHI-00184, PNNL-12261, DOE/RL-2002-39, RPP-14430, PNNL-15955, PNNL-17913, PNNL-19702). In WMA A-AX, the CCU can be subdivided into an upper silt and sand unit and a lower gravel unit (RPP-14430, PNNL-15955, RPP-ENV-58578).

3.2.4.1 Plio-Pleistocene Cold Creek Silt and Sand Unit

The informal Cold Creek silt and sand unit is a thin unit that is present beneath much of the WMA A-AX area (BHI-00184, RPP-14430, PNNL-15955, RPP-ENV-58578). The Cold Creek silt portion of this unit is typically less than 15 ft thick (e.g., Figure 3-4, Figure 3-5, and Figure 3-6; Table 3-1 and Table 3-2) and, where present beneath the WMA A-AX area, is described as a light brown to greenish gray, compact or cohesive, very well sorted, micaceous silt displaying either small-scale laminations/bedding or as massive with no discernable bedding (BHI-00184, RPP-14430, DOE/RL-2002-39, PNNL-15955, PNNL-19702, RPP-ENV-58578). This silt is also moderately calcareous (commonly a weak to strong reaction to dilute HCl), often exhibits iron-oxide staining, and may display evidence of weakly-developed paleosols (i.e., root casts with organic carbon traces) (PNNL-15955, PNNL-19702, RPP-ENV-58578).

The thickest portions of the Cold Creek sand occur where the Cold Creek silt is absent (see Section 4.2.2) and directly overlie the Cold Creek gravel unit. The Cold Creek sand is suspected to be present as a thin layer between the Cold Creek silt and the HF3 Unit in a few deep wells in the WMA A-AX area (wells 299-E24-94, 299-E25-236 and 299-E25-237; see unit picks in Table 3-1 and interpreted logs in Attachment B). The Cold Creek sand is typically described as being cohesive to weakly- to moderately-cemented, thin-bedded to massive, poorly- to moderately-sorted, fine- to medium-grained, micaceous sand to silty sand that typically exhibits a moderate to strong reaction in response to dilute HCl. The sand is composed of predominately quartz/felsic grain lithologies with minor basalt grain content, in contrast to the basalt-rich sands that dominate the overlying HF2 sand unit and occur within the HF3 gravel unit. This Cold Creek sand likely represents fluvially reworked and deposited Ringold Formation sands and silts.

3.2.4.2 Plio-Pleistocene Cold Creek Gravel Unit

The Cold Creek gravel consists of fluvial deposits that are poor- to moderately-sorted, weakly- to moderately-cemented (with minor iron oxide staining), subrounded to rounded, clast-supported pebble to cobble-size gravel with a micaceous, quartzo-feldspathic sand matrix, and sandy to muddy gravel with a variable range (basalt rich to felsic rich) clast lithology (RPP-14430, PNNL-19702, RPP-ENV-58578). Borehole data suggests that the Cold Creek gravel Unit is likely present throughout the WMA A-AX area (Table 3-1, Figure 3-5, and Figure 3-6). Dilute HCl testing of the gravel and sand from this unit exhibits a wide range of responses, from no reaction to a strong reaction. The presence of weak cementation helps to differentiate the Cold Creek gravel from the overlying HF3 gravels.

3.2.5 Mio-Pliocene Ringold Formation Units E and A (Undifferentiated)

The Ringold Formation beneath WMA A-AX (Figure 3-9) consists generally of fluvial conglomerate deposits consisting of weakly- to well-cemented, subrounded to rounded, clast-supported granule to cobble gravels with a micaceous sandy matrix and interbedded sands and mud deposits. Clasts consist of a mix of lithologies (e.g., quartzite, gneiss, cherts, metamorphics, basalt) and have been previously correlated to the E (Rwie) and A (Rwia) Units of the Wooded Island member of the Ringold Formation (Figure 3-9, RPP-14430, PNNL-19702, RPP-ENV-58578).

The younger E unit and older A unit conglomerate Ringold deposits are separated by the presence of a laminated lacustrine silt-clay/paleosol deposit informally designated as the "Ringold lower mud" (Rlm) unit (Figure 3-9).

3.2.6 Clastic Dikes

Clastic dikes (includes both vertical to near-vertical dike and horizontal sill structures) are common in pre-Holocene suprabasalt sediments in the Pasco Basin and at the Hanford Site (BHI-01103) and are inferred to have been hydraulically injected during, or immediately after, Pleistocene cataclysmic flooding, earthquakes, or mass-wasting events. On the 200 Area Central Plateau, clastic dikes and sills are especially common features within the sand-dominated HF2 Unit and are less commonly found in the gravel-dominated HF1 and HF3 Units (PNNL-15955, PNNL-19702, BHI-01103). BHI-01103 provides detailed descriptions and discussions of the

physical and hydraulic characteristics of clastic dikes found within the Hanford Site and Pasco Basin.

Whereas there does not appear to be reported occurrence of clastic dikes at WMA A-AX in more recent summaries of surficial or near-surface geology, ARH-LD-127 and ARH-LD-128 reported that clastic dikes had been penetrated by wells, though the extent of these clastic dikes could not be mapped based on the available data. BHI-01103 (pp. 2-6, Section 2.5) again confirmed the presence of clastic dikes in WMA A-AX. While available historical photographs of the various excavations' pit-walls during the construction of the WMA A-AX site show no positive visual proof of clastic dikes, these photographs do contain a number of suspect features that could potentially be clastic dikes (e.g., Figure 3-7 and Figure 3-8). Collectively, this information suggests that the clastic dikes (and sills) are very likely present within WMA A-AX (ARH-LD-127, ARH-LD-128, and BHI-01103), but have a random distribution and are not part of a regular network of clastic dikes (e.g., polygonal-pattern ground; see BHI-01103, Section 5).

3.3 WASTE MANAGEMENT AREA A-AX GEOLOGIC FRAMEWORK MODEL – ALTERNATIVE CONCEPTUAL MODELS ACM 1 AND ACM 2

The foundation for any GFM of the WMA A-AX area is the distribution, depth, and quality of subsurface stratigraphic control points that are available to be used in the geologic interpretation process. The geologic interpretation process is very dependent on overall quality of the geologic logs (and geophysical logs, if available). Within the boundaries of the WMA A-AX model domain, 43 "deep" (penetrated ≥ 150 ft bgs) boreholes or wells were identified that had geologic logs or both geologic logs and geophysical logs (Figure 3-3), from which subsurface stratigraphic unit picks have previously been made (Table 3-1 and Table 3-2). The geologic logs (and geophysical logs, if available) for each of these deep boreholes were reviewed by multiple experienced Hanford geologists, a consensus on the geologic interpretation of each well was reached, and the overall quality of the geologic and geophysical logs was judged (Table 3-1 and Table 3-2). The qualitative evaluation of the geologic and geophysical data from each deep borehole was primarily focused on the level and quality of detail and completeness of the logs. The quality ranking designations were:

- "1" (excellent – well-site geologist's systematic, detailed lithologic descriptions and sediment-size percentage estimates and excellent geophysical logs; example: 299-E25-237)

- "2" (fair to good – well-site geologist's detailed lithologic descriptions and sediment-size percentage estimates, but may be missing data for some intervals or have poor to incomplete geophysical logs; example: 299-E25-46)

- "3" (poor to very bad – Only driller's lithology identifications and notes with no systematic sediment-size percentage estimates and incomplete or poor geophysical logs; example: 299-E24-14).

Based on the quality of data and information that was available, the development effort identified two geologic ACMs, ACM 1 and ACM 2. ACM 1 was developed using only the best-quality subsurface geologic data from boreholes that received either a “1” or “2” quality designation. Geologic data from 29 of the 43 total boreholes were used to develop ACM 1 (Table 3-1). ACM 2 was developed using subsurface geologic data from all 43 deep boreholes (Table 3-2). In addition to using the entire borehole dataset, ACM 2 also considers differentiation of the uppermost CCU unit by incorporating an estimation of the extent and thickness of Cold Creek silt and sand beds. Thus, the primary difference between ACM 1 and ACM 2 is that ACM 2 provides a more detailed lateral extent and thickness of the Cold Creek silt unit, which results from the inclusion of additional borehole data omitted from ACM 1 and allows the depiction of the Cold Creek sand unit to be generated in ACM 2.

4.0 GEOLOGIC MODEL IMPLEMENTATION

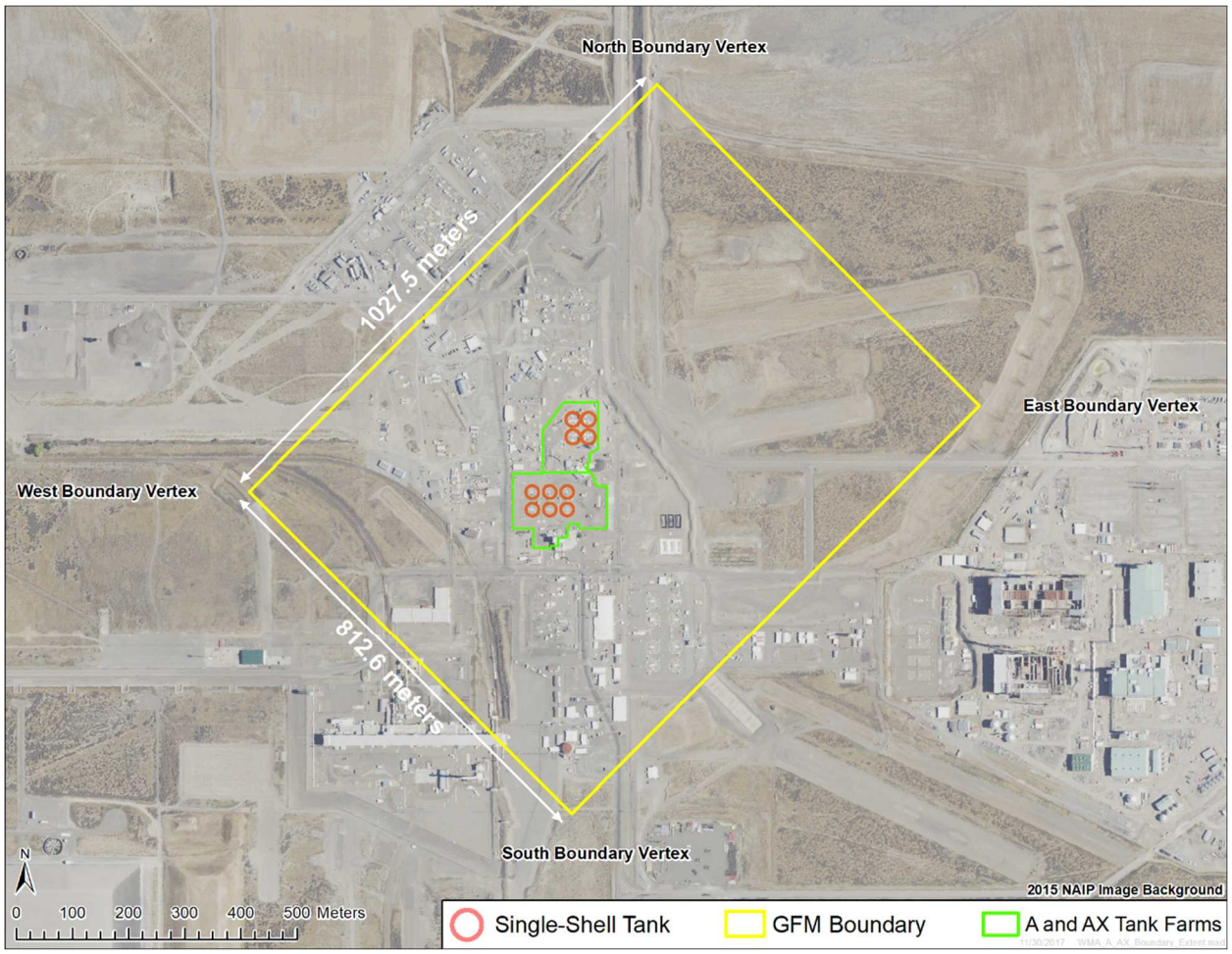
As discussed previously in Section 3.3, two alternative GFMs have been developed for the WMA A-AX area. Each of these GFMs is based on the correlation and interpolation of stratigraphic unit contacts between selected boreholes (Figure 3-3; Table 3-1 and Table 3-2) generated by the Kingdom® software, which creates a series of stratigraphic unit surfaces that form the upper (i.e., top of the stratigraphic unit surface) and lower bounding model surfaces of the stratigraphic unit intervals. The stratigraphic units included in the WMA A-AX GFMs are the suprabasalt sediments units from the land surface to the underlying top of the Columbia River basalt. These stratigraphic unit surfaces are exported from Kingdom® into Tecplot®, which stacks together and integrates these stratigraphic unit surfaces to create a 3D representation (model) of the lateral extent and thickness of each geologic unit within the WMA A-AX domain. The following discussion presents a more detailed account of how the 3D GFMs were constructed.

4.1 MODEL BOUNDARIES AND COORDINATE SYSTEM

The uppermost boundaries of the GFMs are the land surface. This digital surface topography was defined by a light detection and ranging (LiDAR) survey ("RCCC-Hanford Battelle/PNNL/DOE, Digital Orthophotography & LiDAR Surveys Photogrammetric Report" [Aero-Metric LiDAR 2008]). The lower boundary of the GFM is the previously interpreted top of the Columbia River basalt (TOB) surface (ECF-Hanford-16-0128, "*Development of Contiguous Top of Basalt Surface for Use in Development of Site Geoframeworks*"). This TOB surface is the exact same TOB surface used in the Hanford South GFM (ECF-Hanford-16-0128).

The geographic extent of the WMA A-AX 3D GFM domain is a rectangle rotated 45 degrees to align the model with the contaminant fate and transport model reported in RPP-RPT-60101, "*Model Package Report, Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*" (Figure 4-1). The lengths of this rectangular domain are 812.6 m northwest to southeast by 1,027.5 m northeast to southwest by 126.7 m vertically (maximum thickness). The extent of this rectangular domain is considered to be large enough to include the likely extents of key features and stratigraphic unit boundaries. Table 4-1 lists the vertex coordinates of the lateral boundary extents of the WMA A-AX GFM rectangular domain. All coordinates for the extents of the GFM are in Lambert Coordinate system easting, National Oceanic and Atmospheric Administration (NOAA) Manual NOS NGS 5, State Plane Coordinate System of 1983. The bottom and top of the model domain vary spatially according to the TOB elevation and ground surface relief, respectively. Vertical coordinates are stated as depths below ground surface as provided in primary data in drilling and borehole logs or as corresponding elevations with NAVD88 as the datum. Note that many boreholes predate the adoption of the State Plane Coordinate System of 1983 and/or NAVD88 in Hanford Site modeling. These historical documents may state coordinates relative to older local or national datums.

Figure 4-1. Vertical Boundary Extents of the Waste Management Area A-AX Three-Dimensional Geologic Framework Model.



GFM = geologic framework model

Even though the WMA A-AX GFM domain is constrained to the dimensions discussed above, the original interpolations of the stratigraphic unit surfaces used in both GFMs (ACM 1 and ACM 2) go beyond those boundaries to allow for more accurate calculations of the interpolated stratigraphic unit surface elevations and to assess unit surface elevation agreement with the Hanford South GFM (ECF-HANFORD-13-0029). After interpolation and conversion to *.asc format, the surfaces were clipped to the WMA A-AX GFM domain (Table 4-1 and Figure 4-1). Because numerical flow and transport models will conform to the above described domain, areas of the interpolated surfaces outside of the numerical model domain are not discussed in this document. However, the 3D GFM model created from the broader interpolated surfaces also has a domain that extends beyond what is listed in Table 4-1 (i.e., ECF-HANFORD-13-0029) to more accurately calculate 3D unit volumes with respect to geologic features such as structural highs, lows, and pinch-outs.

Table 4-1. Waste Management Area A-AX Three-Dimensional Geologic Framework Model Lateral Boundary Vertices.

X Coordinate	Y Coordinate	Boundary Vertex
574817.91	136075.33	West
575392.51	135500.73	South
576119.09	136227.31	East
575544.49	136801.91	North

4.2 TECHNICAL APPROACH USED IN MODEL DEVELOPMENT

Building a GFM is a process of successive refinements made up of defining the model's domain and developing and building the internal structures. A geological model typically consists of nonintersecting volumes that fit together to exactly fill a 3D domain defined by the lateral and vertical extent of the model. The stratigraphic unit layers within the geological model are built from oldest to youngest or from youngest to oldest. For both WMA A-AX GFMs, the model domain defaults vertically to the land surface topography and TOB, but different lateral extents can be made if desired.

The workflow overview for creating the WMA A-AX GFMs follows a generalized, but consistent, structure. In summary, interpreted borehole data are used to define stratigraphic unit contacts as subsurface elevations. These data inputs are interpolated within the Kingdom® software. The stratigraphic unit surfaces that form the upper (i.e., top of the stratigraphic unit surface) and lower bounding surfaces of the stratigraphic units' intervals are combined to represent the lateral extent and thickness of each stratigraphic unit. Two-dimensional stratigraphic unit columns constructed from imported borehole stratigraphic unit contact data and are used as the basis to form the internal structure of the GFMs. It should be noted that the uppermost stratigraphic unit recognized within the WMA A-AX model domain by Kingdom® is the HF1 Unit and Kingdom® does not account for the potential presence of either recent backfill materials or eolian sand deposits overlying the Hanford formation. This generates a "gap" between the top of the uppermost Hanford formation unit and ground surface where either backfill materials or eolian sand deposits are present. This issue was addressed in Tecplot® where both recent backfill materials and eolian sand were added in as additional surfaces.

4.2.1 Interpolation of Stratigraphic Unit Surfaces

Stratigraphic unit tops data interpreted from borehole geologic, drillers', and geophysical logs (Attachment B) were used in the interpolation of elevation grid surfaces representing the upper extents of each of the stratigraphic units. This process was undertaken using the Kingdom® Geology software employing its interpolation algorithms. Specific steps in the sequence of stratigraphic unit surface interpolation in Kingdom® are summarized for a general audience in

this section and detailed in Attachment C for modelers desiring the ability to reproduce the Kingdom® results. The steps are:

1. *Import borehole location and tops data into Kingdom®*. Interpreted stratigraphic unit tops (such as presented in Table 3-1 and Table 3-2) are imported in the Kingdom® database. Quality checks were performed visually, first to ensure unit tops were appropriately located at borehole locations and secondarily to assess conformity of unit tops with borehole log descriptions and geophysical log curves. Next, unit tops were examined in relation to prior interpretations and to neighboring borehole interpretations.

2. *Run interpolation algorithm*. The "Flex Gridding" algorithm in the Dynamic Map Update Modeling module in the Kingdom® Geology software was selected as the most appropriate gridding algorithm to use for the GFM. In the setup of the dynamically updated model, stratigraphic units are referred to as "layers" and are organized in stratigraphic order. The gridding module produces gridded surfaces that represent those model layers.

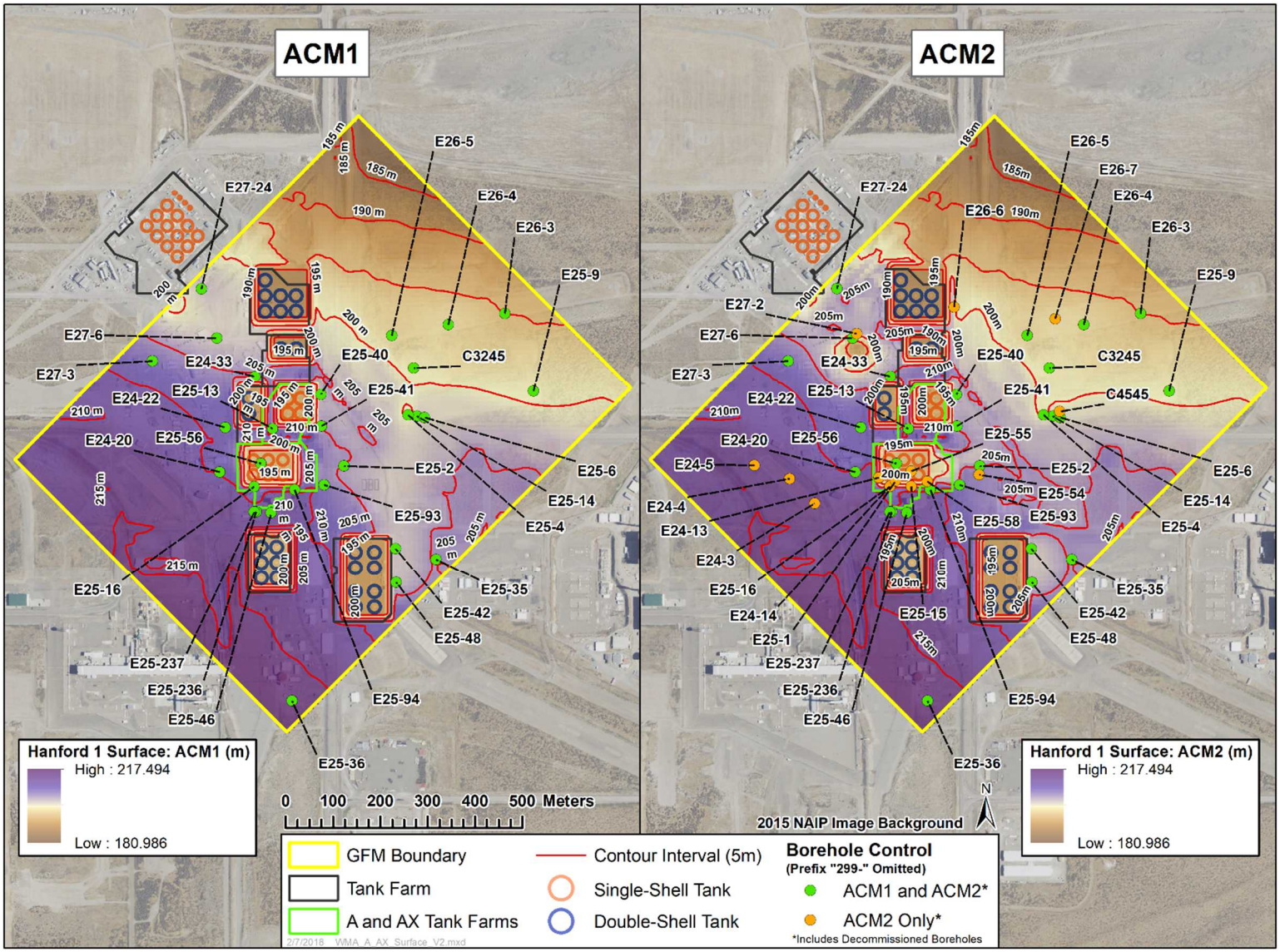
   Settings applied for each stratigraphic unit layer are given in Attachment C.

3. *Assess stratigraphic unit tops in the context of gridded surfaces*. Gridded surfaces were assessed for continuity or discontinuity according to their observed presence or absence at borehole locations. In areas where boreholes were too shallow to encounter deeper geologic units, checks were done to ensure that the deep geologic units were interpolated through consistently. Because of the adequate amount of borehole data for the relatively small WMA A-AX GFMs domain, no "stratigraphic unit" control points were needed to force the geologic unit surfaces to comply better with borehole data or professional judgment.

4. *Export and convert stratigraphic unit surfaces to format usable by Tecplot® software*. A gridded surface for each model layer was exported as an XYZ *.dat file for use as input by Tecplot®. The *.dat surfaces exported from Kingdom® are in text format and require reformatting to be usable by Tecplot®. Therefore, a Python script (rasta.py, Attachment D) developed for this purpose was employed. Following completion of these steps, quality assurance checks were performed as described in Attachment C.

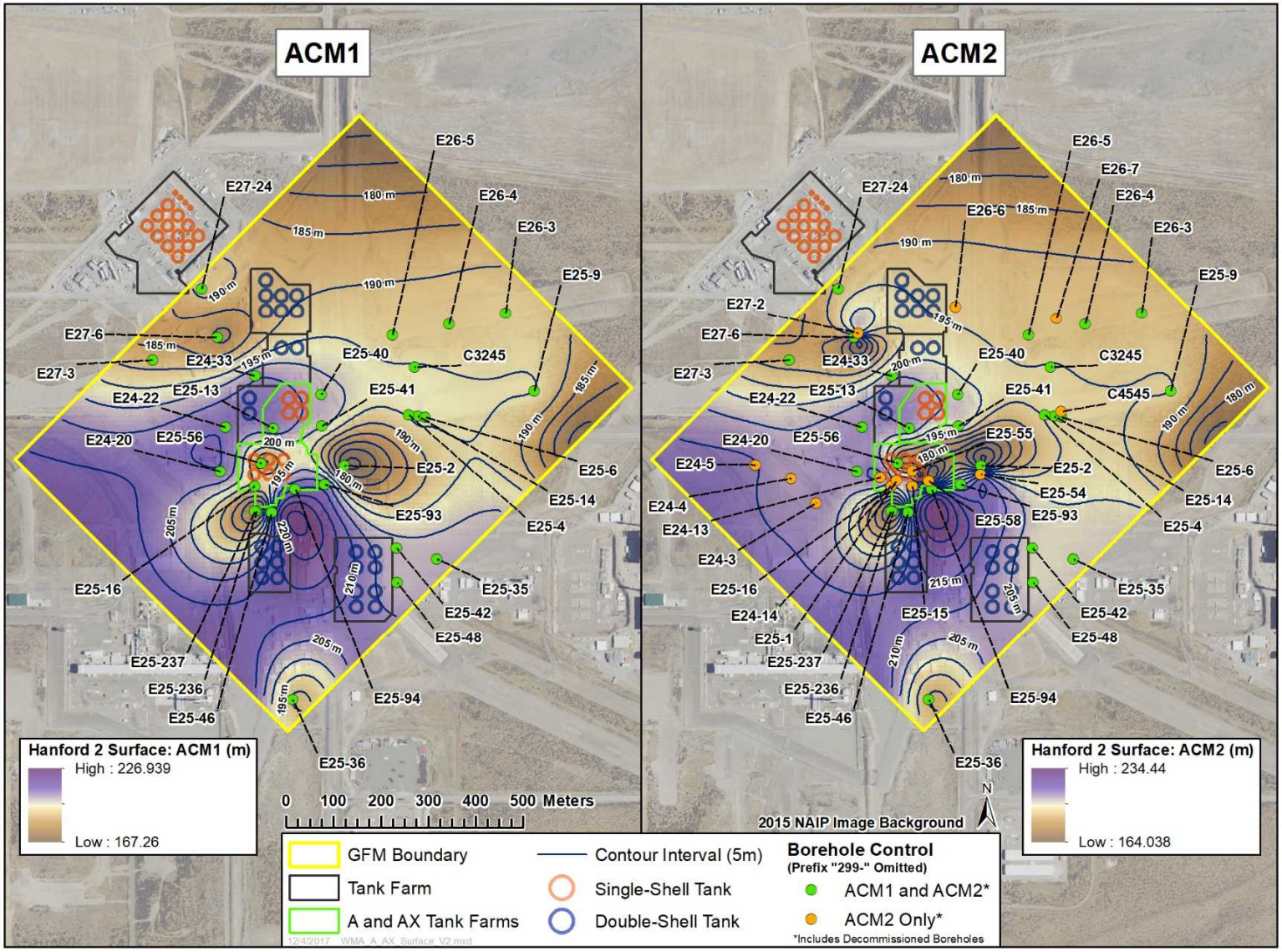
Figure 4-2 through Figure 4-9 show the structure contour maps of the checked, finished stratigraphic unit surfaces and Figure 4-10 through Figure 4-16 are isopach maps showing stratigraphic unit thicknesses based on each surface and the surfaces immediately below it.

Figure 4-2. Hanford Formation Unit 1 Surface Structure Contours.



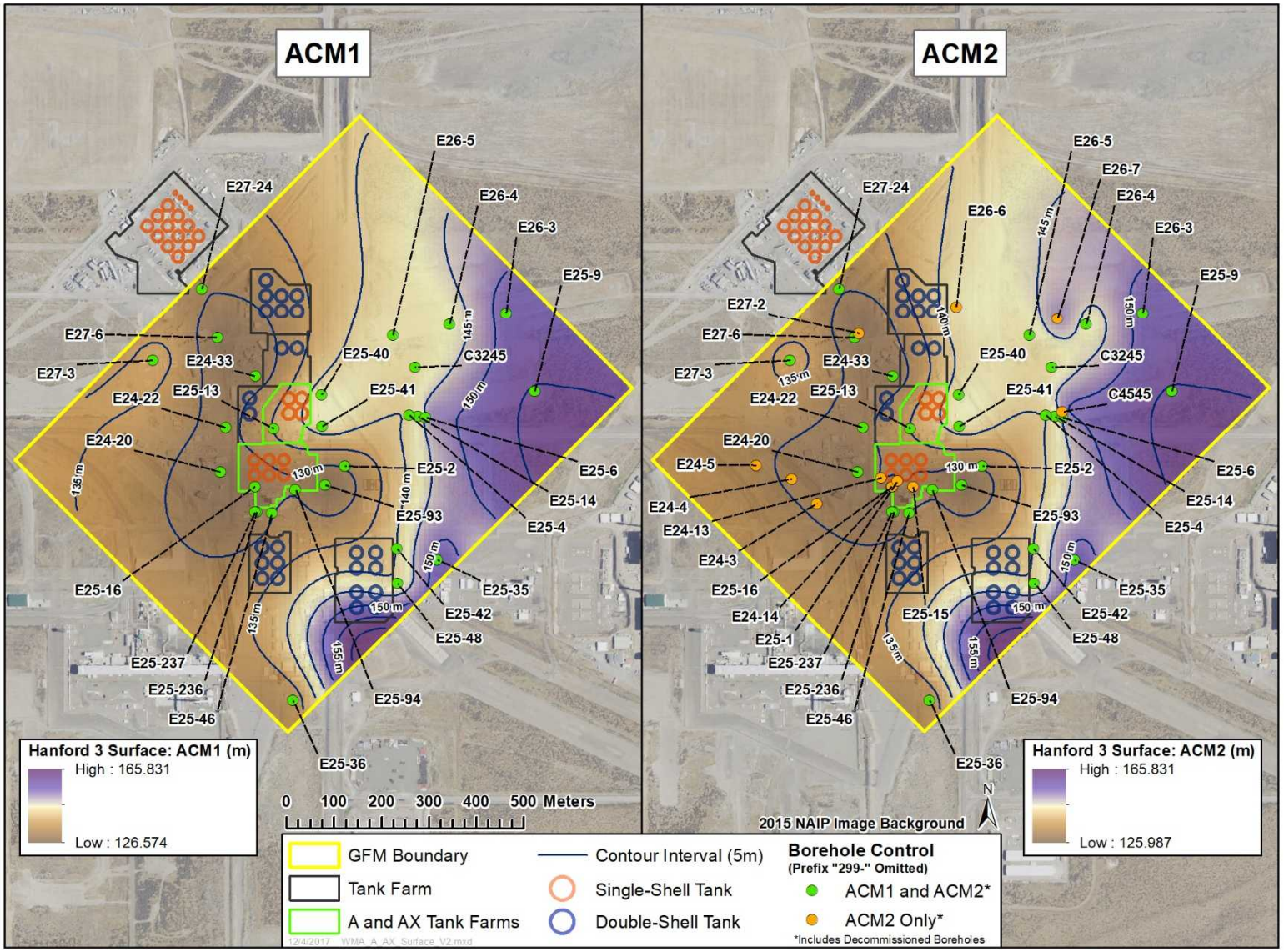
ACM = alternative conceptual model GFM = geologic framework model

Figure 4-3. Hanford Formation Unit 2 Surface Structure Contours.



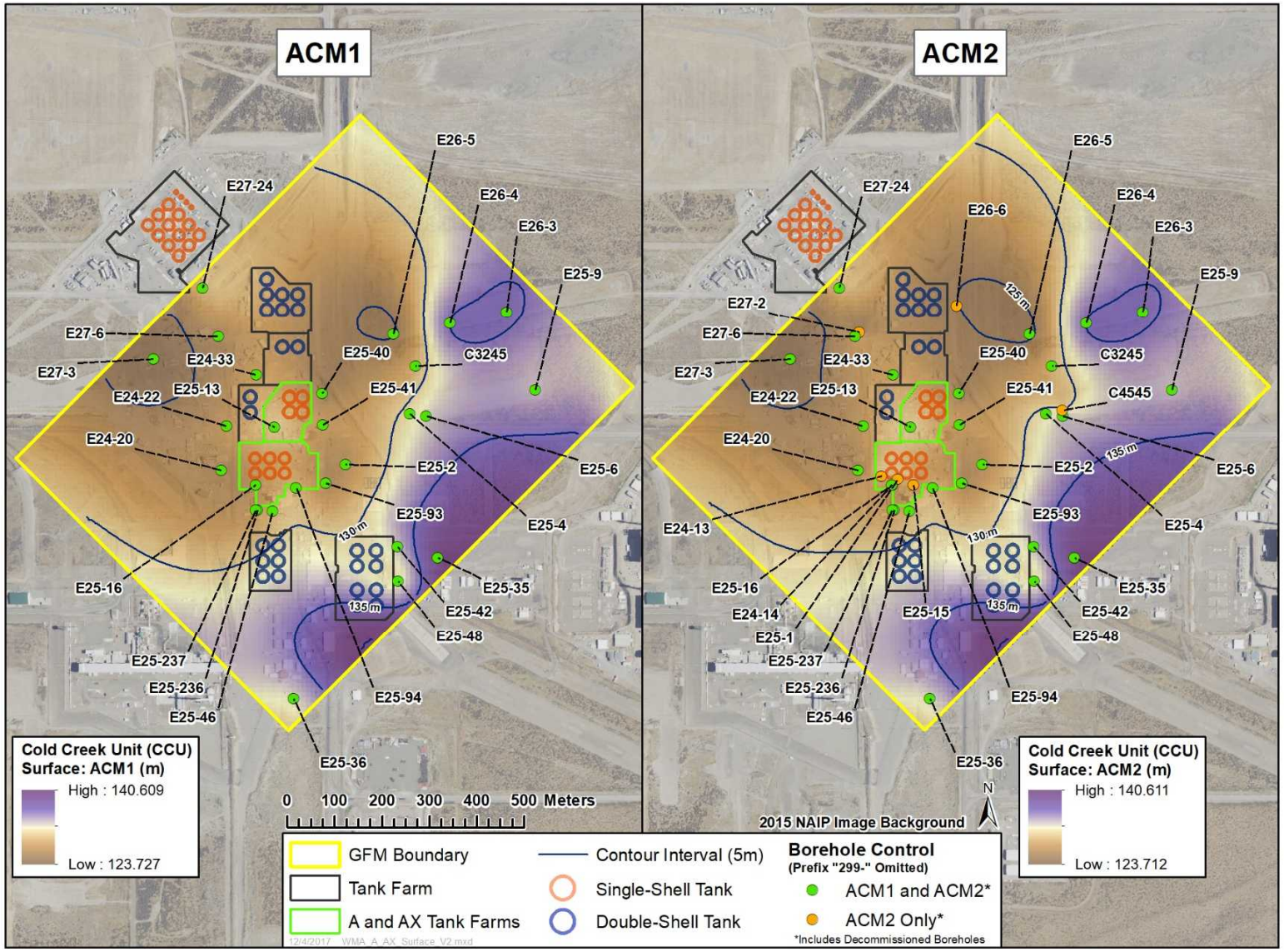
ACM = alternative conceptual model GFM = geologic framework model

Figure 4-4. Hanford Formation Unit 3 Surface Structure Contours.



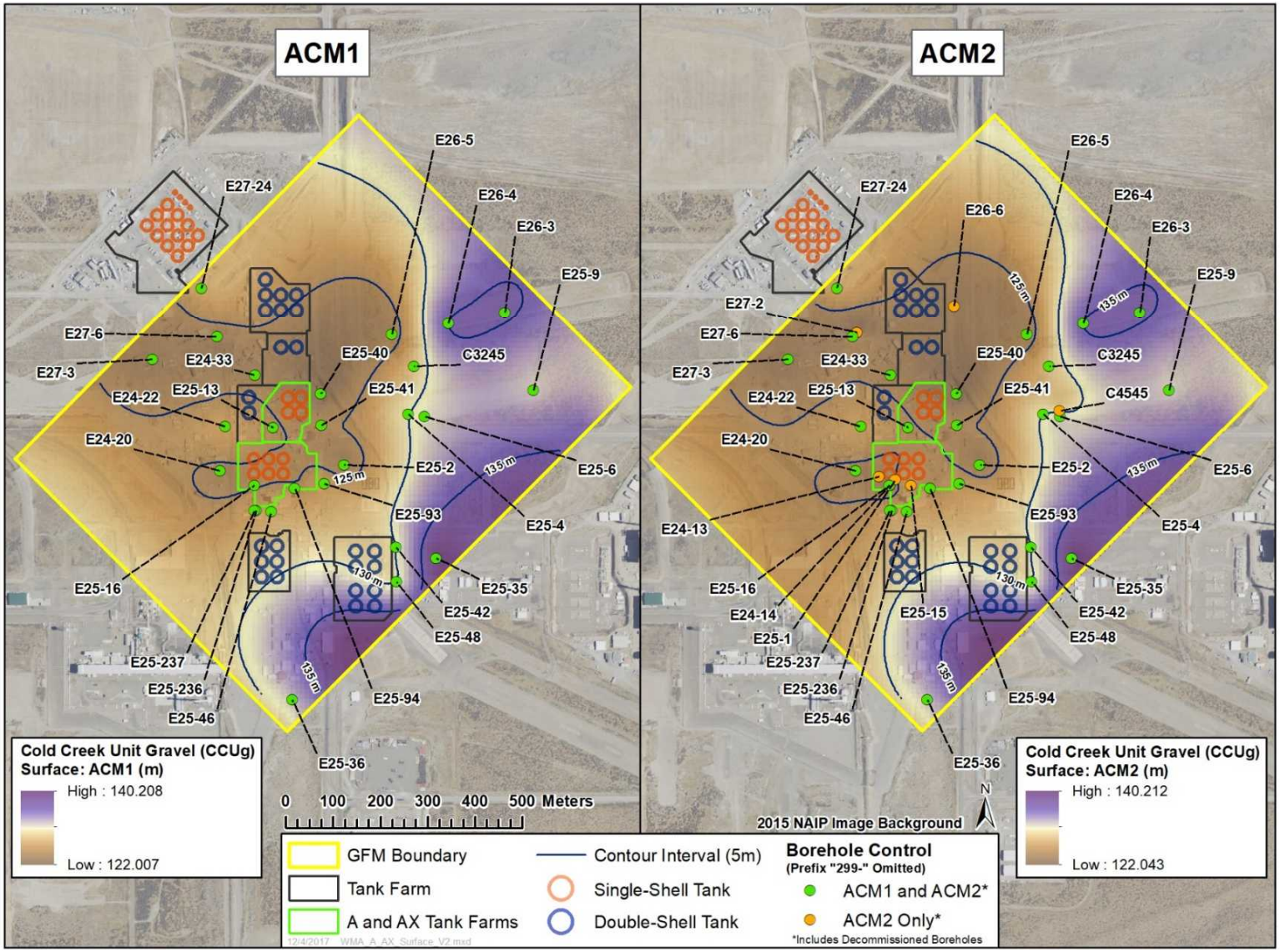
ACM = alternative conceptual model GFM = geologic framework model

Figure 4-5. Cold Creek Unit Undifferentiated Surface Structure Contours.



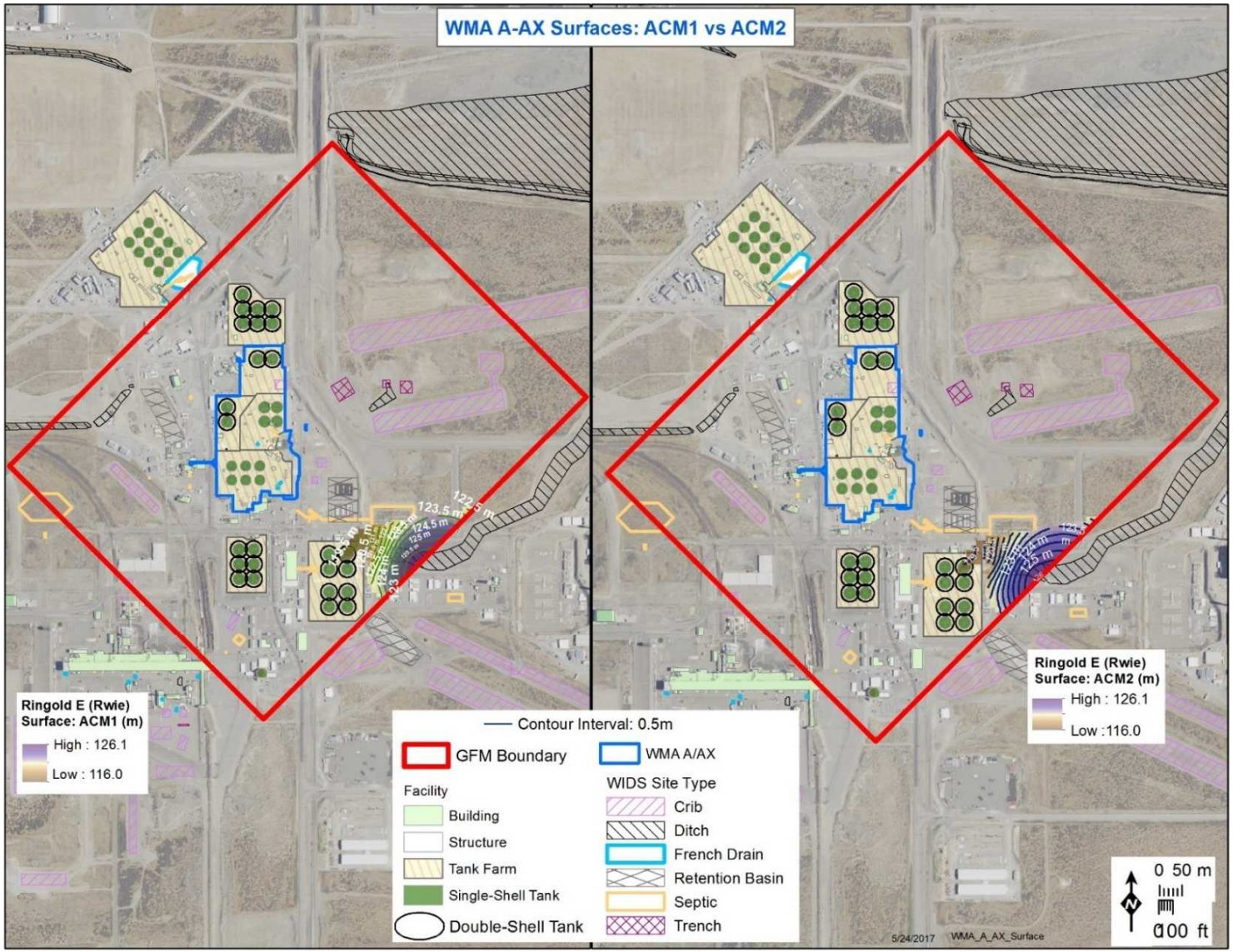
ACM = alternative conceptual model GFM = geologic framework model

Figure 4-6. Cold Creek Unit Gravels Surface Structure Contours.



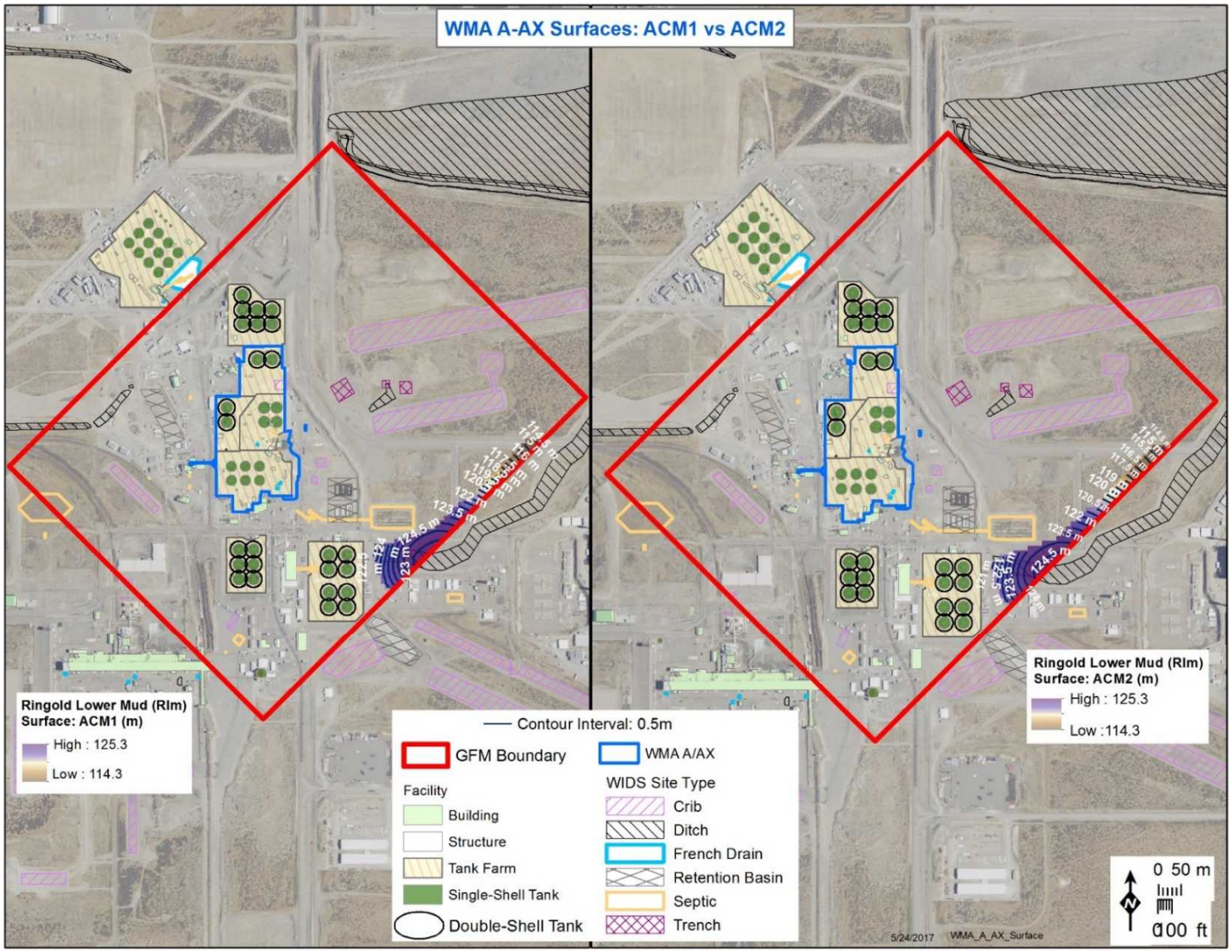
ACM = alternative conceptual model GFM = geologic framework model

Figure 4-7. Ringold Formation Wooded Island Unit E Surface Structure Contours.



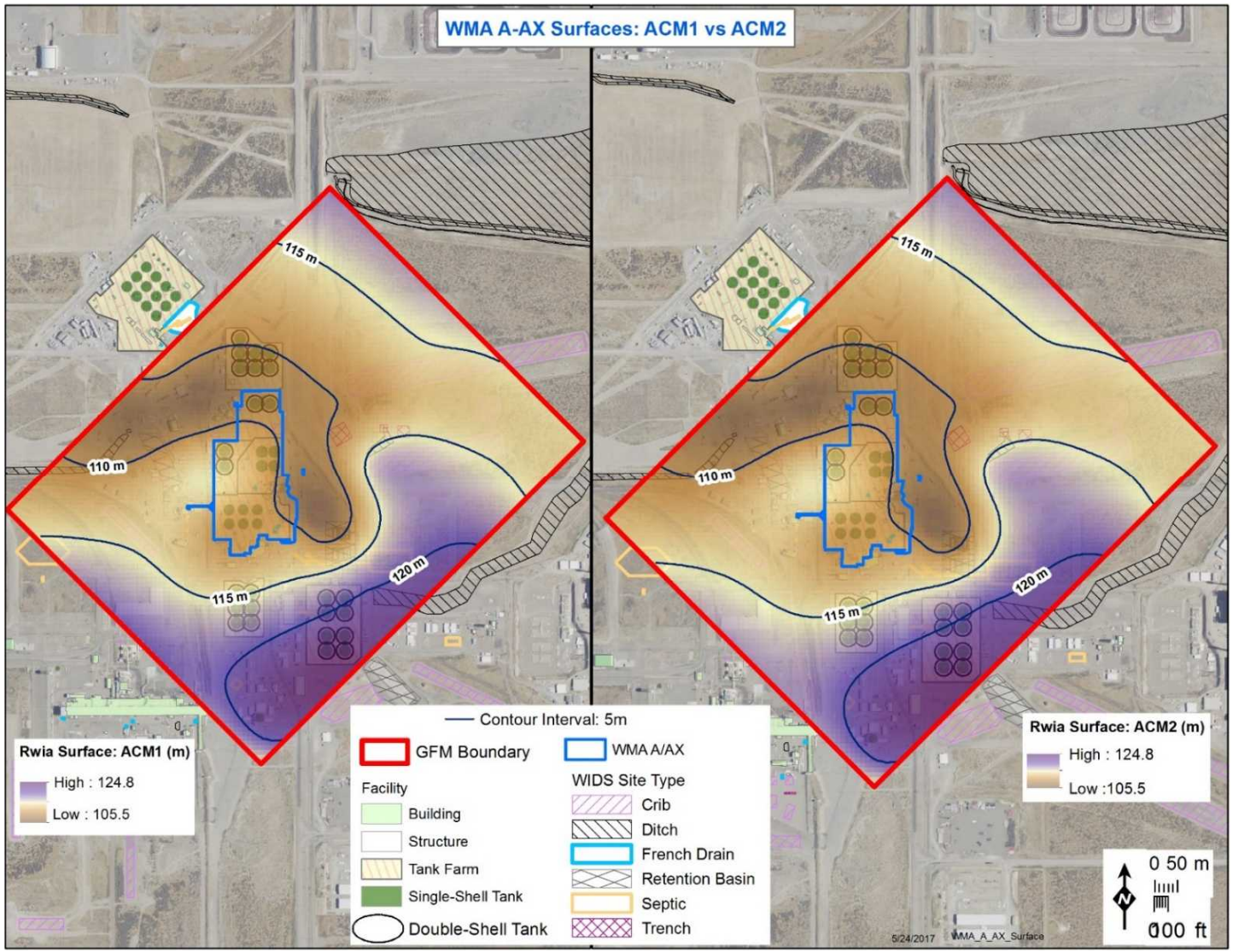
ACM = alternative conceptual model GFM = geologic framework model WIDS = Waste Information Data System WMA = Waste Management Area

Figure 4-8. Ringold Formation Wooded Island Lower Mud Unit Surface Structure Contours.



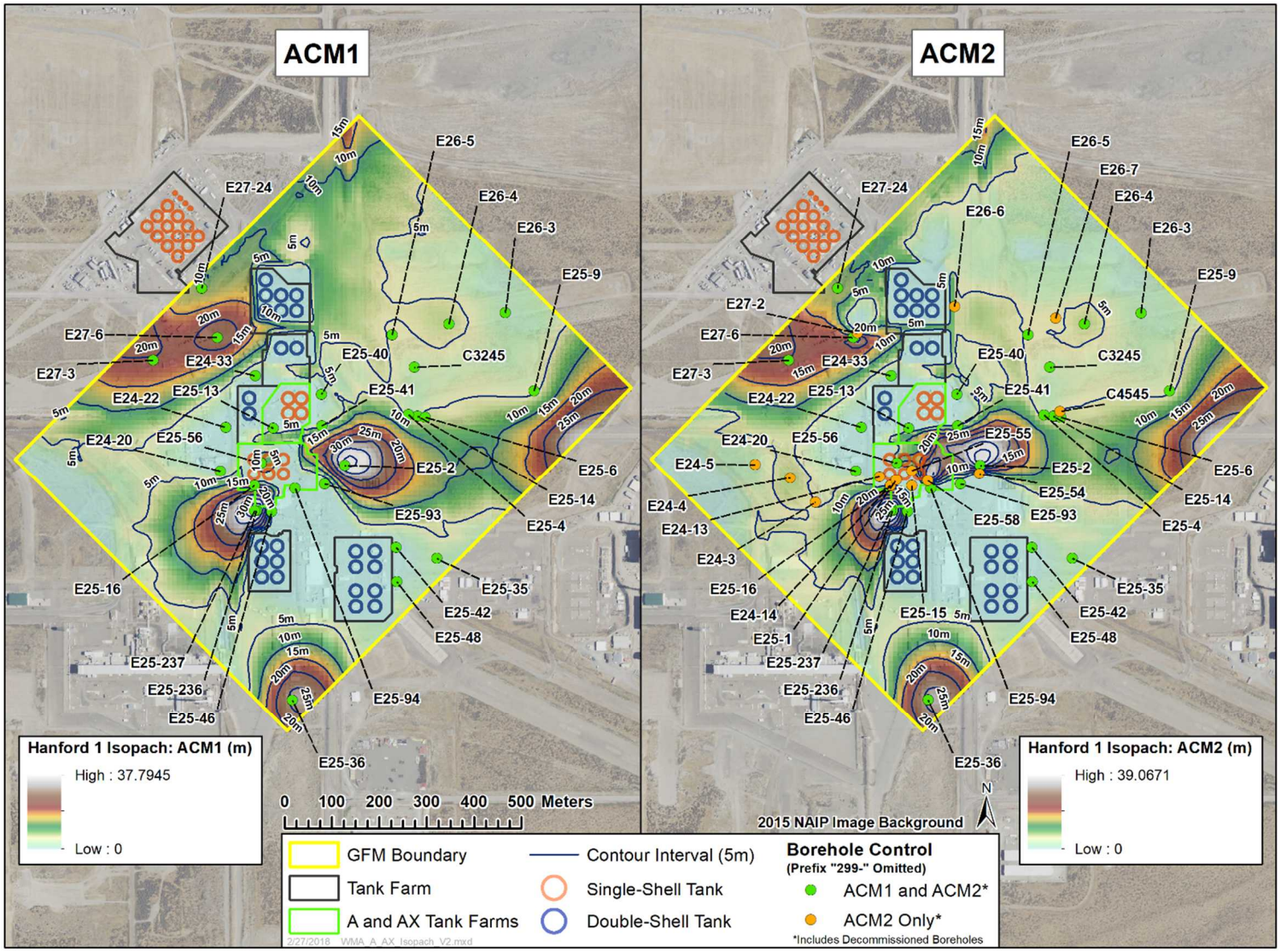
ACM = alternative conceptual model GFM = geologic framework model WIDS = Waste Information Data System WMA = Waste Management Area

Figure 4-9. Ringold Formation Wooded Island Unit A Surface Structure Contours.



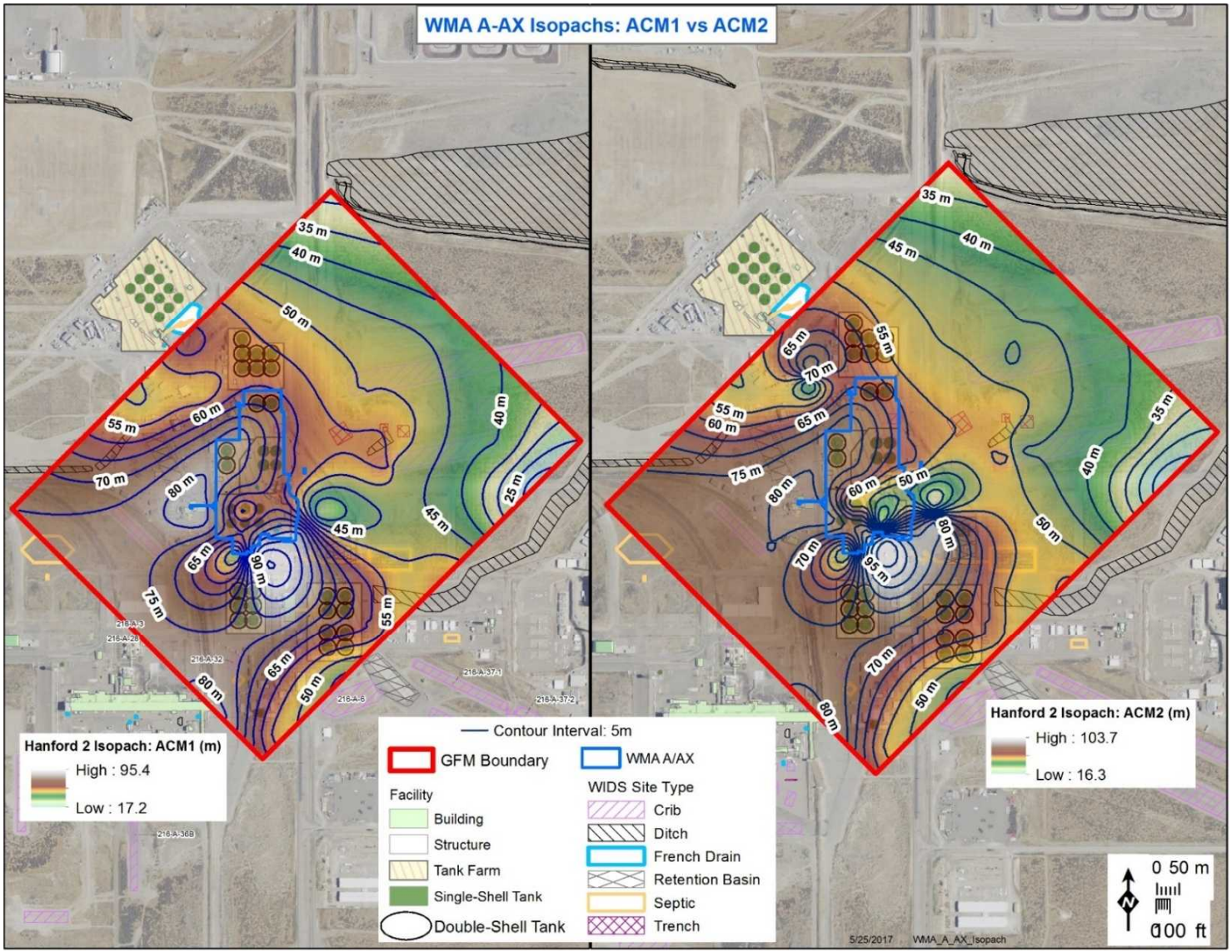
ACM = alternative conceptual model
GFM = geologic framework model
Rwia = Ringold Formation Wooded Island Unit A
WIDS = Waste Information Data System
WMA = Waste Management Area

Figure 4-10. Hanford Formation Unit 1 Isopach Map.



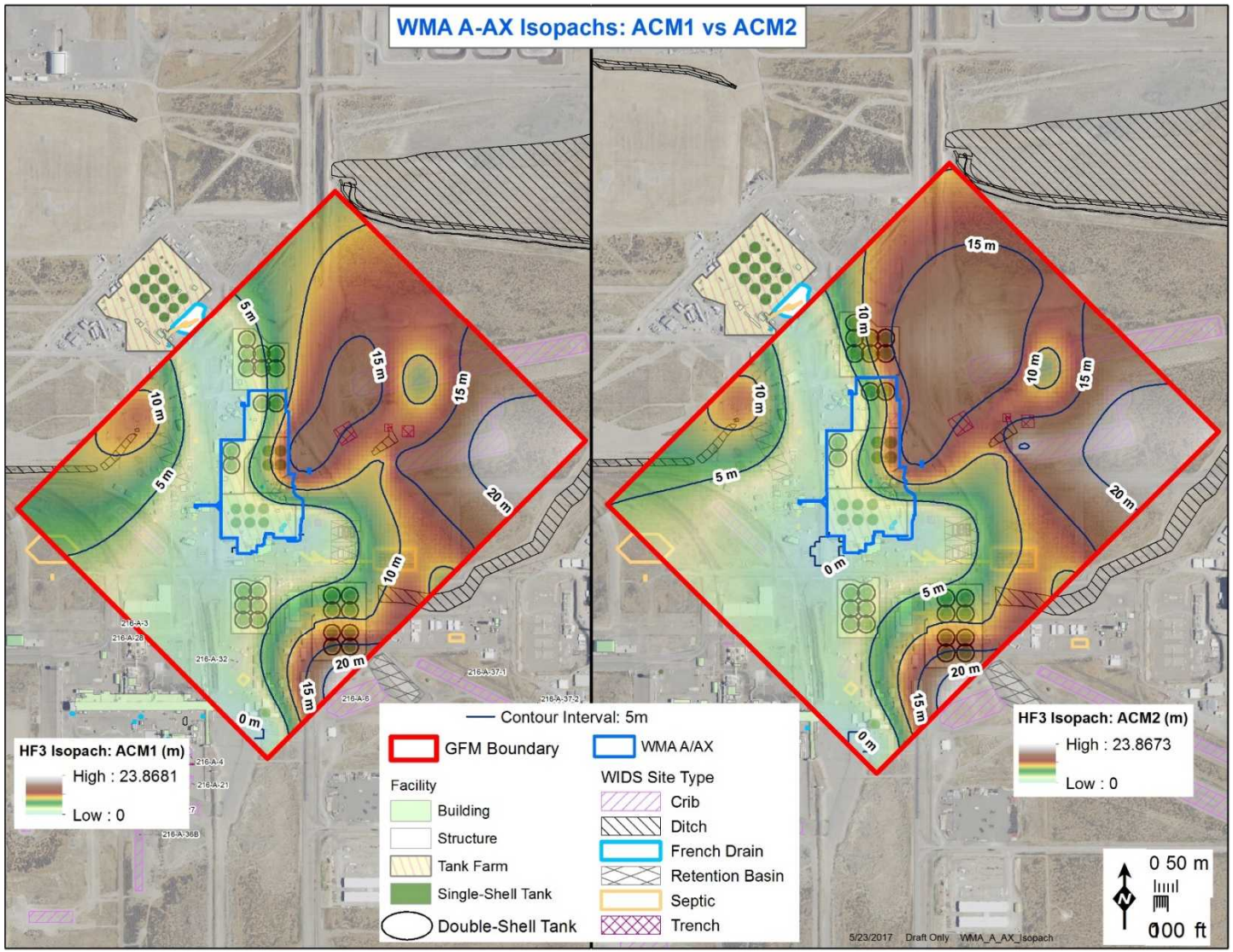
ACM = alternative conceptual model
GFM = geologic framework model
WIDS = Waste Information Data System
WMA = Waste Management Area

Figure 4-11. Hanford Formation Unit 2 Isopach Map.



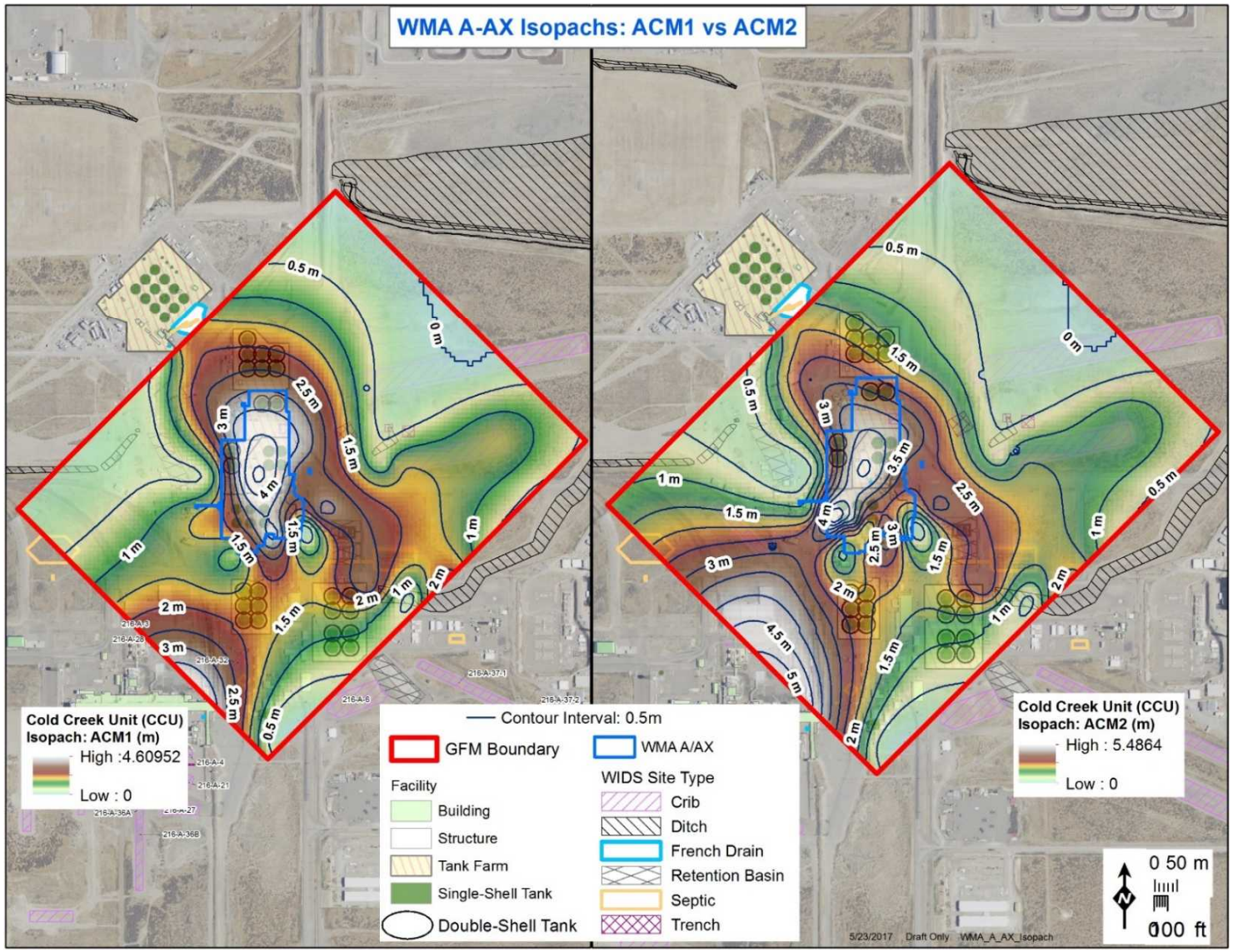
ACM = alternative conceptual model GFM = geologic framework model WIDS = Waste Information Data System WMA = Waste Management Area

Figure 4-12. Hanford Formation Unit 3 Isopach Map.



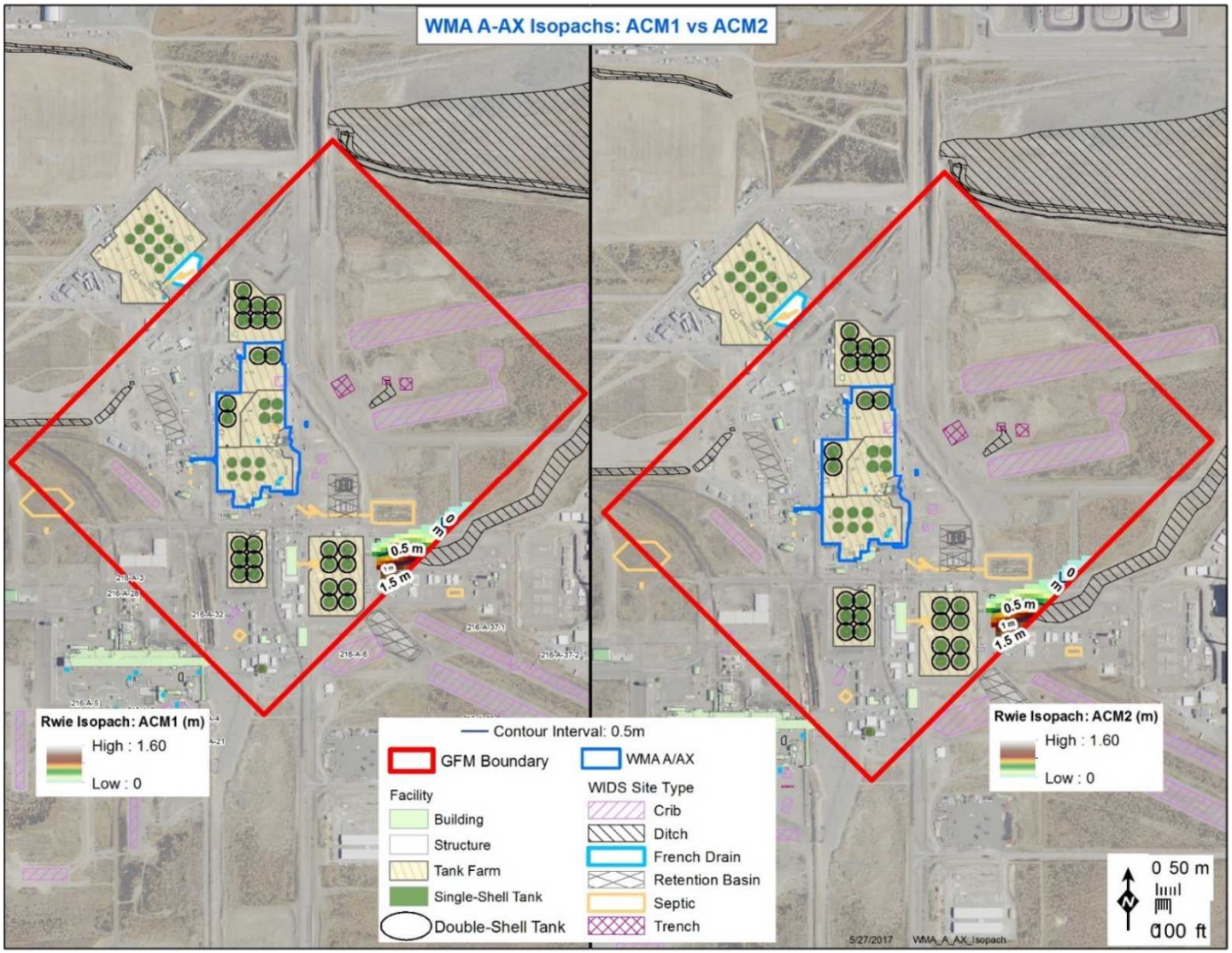
ACM = alternative conceptual model
GFM = geologic framework model
HF3 = Hanford formation Unit 3
WIDS = Waste Information Data System
WMA = Waste Management Area

Figure 4-13. Cold Creek Unit Undifferentiated Isopach Map.



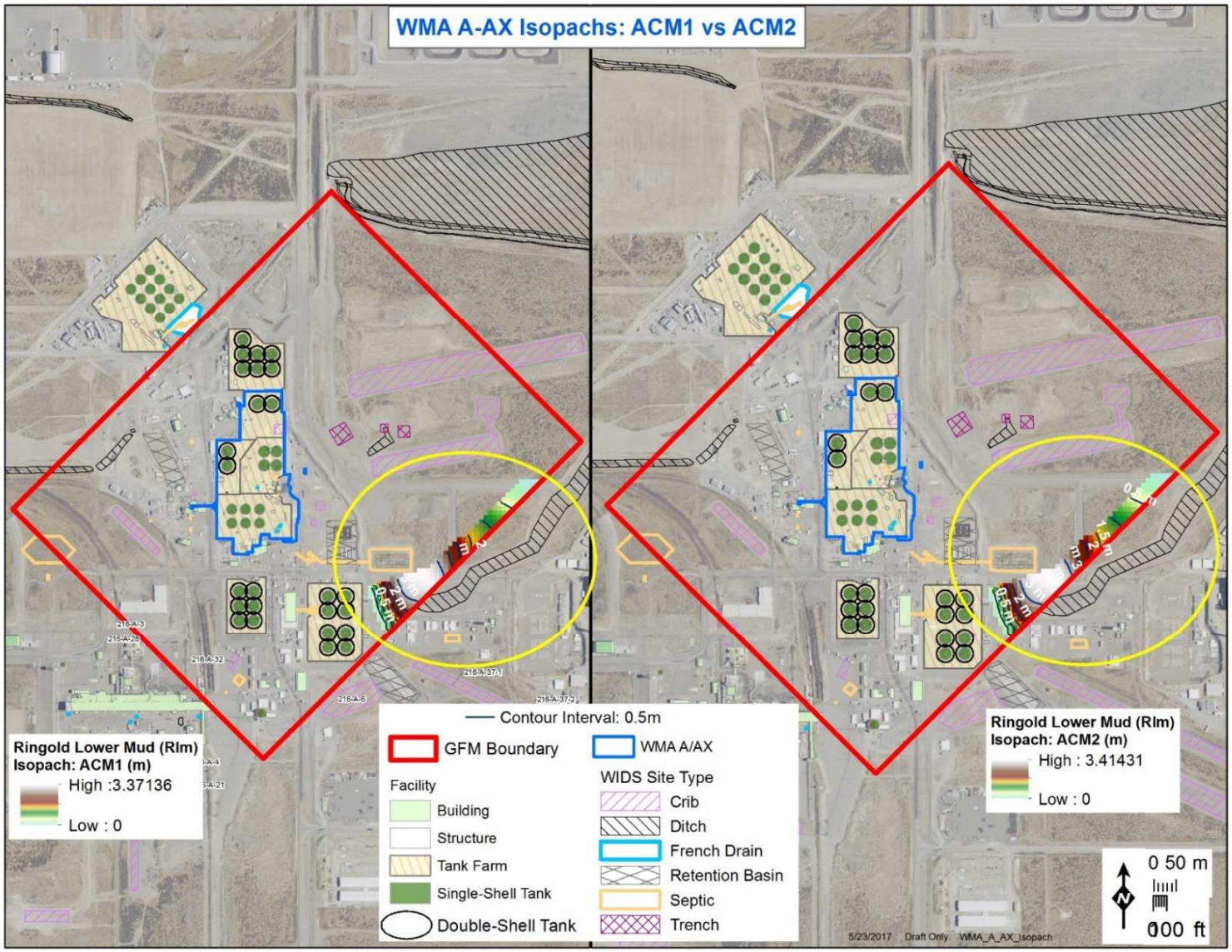
ACM = alternative conceptual model GFM = geologic framework model WIDS = Waste Information Data System WMA = Waste Management Area

Figure 4-14. Ringold Formation Wooded Island Unit E Isopach Map.



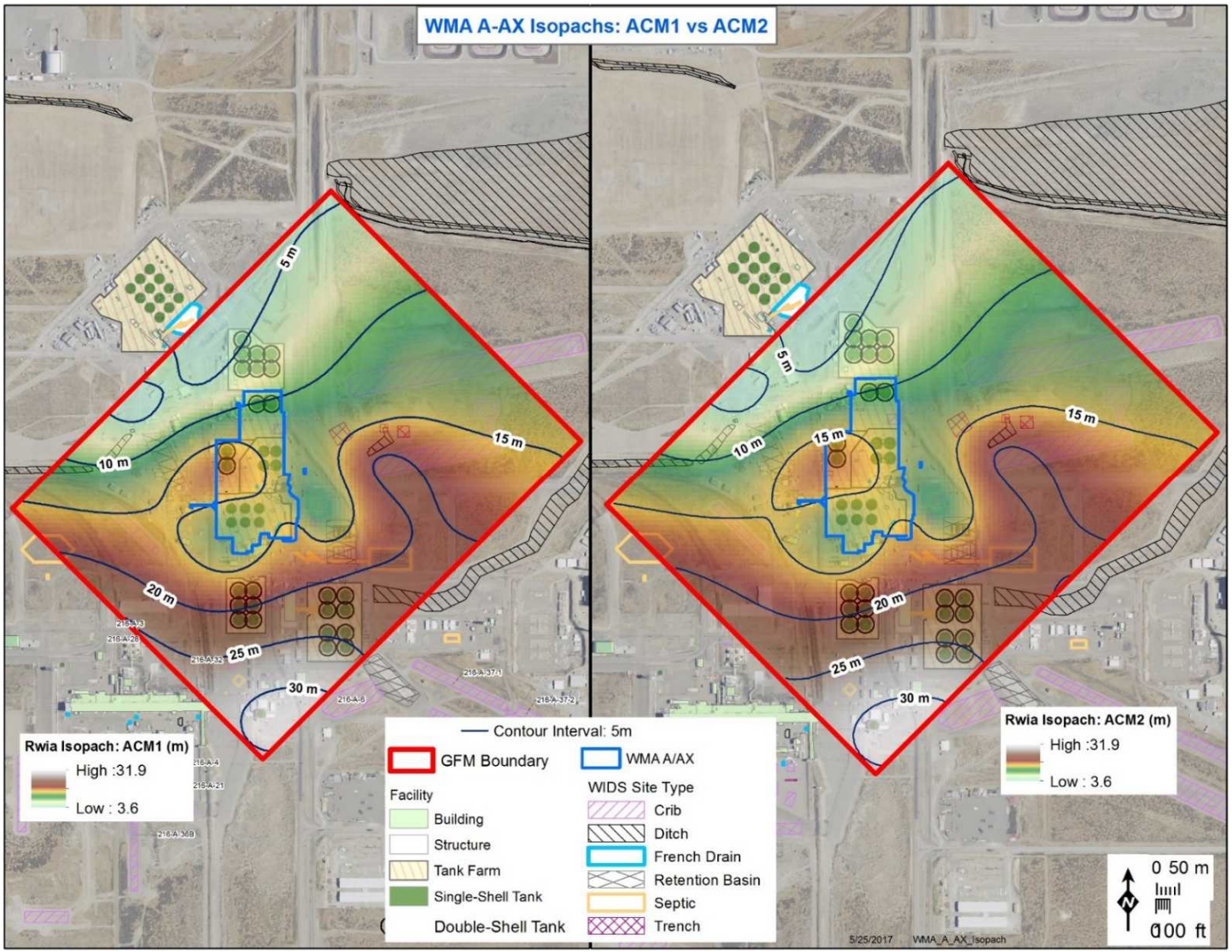
ACM = alternative conceptual model
GFM = geologic framework model
Rwie = Ringold Formation Wooded Island Unit E
WIDS = Waste Information Data System
WMA = Waste Management Area

Figure 4-15. Ringold Formation Wooded Island Lower Mud Unit Isopach Map.



ACM = alternative conceptual model GFM = geologic framework model WIDS = Waste Information Data System WMA = Waste Management Area

Figure 4-16. Ringold Formation Wooded Island Unit A Isopach Map.



ACM = alternative conceptual model
GFM = geologic framework model
Rwia = Ringold Formation Wooded Island Unit A
WIDS = Waste Information Data System
WMA = Waste Management Area

4.2.2 Alternative Conceptual Model 2 Cold Creek Unit Silt Extents Determination

The presence of the Cold Creek Unit silt (CCUz) was often noted, even on driller's logs of questionable quality, because its fine-grained nature, which easily distinguished it from the overlying coarser cataclysmic flood deposits of the Hanford formation. To capture and estimate the extent of this important stratigraphic unit adequately, third-tier ("poor quality") borehole data were included in ACM 2 (Table 3-2). The same stratigraphic units found in ACM 1 are incorporated into ACM 2 and their surfaces have been interpolated from the full set of boreholes with no omissions. Since the top of the Cold Creek Unit undifferentiated (CCUu) (including CCUz, Cold Creek Unit gravels [CCUg] and CCUu undifferentiated) was interpolated as a ubiquitous stratigraphic unit surface within the model domain, probability kriging (PK) was performed to estimate the extent of CCUz within the CCUu in a more quantifiable manner for ACM 2.

Using the additional borehole data to develop ACM 2 affected all stratigraphic unit surfaces, but particular emphasis was placed on CCUz for ACM 2 because of this stratigraphic unit's potential to affect flow and transport modeling results significantly. Differences between the ACMs are discussed below.

Because CCUz is not geometrically differentiated within the extents of the CCUu surface interpolated by Kingdom® for ACM2, indicator kriging was used to estimate the proportion of the CCUu that can be defined as CCUz by the borehole data. PK ("Matrix Formulation of Co-Kriging" [Myers 1982]) strives to render the same results as indicator kriging, but it uses co-kriging to obtain a more robust estimate. ArcGIS® Geostatistical Analyst[7] toolbox was used to perform the PK interpolation of the CCUz extents using the ACM 2 dataset. The results of this interpolation are shown in Figure 4-17.7, and the CCUz thickness extracted to the PK interpolated extents are shown in Figure 4-18.

4.2.3 Development of Three-Dimensional Solids Model of Geologic Framework Model Domain

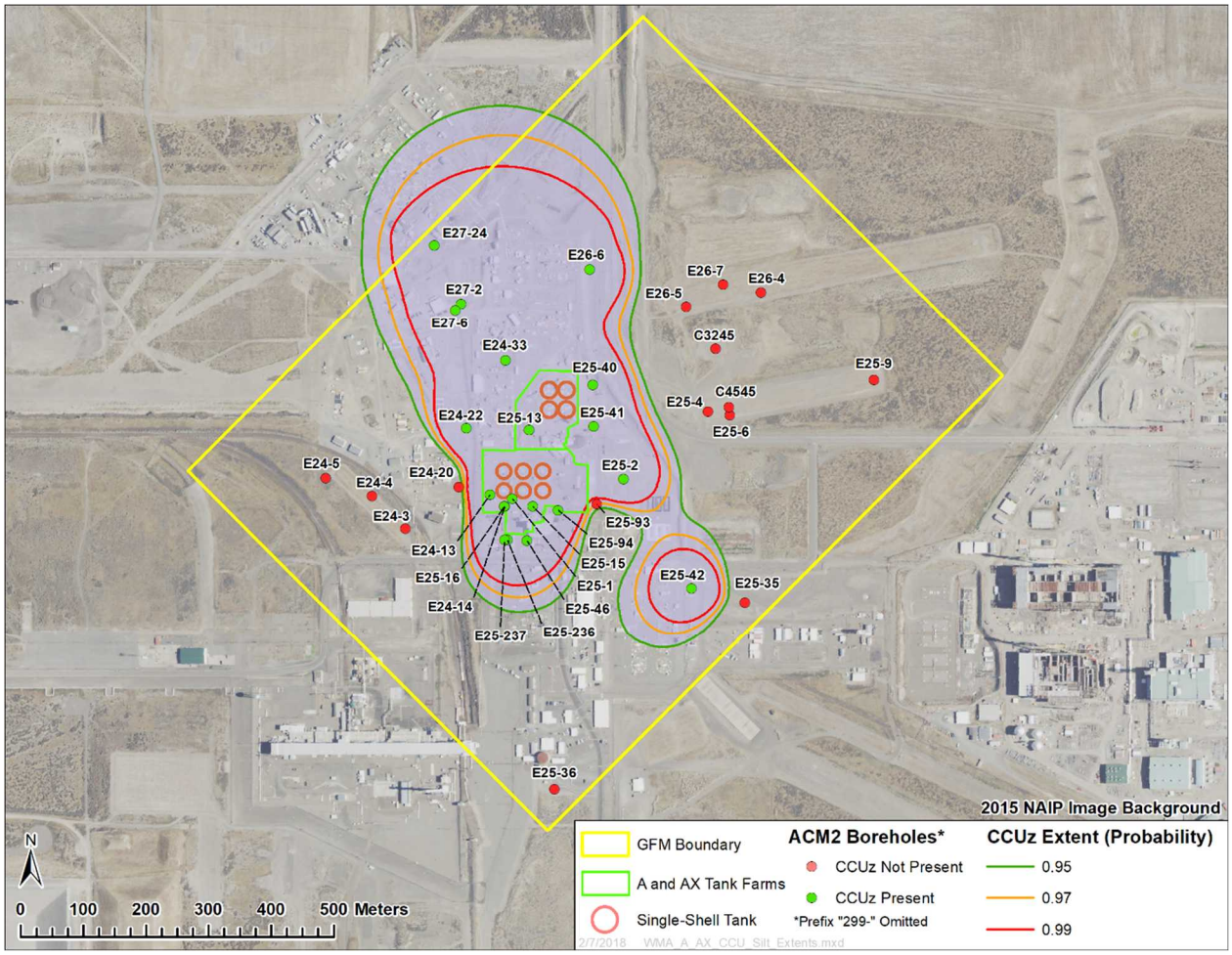
The objective of this section is to document the process for developing 3D digital geologic models for the domain containing WMAs A-AX and C (SSTs) and double-shell tank farms 241-AN, 241-AP, 241 AW, 241-AY, and 241-AZ (Figure 4-19). Between the base of the unconfined aquifer (i.e., TOB) and ground surface, this area of the Hanford Site has the following stratigraphic units present:

1. Top of the Columbia River basalt (TOB)
2. Ringold Formation Wooded Island Unit A (Rwia)[8]
3. Ringold Formation Wooded Island Lower Mud Unit (Rlm)[7]
4. Ringold Formation Wooded Island Unit E (Rwie)[7]
5. Cold Creek Unit gravels (CCUg)[7]

[7] ArcGIS® is a registered trademark of Environmental Systems Research Institute, Inc., Redlands, California.
[8] Indicates this member has been divided into two zones; one that is below the water table (saturated zone), and one that is above the water table (vadose zone).

6. Cold Creek Unit silt (CCUz)[9]
7. Cold Creek Unit sand (CCUs)[8]
8. Hanford formation Unit 3 (HF3)
9. Hanford formation Unit 2 (HF2)
10. Hanford formation Unit 1 (HF1)
11. Eolian sand
12. Backfill.

Figure 4-17. Cold Creek Unit Silt Extents Interpolated by Probability Kriging.



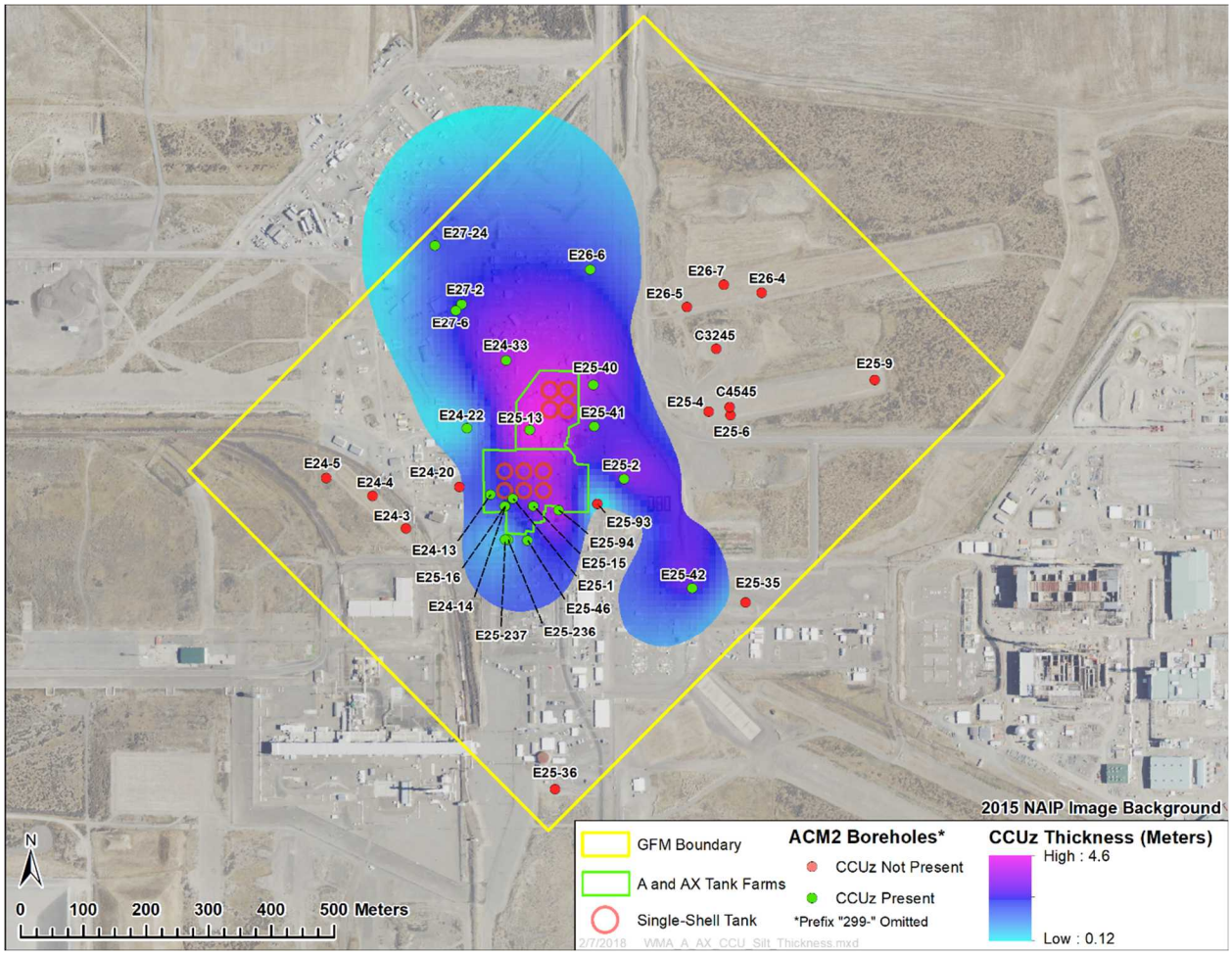
ACM = alternative conceptual model CCUz = Cold Creek unit silt GFM = geologic framework model

For each of these stratigraphic units, a volume which defines the XYZ extent of the unit has been created and assigned a unit number. Once a unit volume is created and assigned a stratigraphic unit number, the volume representing each stratigraphic unit can be used to assign material properties for a vadose zone/groundwater model. Two different 3D GFMs were developed to accommodate the surfaces of both ACM 1 and ACM 2. As noted previously, the primary difference between the two GFMs is the more detailed depiction of the lateral and vertical extent

[9] In ACM 1, CCUz and CCUs are combined into one unit (CCUz), while in ACM 2, CCUz and CCUs are separate units (see Section 4.2.2).

of the Cold Creek silt unit and Cold Creek sand unit in ACM 2 resulting from the inclusion of additional borehole data omitted from ACM 1. The following sections provide the process for developing these digital geologic models of WMA A-AX and WMA C.

Figure 4-18. Cold Creek Unit Silt Thickness Extracted to Extents Interpolated by Probability Kriging.

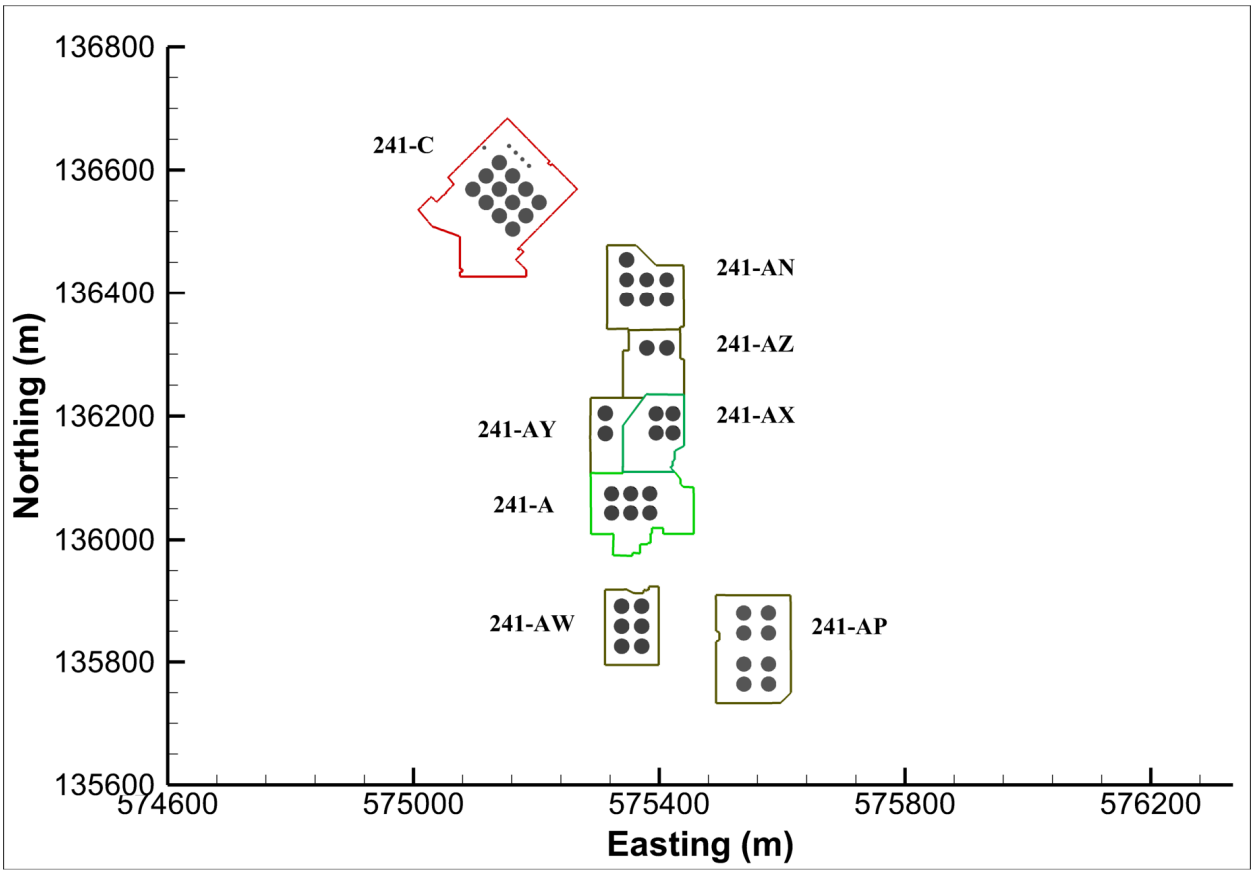


ACM = alternative conceptual model CCUz = Cold Creek Unit silt GFM = geologic framework model

4.2.3.1 Originating Surfaces and/or Thicknesses Used in the Three-Dimensional Geologic Models

This section describes the source of the stratigraphic unit surfaces in each of the 3D GFMs. The borehole geologic interpretations developed to provide data for their interpolation are described in Section 3.0. Interpolation of these surfaces from the borehole data is described in the next section. In addition to the stratigraphic surfaces, two additional surfaces are needed to complete the 3D GFM. These surfaces are (1) the bottom of the excavation for each tank farm and (2) land surface elevation. The source of the data for these additional surfaces are also provided in this section.

Figure 4-19. Location of Single-Shell Tank Farms 241-A, 241-AX, and 241-C along with the Double-Shell Tank Farms 241-AN, 241-AP, 241 AW, 241-AY, and 241-AZ.



4.2.3.1.1 Stratigraphic Surfaces. The top of each of the stratigraphic units were exported from the Kingdom® software and converted to *.asc format to be incorporated into Tecplot® to build the digital 3D model. Table 4-2 lists the files that were used in ACM 1 and ACM 2. In addition to the top of the units given in Table 4-2, a TOB surface from the Hanford South geologic model was provided in raster file TOB_20m_HS051016EXP.asc (ECF-HANFORD-13-0029 and ECF-Hanford-16-0128) and was used to form the base of each of the GFMs.

4.2.3.1.2 Tank Farms Excavation Construction for Backfill. The bottom and sides of the excavation in both the single-shell and double-shell tank farms at the A Complex were developed as part of the PW-1,3,6 3D Waste Sites model (ECF-Hanford-14-0054, "*Three-Dimensional Waste Site Models for the 200-PW-1/3/6 and 200-CW-5 Operable Unit Waste Sites, Central Plateau, Hanford Site, Richland, Washington*") and were provided as the following ASCII data files:

1. 241-A Excavation_pt.asc and 241-A Excavation_tr.asc
2. 241-AX Excavation_pt.asc and 241-AX Excavation_tr.asc
3. 241-AN Excavation_pt.asc and 241-AN Excavation_tr.asc
4. 241-AP Excavation_pt.asc and 241-AP Excavation_tr.asc

5. 241-AW Excavation_pt.asc and 241-AW Excavation_tr.asc
6. 241-AY Excavation(not final)_pt.asc and 241-AY Excavation(not final)_tr.asc
7. 241-AZ Excavation(not final)_pt.asc and 241-AZ Excavation(not final)_tr.asc.

Table 4-2. List of Raster Files Used to Develop Both Geologic Framework Models.

Alternative Conceptual Model 1	Alternative Conceptual Model 2
WMA_A_AX_ACM 1_04272017_Rwia.asc	WMA_A_AX_ACM2_04272017_Rwia.asc
WMA_A_AX_ACM 1_04272017_Rlm.asc	WMA_A_AX_ACM2_04272017_Rlm.asc
WMA_A_AX_ACM 1_04272017_Rwie.asc	WMA_A_AX_ACM2_04272017_Rwie.asc
WMA_A_AX_ACM 1_04272017_CCUg.asc	WMA_A_AX_ACM2_04272017_CCUg.asc
WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc	ccuz_95_thcknss.asc*
	WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc
WMA_A_AX_ACM 1_04272017_HF3.asc	WMA_A_AX_ACM2_04272017_HF3.asc
WMA_A_AX_ACM 1_04272017_HF2.asc	WMA_A_AX_ACM2_04272017_HF2.asc
WMA_A_AX_ACM 1_04272017_HF1.asc	WMA_A_AX_ACM2_04272017_HF1.asc

* In the case of silt unit (CCUz) for ACM 2, a thickness and extent of unit were provided instead of the top of the unit. This thickness was added to the top of the underlying unit to come up with a top for CCUz. The top of the CCUz in ACM 2 is the bottom of Cold Creek Unit sand.

Each tank farm excavation has two files: one contains points with the XYZ information (_pt.asc), while the second file contains the triangles (_tr.asc), which describe how the points are connected to form a surface. The first two tank farms (A and AX) are SST farms; all others are double-shell tank farms.

Bottom of excavation for the tanks at WMA C was created by generating a number of XYZ points in Tecplot 360® using the information given in BPF-73550, "*Specifications For Construction of Composite Storage Tanks Bldg. No. 241 Hanford Engineer Works Project 9536*" (Drawing 1), and ARH-LD-132, *Geology of the 241-C Tank Farm*. Once the XYZ points that describe the dimensions of the excavations were created in Tecplot 360®, a triangulation routine (which is part of Tecplot 360®) was used to connect the XYZ points to create a surface for the bottom of the excavation.

4.2.3.1.3 Land Surface Elevation. Ground surface elevation came from the 2008 WCH/Aero-Metric Flyover Coverage (Aero-Metric LiDAR 2008), including the following files:

- Ground000083.xyz - Ground000088.xyz
- Ground000104.xyz - Ground000109.xyz
- Ground000126.xyz - Ground000131.xyz
- Ground000150.xyz - Ground000155.xyz
- Ground000174.xyz - Ground000179.xyz
- Ground000196.xyz - Ground000201.xyz

These files contained XYZ point data of the land surface and were read into Tecplot 360®. The Tecplot 360® triangulation routine was used to connect the point data to each other to create a surface.

4.2.3.2 Development of Two-Dimensional Triangular Mesh for the Geologic Framework Models

Not all stratigraphic unit surfaces provided in the previous section had the same XY extent or the same grid resolution, which are necessary to build a 3D GFM of the region of interest. Therefore, a common 2D triangular, finite element mesh was developed that would be used for all the stratigraphic units in both GFMs. The details of building this mesh are given in Attachment F. Figure 4-200(a) shows the final triangular mesh for the domain. It consists of 25,908 nodes and 51,444 elements. Figure 4-200(b) shows the finer mesh at WMA A-AX. The nodes are color coded to the grid from which they originated.

4.2.3.3 Construction of Three-Dimensional Geologic Framework Models

This section describes the process of building ACM 1 and ACM 2 GFMs within Tecplot 360® using the surfaces/files listed in Section 4.2.2.1 and triangular finite element mesh (TFEM).

4.2.3.3.1 Alternative Conceptual Model 1. Initially, the TFEM described in Section 4.2.3.2 is loaded into Tecplot 360®. The TOB unit (TOB_20m_HS051016EXP.asc) is then loaded into Tecplot 360®. The TFEM is then duplicated twice, with the first duplication becoming the "bottom" of the Columbia River basalt (this was arbitrarily set to 50 m NAVD88 [base of the model]), while the second duplication was the target of linear interpolation from TOB_20m_HS051016EXP.asc. Once the elevations defining the base of the model and the TOB are interpolated onto a TFEM, the thickness between the surfaces is calculated by subtracting the bottom surface from the top surface. The top and bottom TFEM surfaces are then joined together using Volume Zone Add-On in Tecplot 360® to create a unit zone, which has twice as many nodes as the TFEM but the same number of elements. The steps followed for creating a volume zone for each lithologic unit are given in Table F-1 of Attachment F. The final solids model for ACM 1 is shown in Figure 4-21. The upper Figure 4-21(a) shows a cutaway view along a north-south section of A Farm and an east-south cross-section through AX Farm. The lower Figure 4-21(b) depicts close-up views of several west-east and north-south cross-sections through ACM 1 in the vicinity of WMA A-AX.

4.2.3.3.2 Alternative Conceptual Model 2. ACM 2 was built in the same manner as ACM 1, as shown in Table 4-2, with a few exceptions. Only the exceptions will be discussed. First, the source raster file grids (i.e., WMA_A_AX_ACM 1_*.asc) given in Table F-1 of Attachment F were replaced with those listed on the right side of Table 4-2. A major difference was for the CCUz, for which a raster file grid of the thickness and extent of the unit was provided. The first step was to take the null value (area in which there is no CCUz) and set it to thickness of 0. The next step was to linearly interpolate the thickness of the unit onto the TFEM mesh with the points located outside the range of the raster file grid set to 0. This TFEM mesh was then added to the top of the CCUg to come up with the top of the CCUz. The thickness between was calculated by subtracting the top of the CCUg from the CCUz and blanking areas where the elevations coincide (i.e., areas of zero thickness). These are the only differences in the building of ACM 2 over ACM 1; otherwise, the steps listed in Table 4-2 are the same for both models.

For comparison purposes, Figure 4-22 provides the same cross-sectional views for ACM 2 as Figure 4-21 does for ACM 1, with the exception of adding the extent of CCUz in Figure 4-22. Other differences are given in Table F-2, starting with the Cold Creek silt. Units below the Cold Creek silt are the same as in Table F-1.

The Kingdom® software was used to generate raster file grids of the top surface of all stratigraphic units except for CCUz in ACM 2; for that unit, the lateral extent and thickness of the unit was provided. These raster file grids were used to linearly interpolate the values from the raster file grids onto the Tecplot 360® TFEM with Tecplot®. Attachment F provides a comparison of contour values between the linearly interpolated TFEM and the original Kingdom® raster file grid.

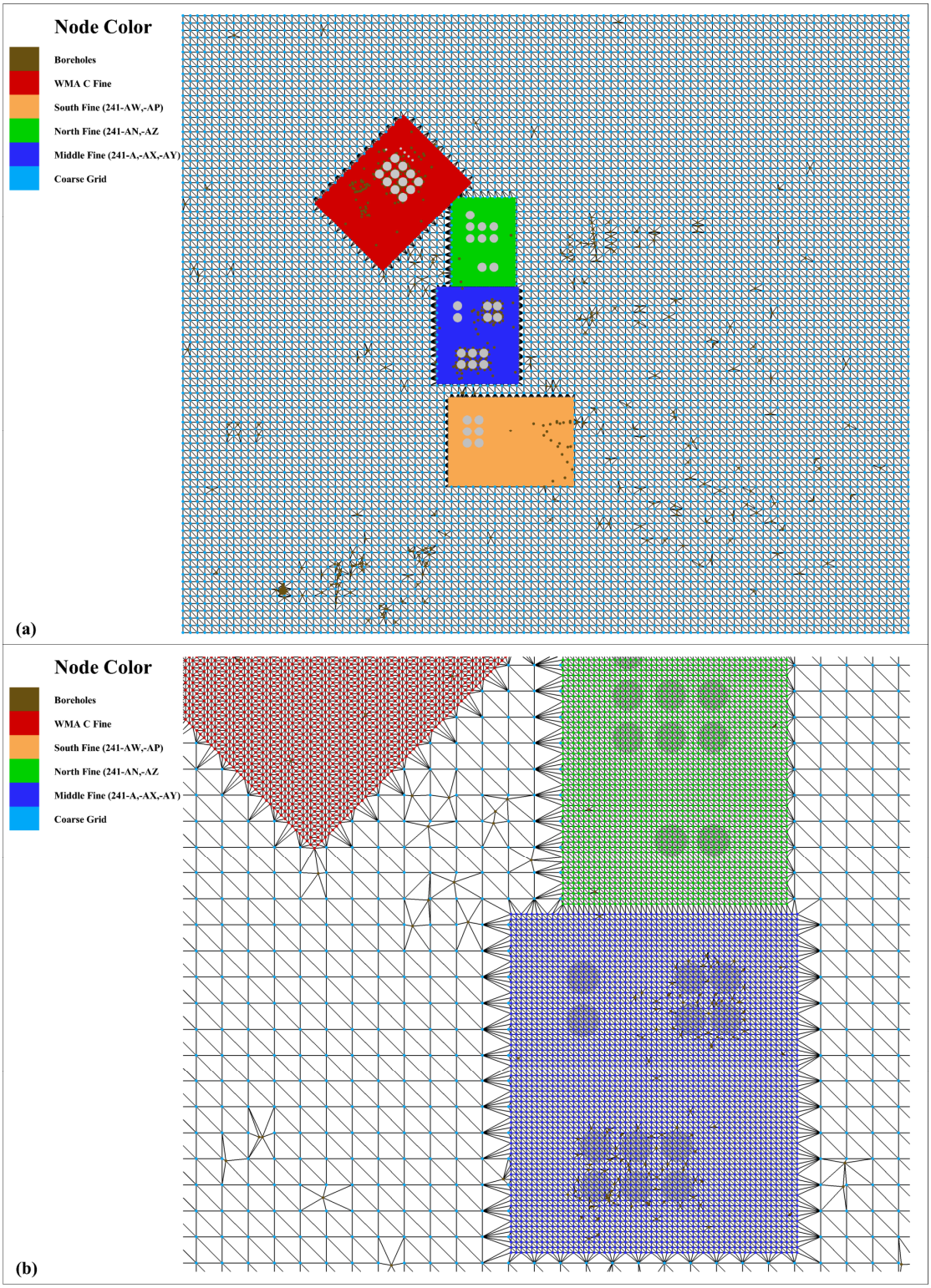
4.3 RESULTS OF GEOLOGIC FRAMEWORK MODEL DEVELOPMENT

Results of both GFMs' interpolation within Tecplot® can be examined by viewing the model in the software itself or by exporting images of cross-sections and 3D slices. Current examples of the completed WMA A-AX GFM ACM 1 are shown in Figure 4-21 and WMA A-AX GFM ACM 2 are shown in Figure 4-22. The 3D volumes and cross-sections in both GFMs' images were generated in Tecplot®.

All electronic files supporting this model construction are archived in the Environmental Model Management Archive (EMMA) indexed to this MPR number (RPP-RPT-60171), which is stored both at INTERA Incorporated and on the PRC-Spatial server at CH2M HILL Plateau Remediation Company (CHPRC).

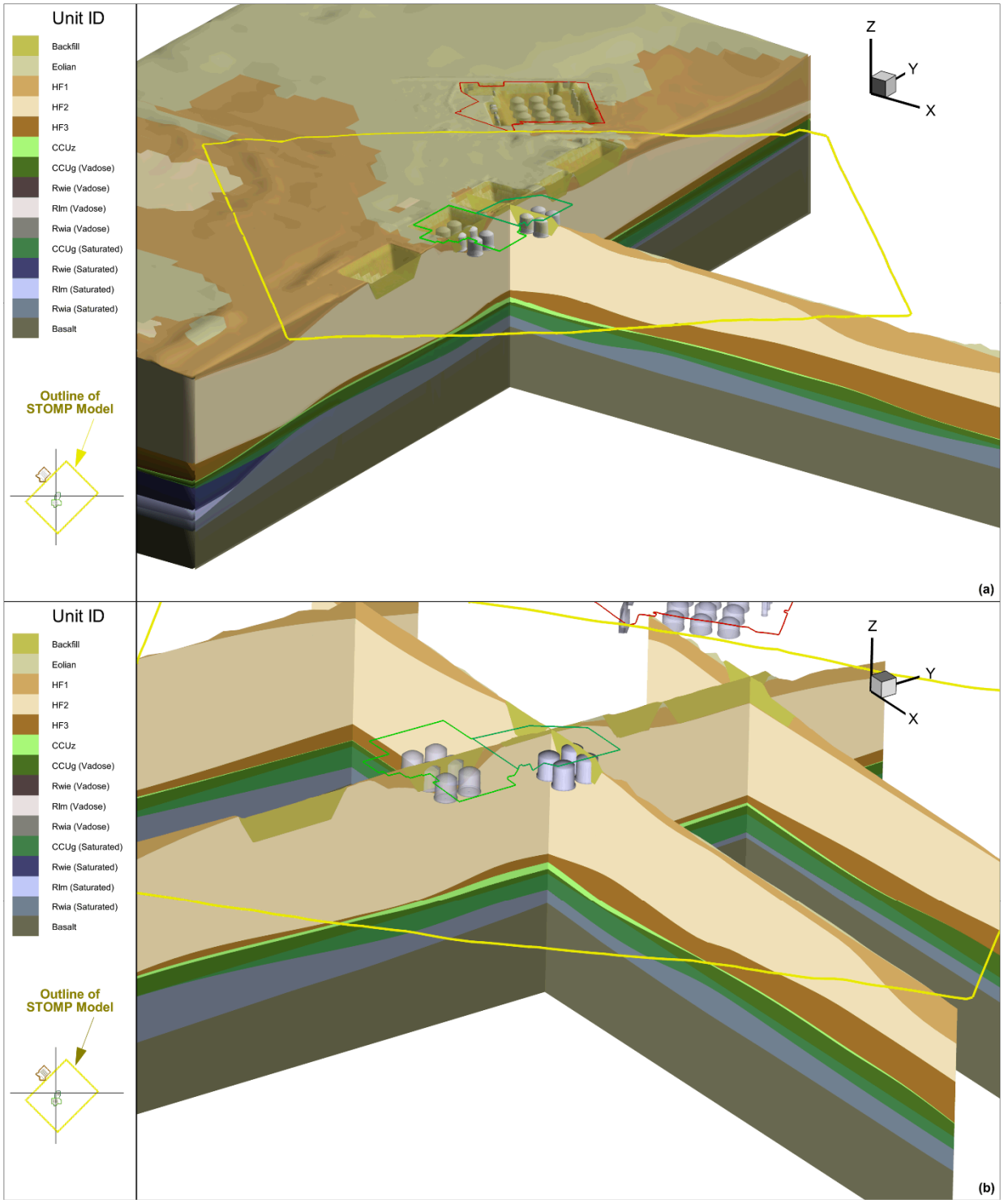
It should be noted that saturated flow and transport simulation for WMA A-AX utilizes the established Central Plateau Model (CPM), which incorporates the latest version of the Hanford South GFM (ECF-HANFORD-13-0029).

Figure 4-20. Triangular Finite Element Mesh Used for the ACM 1 and ACM 2 Geologic Framework Models – Whole Domain (a) and Close-Up View around Waste Management Area A-AX (b).



ACM = alternative conceptual model WMA = Waste Management Area

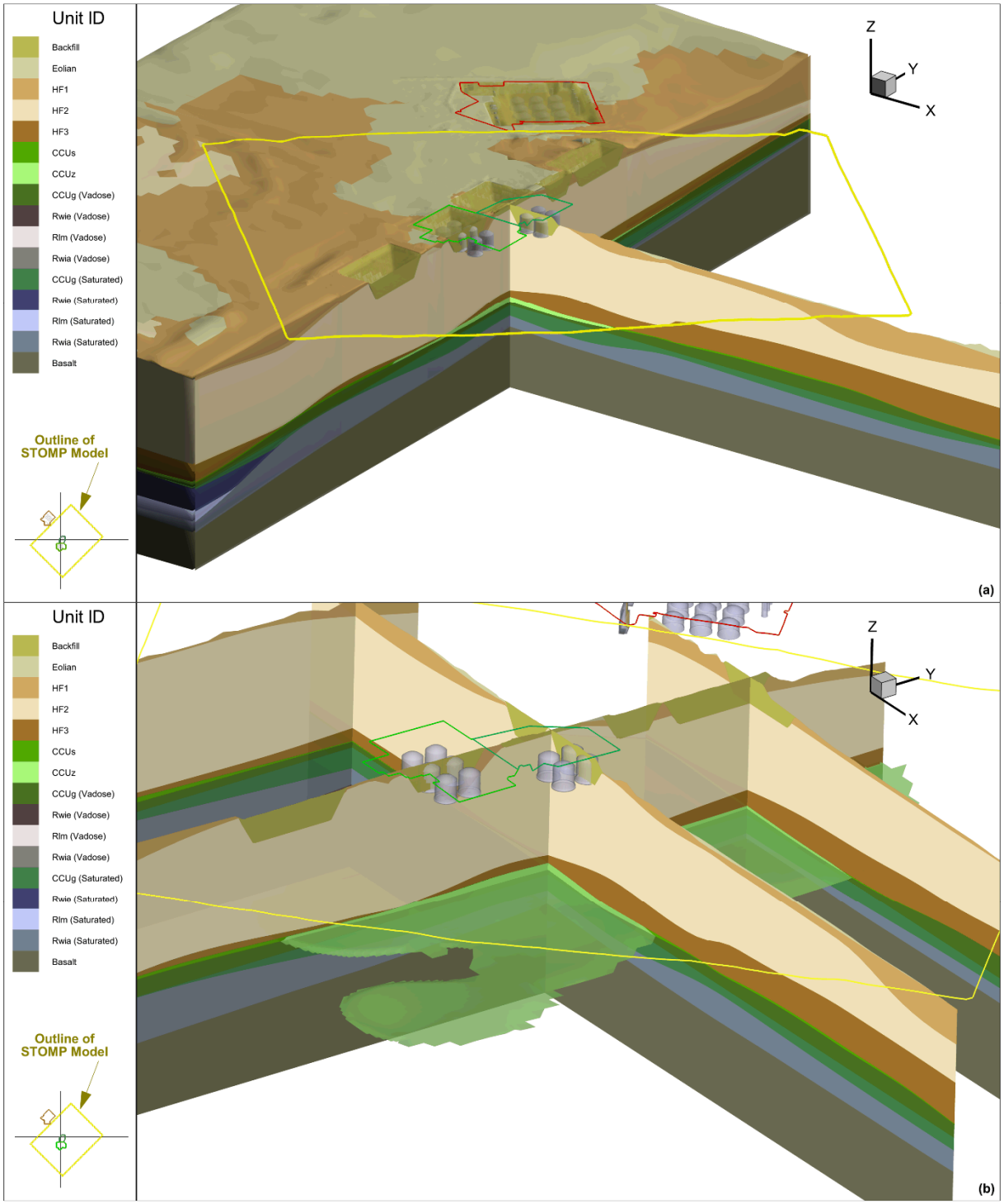
Figure 4-21. Views of ACM 1 Geologic Framework Model.



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
HF1 = Hanford Formation Unit 1
HF2 = Hanford Formation Unit 2
HF3 = Hanford Formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.

Figure 4-22. Views of ACM 2 Geologic Framework Model.



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
HF1 = Hanford Formation Unit 1
HF2 = Hanford Formation Unit 2
HF3 = Hanford Formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwi = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.

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5.0 MODEL LIMITATIONS

The applicability of the WMA A-AX GFMs must consider limitations associated with the overall availability and quality of geologic data and other related information used in each alternative model development. These limitations primarily depend on uncertainty associated with four identified sources that include (1) density of subsurface geologic data (and its quality) that represents the entire suprabasalt sediment section within the GFM domain; (2) identification, correlation, and extrapolation of major stratigraphic units; (3) the available vertical survey and depth control for boreholes and wells of interest; and (4) potential errors induced during the interpolation/construction of surfaces for individual stratigraphic units. The following subsections address each of these potential sources of uncertainty and how they can be controlled and/or minimized, within acceptable limits, during the development of GFMs.

5.1 DENSITY OF SUBSURFACE GEOLOGIC DATA

One of the fundamental limitations that can contribute elevated levels of uncertainty in constructing a GFM is lack of sufficient, high-quality, subsurface geologic data that can be used to identify and correlate (interpolation) all stratigraphic units throughout the model's domain. The density, distribution, and quality of subsurface geologic data is reliant upon (1) the number, maximum depth, and distribution of boreholes and (2) the quality of subsurface data collection techniques (geologic logging, sample collection and analysis, and geophysical logging) employed during and after the drilling of the borehole.

The density and distribution of subsurface geologic data is controlled by number, distribution, and depths of boreholes in the area to be modeled. For example, within and immediately around the boundaries of the WMA A-AX GFM domain, there are more than 100 boreholes/wells, but only 43 of these boreholes/wells penetrated more than 150 ft bgs and have geologic or geophysical data, or both, from which subsurface geologic unit picks have, or can be, made (Table 3-1, Table 3-2, and Figure 3-3). As seen in Figure 3-3, these 43 "deep" boreholes/wells are not uniformly distributed throughout the GFM domain, requiring the stratigraphic unit contacts to be interpolated into areas where there is little to no subsurface geologic data.

The overall quality of the stratigraphic unit contact extrapolations within the GFM domain is directly tied to the quality of the geologic/geophysical data collected from each of the deep wells/boreholes that serve as subsurface geologic control points. As discussed in Section 3.3, the type of geologic/geophysical data available for 14 of the 43 deep wells was of questionable quality and was of limited value. Most of these boreholes/wells that were installed prior to the 1990s were drilled without a well-site geologist present to systematically describe the drill cuttings. For these boreholes/wells, only a driller's log is available, and the overall usefulness of the geologic descriptions recorded varies greatly. This varying quality of geologic descriptions can mask subtle differences and gradational changes among the suprabasalt sediment stratigraphic units and further complicate and hamper reliable identification and correlation of stratigraphic units across the GFM domain.

5.2 IDENTIFICATION, CORRELATION, AND EXTRAPOLATION OF MAJOR STRATIGRAPHIC UNITS

As discussed in Sections 3.0 and 4.0, the WMA A-AX GFMs developed here in Tecplot 360® contain 12 stratigraphic units (see Section 4.2.3, Figure 4-21, and Figure 4-22). This includes subdivisions of the Hanford formation and CCU which currently have not been identified and mapped within the Hanford South GFM (ECF-HANFORD-13-0029 and ECF-Hanford-16-0128) but are treated as undifferentiated units. Some previous geologic investigations of the WMA A-AX region have identified and subdivided out the HF1 and HF2 units of the Hanford formation but did not identify and extrapolate all of the units that comprise both the Hanford formation and CCU (e.g., PNNL-15955; DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* [vadose zone only]). Even major stratigraphic unit contacts (e.g., Hanford formation/CCU/ Ringold Formation) identified in previous investigations can differ due to lack of quality data, different criteria for defining and identifying contacts depending on the objectives of the specific project (e.g., geologic or hydrologic in nature), and the experience and professional judgment of previous investigators. For these reasons, it was determined that the 12 geologic units in the 43 boreholes/wells used to construct the WMA A-AX GFMs using Tecplot 360®would be re-evaluated and interpreted for this effort.

As a result of the variability of geologic and geophysical data from the 43 deep boreholes/wells and the experience and professional judgment of the different investigators making interpretations, the tops of many of the same stratigraphic contacts have been picked at slightly different depths by different investigators. Different investigators may use different criteria for defining and identifying stratigraphic unit contacts, depending on the objectives of the specific project (e.g., geologic or hydrologic in nature). Therefore, contact identification may be subjective and inconsistent, resulting in uncertainty as to the depth of stratigraphic unit contacts. In some cases, differences in the stratigraphic unit contact elevations may be attributable to differences in methods used to establish the borehole's ground-surface elevations (e.g., ground survey, digital elevation model, LiDAR) available at the time to the different investigators.

An effective means to minimize such differences in individual interpretations of stratigraphic unit contacts was to employ a team of four expert geologists (Mr. Bruce Williams, Ms. Sarah Springer, Mr. Travis Hammond, and Mr. Terry Tolan) familiar with the Hanford Site suprabasalt sediment geology. Each geologist reviewed and interpreted the available geologic and geophysical data for the selected boreholes/wells and made preliminary stratigraphic unit contact picks for each borehole/well. These stratigraphic unit picks included the subunits for both the Hanford formation and CCU. The preliminary stratigraphic unit contact picks for each borehole/well made by the geologists were transferred onto a Kingdom®-generated geologic log to evaluate initial contact pick agreement among the geologists and to compare to past stratigraphic unit picks (e.g., PNNL-15955). In the case where disagreements occurred between geologist's preliminary stratigraphic unit contact picks, measures for achieving a consensus in interpretation were employed. These measures included having the team of geologists review all available geologic and geophysical data for the unit contact in question and how it compares to the same stratigraphic unit pick in any nearby boreholes/wells. The team of geologists met to discuss the data and arrive at a consensus for the stratigraphic unit contact pick. The

stratigraphic unit surface tops identified in each of the 43 deep boreholes/wells (Table 3-1 and Table 3-2) represent the consensus "picks" by the four expert geologists.

5.2.1 Vertical Survey and Depth Control

Limitations and potential uncertainties in interpretations of stratigraphic unit contacts can originate from poor vertical survey and depth control. Sources of uncertainty include poorly documented information such as ground-surface elevation at the time of drilling and sampling, the exact location of the reference point elevation on the well casing at the time of borehole geophysical logging or other measurements, and the accuracy of depth measurements. These sources can impart errors in the slopes of the stratigraphic unit surfaces and associated extrapolation of the 3D configuration of the stratigraphic units.

For this study, the means to deal with these issues was by primarily relying on boreholes/wells that had good vertical survey and depth measurements (Table 3-1 and Table 3-2).

5.2.2 Potential Errors Introduced During Interpolation/Construction of Surfaces for Individual Stratigraphic Units

As discussed in the above sections, there are a number of potential ways that errors may be introduced into the constructed model surfaces for each individual stratigraphic unit. To evaluate this source(s) of error for individual stratigraphic unit surfaces in ACM 1 and ACM 2, each individual stratigraphic unit surface developed and used in Tecplot® was cross-checked with stratigraphic unit elevations from the set of geological control points (43 deep boreholes/wells, Table 3-1 and Table 3-2). How this comparison check was performed, and the results of this comparison check for ACM 1 and ACM 2 stratigraphic unit surfaces, is documented in Attachment H.

For this comparison check, it was assumed that if the elevation of stratigraphic unit surface at the geologic control point (well/borehole) was within $\pm$ 1 m of the geologic control point elevation, then the stratigraphic unit surface elevation was within acceptable limits. The $\pm$ 1-m tolerance limit for stratigraphic unit top elevations in the ACM 1 and ACM 2 GFMs was adopted to reflect the overall inherent uncertainty in these elevation (depth) determinations where they are based solely on driller's or geologist's logging of "grab samples" during drilling. As identified in Attachment H, there are a few cases where interpolated stratigraphic unit surfaces and their geologic control points exceed our tolerance limit. In most cases, these exceedances are related to either the HF1/HF2 (shallow) or Ringold unit (deep) stratigraphic unit surfaces. The shallow exceedances associated with HF1 or HF2 surfaces appear to be the result of differences in backfill thicknesses. The deeper exceedances generally appear near the model domain boundary and appear to reflect differences in elevations of the stratigraphic unit surfaces between ACM 1 and ACM 2 and the 200 Area Central Plateau GFM.

5.3 WASTE MANAGEMENT AREA A-AX PERFORMANCE ASSESSMENT MODEL

Being that the current WMA A-AX GFMs are comparable to other geologic models for the facility, and that ACM 1 and ACM 2 have been developed from the best available "deep" borehole geologic unit interpretations and extrapolations, it is recommended that the two GFMs serve as the initial geologic framework for the flow and transport modeling assessment efforts for the WMA A-AX region.

The existing WMA A-AX GFMs are based on geologic and geophysical information and data from 43 deep (>150 ft) boreholes/wells within, and around, the tank farm area. There are also a very large number of shallow dry wells and direct push boreholes (< 150 ft deep) that were not evaluated and interpreted for this effort because they did not penetrate the entire sequence of stratigraphic units beneath the WMA A-AX domain. However, geologic and geophysical data from these shallow wells/boreholes could potentially provide information that would allow silt deposits within the HF1 and HF2 stratigraphic units to be identified and evaluated as to their potential extent. Geologic and geophysical data and information that is collected from future characterization efforts at WMA A-AX should be incorporated into GFMs.

6.0 MODEL DEVELOPMENT SOFTWARE

Environmental modeling software for activities on the Hanford Site related to the Hanford Site Composite Analysis and Tank Closure and Waste Management Environmental Impact Statement is maintained and updated by DOE prime contractor CHRPC under their modeling integration role for the Hanford Site. For consistency across the Hanford Site, performance assessments for waste management areas utilize the same modeling software.

Software used primarily for visualization of model output or used in cited work supporting this report (Leapfrog Geo) are not detailed here.

Kingdom® Geology users can select among various algorithms and parameters to construct 2D interpolations based on borehole stratigraphic unit contact elevations to create continuous surfaces representing geologic lithostratigraphy. Tecplot 360® has the capabilities to import the interpolated surfaces and construct a 3D GFM complete with stratigraphic unit volumes. If the user needs to create these surfaces using a different geo-statistical function (e.g., ordinary kriging or inverse distance weighting), then these surfaces can be created using any geographic information system tool to generate a continuous gridded surface, and these surfaces can be imported into Tecplot 360®.

6.1 SOFTWARE INSTALLATION AND CHECKOUT

Approved software is used following PRC-PRO-IRM-309. The installed Kingdom® Geology software was tested in accordance with the procedure per CHPRC-02937, "*Kingdom-Geology Software Management Plan*." The installed Tecplot 360® software was tested in accordance with the procedure per CHPRC-02806, "*Tecplot 360 Integrated Software Management Plan*." For approved calculation software used in this calculation, the required descriptions are provided below. ArcGIS software was tested in accordance with software management plan CHPRC-03595, "*ArcGIS for Desktop and License Manager*."

6.1.1 Kingdom® Geology

- Software Title: Kingdom® Geology
- Software Version: 2016.1
- Hanford Information System Inventory (HISI) Identification Number: 3899 (Safety Software, Level C)
- Workstation type and property number: USDOES WF34759; Dell Work Station INTERA #00771.

6.1.2 Tecplot 360®

- Software Title: Tecplot 360®

- Software Version: 2013 R1 and 2017 R2
- HISI Identification Number: 3882
- Workstation type and property number: TecGeo Inc.-owned hardware. Puget Systems Spirit Intel, Number Puget-120734 (for 2013 R1); Puget Systems Traverse Pro M560i 15-inch, Number Puget-116138 (for 2017 R2).

6.1.3 ArcGIS

- Software Title: ArcGIS
- Software Version: 10.4.1
- Hanford Information System Inventory (HISI) Identification Number: 3402 (Level D)
- Workstation type and property number: Network installation managed using the license management group ArcGIS_Concurrent_Use_CHPRC.

6.2 SUPPORT SOFTWARE

Software used only in a supporting capacity for this work is summarized below. Scripts were fully checked as part of the checking process for this work.

6.2.1 Python

- Software Title: Python
- Software Version: 3.5.2
- Workstation type and property number: Lenovo Laptop INTERA #00669.

6.3 SOFTWARE INSTALLATION AND CHECKOUT

A copy of the approved Software Installation and Checkout Form for Kingdom® Geology is provided in Attachment E. Copies of the approved Software Installation and Checkout Forms for Tecplot 360® are provided in Attachment G.

6.4 STATEMENT OF VALID SOFTWARE APPLICATION

The preparers of this calculation attest that the software identified above, and used for the calculations described in this calculation, is appropriate for the application and used within the range of intended uses for which it was tested and accepted by CHPRC.

7.0 MODEL CONFIGURATION MANAGEMENT

All inputs and outputs for the development of WMA A-AX PA models are committed to EMMA to maintain and preserve configuration-managed models. Inputs include the input files used in the GFM development (i.e., borehole and well geology tables in Attachment B). All model outputs in the form of stratigraphic unit surfaces are also archived in EMMA. Use of the Kingdom® Geology and Tecplot® software for implementing the model described in this report is consistent with its intended use for CHPRC, as indicated in Section 6.4.

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Attachment A

Features, Events, and Processes Relevant to Geologic Framework Model for Waste Management Area A-AX

Features, Events, and Processes Relevant to Geologic Framework Model for Waste Management Area A-AX

The International Atomic Energy Agency Features, Events, and Processes (FEPs) list ("*Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a coordinated research project, Volume 1: Review and enhancement of safety assessment approaches and tools*" [IAEA 2004]) is a list of FEPs relevant to the assessment of long-term safety of near-surface disposal facilities, which attempts to be comprehensive within reasonable bounds. Because these FEPS are an adaptation of the FEPs used for near-surface disposal facilities, the term repository is used to refer to the disposal system. It consists of 141 FEPs, each with an identifying number. The numbers reflect a classification system, as shown in Figure A-1 (IAEA 2004). At its center, the classification scheme includes processes related to contaminant release, migration and exposures (radionuclide and contaminant factors). The next tier are the features of the disposal system (wastes, engineered and natural barriers and human behavior) and events and processes which may cause the system to evolve (environment factors). Further out, there are processes and events originating outside the disposal system, but which act upon it (external factors). These external factors (or external FEPs) are often considered to be scenario-generating FEPs.

For this model package report that is focused on developing the three-dimensional geologic framework model (GFM) for the Waste Management Area A-AX, only FEPs associated with geologic processes/environment or model domain are evaluated. These are presented in Table A-1. The second column indicates whether the relevant FEP was included or not during development of the GFM. The third column indicates whether the FEP is judged to be relevant to GFM regardless of its inclusion or exclusion.

Figure A-1. Feature, Event, and Process Numbering Classification System.

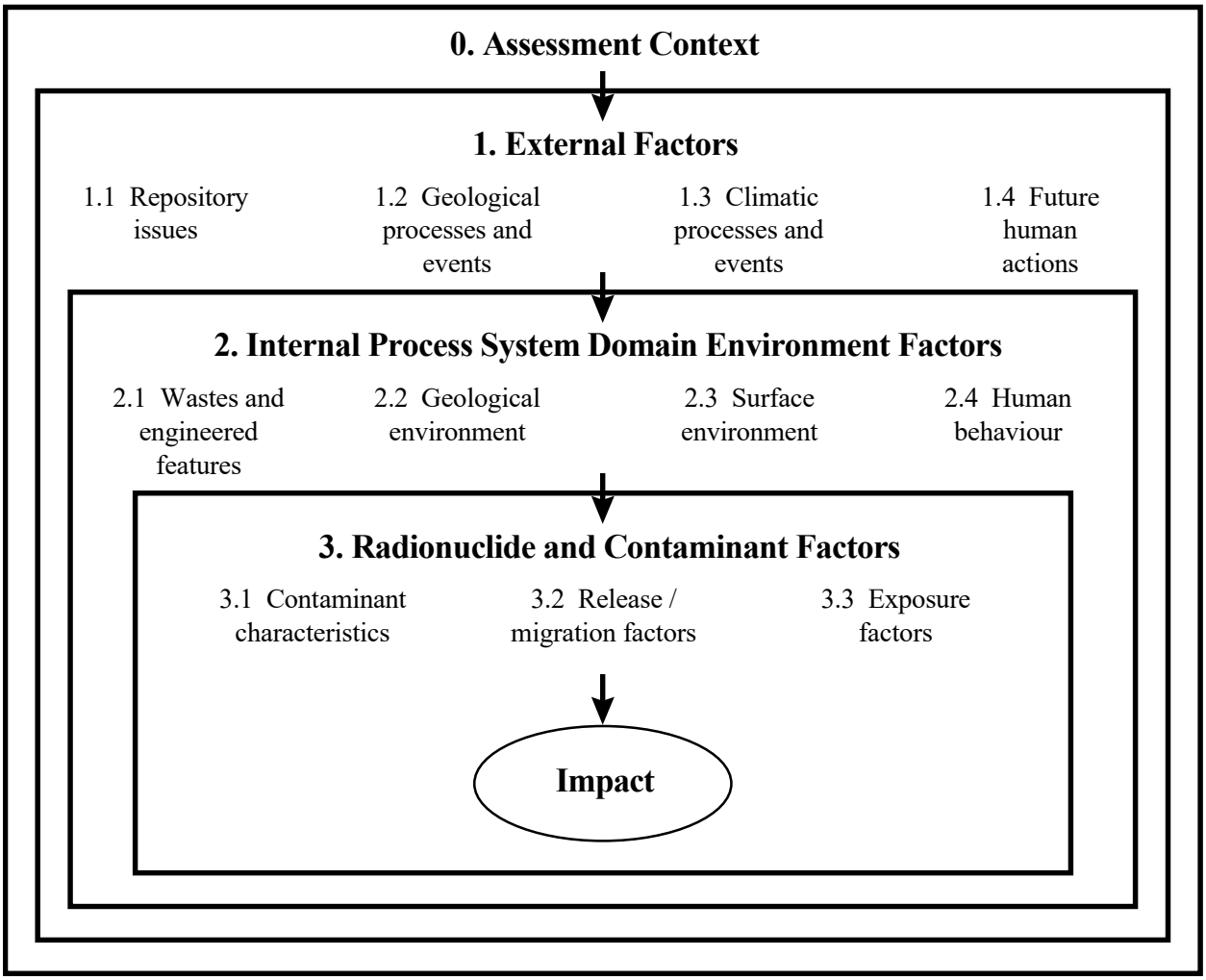


Figure excerpted from "*Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a coordinated research project, Volume 1: Review and enhancement of safety assessment approaches and tools*" (IAEA 2004).

Table A-1. Features, Events, and Processes Relevant to Geologic Framework Model for Waste Management Area A-AX.

Relevant Feature, Event, Process	Included	Relevant to GFM
0 ASSESSMENT CONTEXT		
0.03 Spatial domain of concern	Yes	Yes
1.2 GEOLOGICAL PROCESSES AND EVENTS		
1.2.01 Orogeny and related tectonic processes at plate boundaries	No	No
1.2.02 Anorogenic and within-plate tectonic processes (Deformation, elastic, plastic and brittle)	No	No
1.2.03 Seismicity	No	No
1.2.04 Volcanic and magmatic activity	No	No
1.2.05 Metamorphism	No	No
1.2.06 Hydrothermal activity	No	No
1.2.07 Erosion and sedimentation	No	Yes
1.2.08 Diagenesis and pedogenesis	No	Yes
1.2.09 Salt diapirism and dissolution	No	No
1.2.10 Hydrological/hydrogeological response to geological changes	No	No
2.2 GEOLOGICAL ENVIRONMENT		
2.2.01 Disturbed zone, host lithology	Yes	Yes
2.2.02 Host lithology	Yes	Yes
2.2.03 Lithological units, other	Yes	Yes
2.2.04 Discontinuities, large scale (in geosphere)	No	No
2.2.05 Contaminant transport path characteristics (in geosphere)	No	No
2.2.06 Mechanical processes and conditions (in geosphere)	No	No
2.2.07 Hydraulic/hydrogeological processes and conditions (in geosphere)	No	No
2.2.08 Chemical/geochemical processes and conditions (in geosphere)	No	No
2.2.09 Biological/biochemical processes and conditions (in geosphere)	No	No
2.2.10 Thermal processes and conditions (in geosphere)	No	No
2.2.11 Gas sources and effects (in geosphere)	No	No
2.2.12 Undetected features (in geosphere)	No	Yes
2.2.13 Geological resources	No	No

GFM = geologic framework model

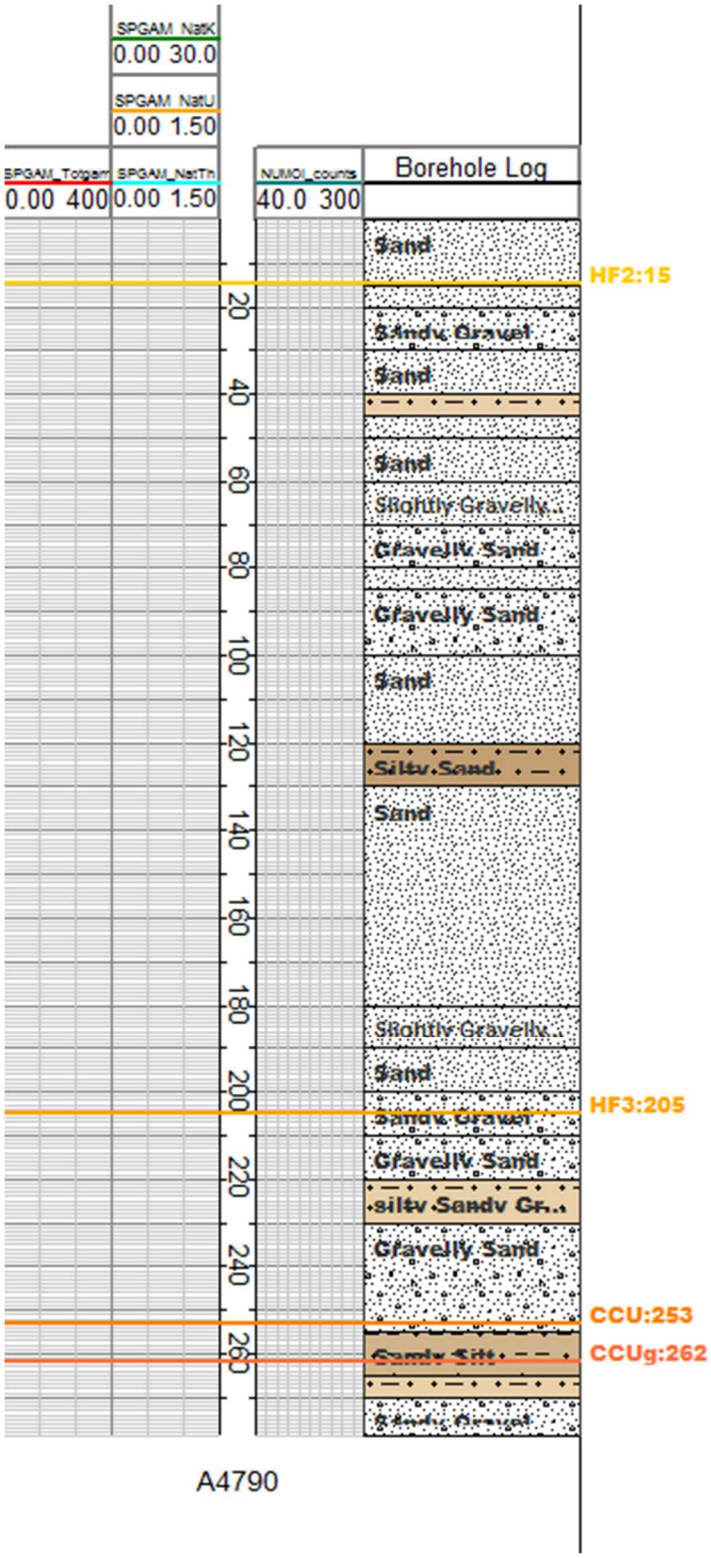
Attachment B

Interpretation of Selected Borehole Geologic and Geophysical Logs

Borehole Geologic and Geophysical Logs

This attachment contains Kingdom®[10]-generated markups of the original geologic, drillers', and geophysical logs obtained from the Hanford Environmental Information System that were interpreted to provide the data for the Waste Management Area A-AX ACM 1 and ACM 2 geologic framework models. These logs are labeled with the Hanford borehole ID number (e.g., A4749) rather than the borehole name (e.g., 299-E24-13). All logs for both alternative conceptual models (ACMs) are presented within. Unit picks are also labeled on the logs in feet. Note that no stratigraphic units younger than the Hanford formation (i.e., Eolian sand or Backfill) are depicted on these logs. This issue is being addressed and the post-Hanford formation units will be represented within future updates to Kingdom®.

[10] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.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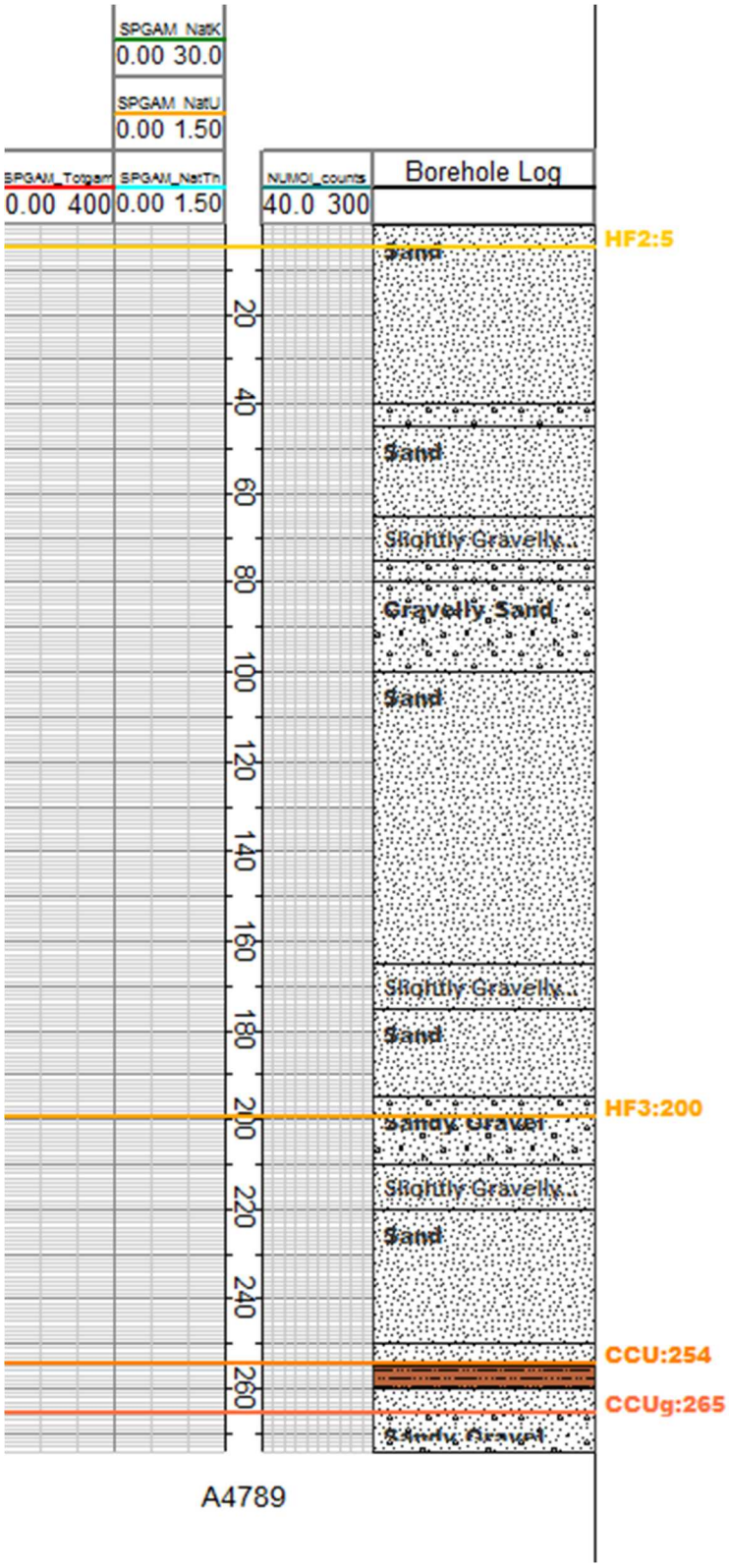
Borehole Log
Sand
HF2:15
Sandy Gravel
Sand
Sand
Slightly Gravelly
Gravelly Sand
Gravelly Sand
Sand
Silty Sand
Sand
Slightly Gravelly
Sand
HF3:205
Sandy Gravel
Gravelly Sand
silty Sandy Gr
Gravelly Sand
CCU:253
CCUg:262
Sandy Silt
Sandy Gravel
20
40
60
80
100
120
140
160
180
200
220
240
260
A4790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Borehole Log
HF2:5
Sand
Sand
Slightly Gravelly...
Gravelly Sand
Sand
Slightly Gravelly...
Sand
HF3:200
Sandy Gravel
Slightly Gravelly...
Sand
CCU:254
CCUg:265
Sandy Gravel
20
40
60
80
100
120
140
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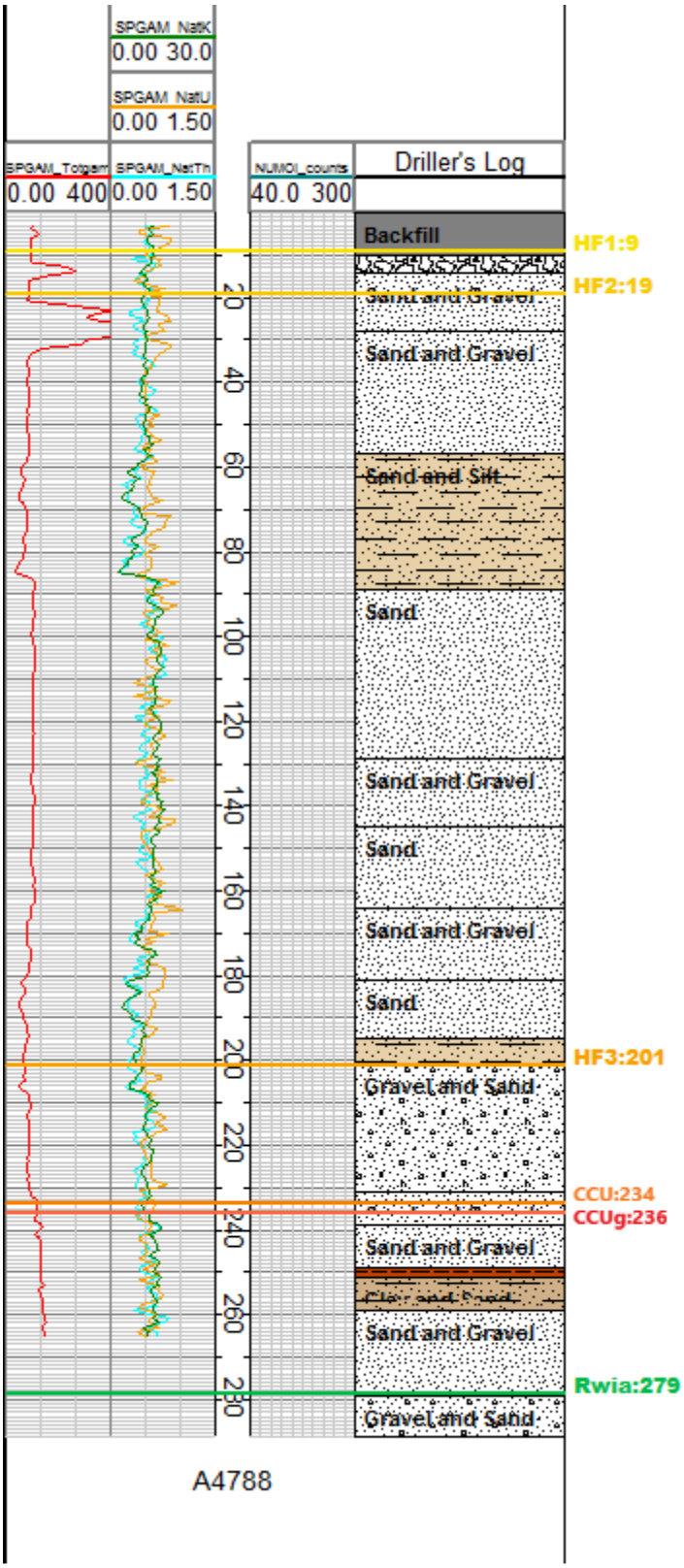
180
200
220
240
260
A4789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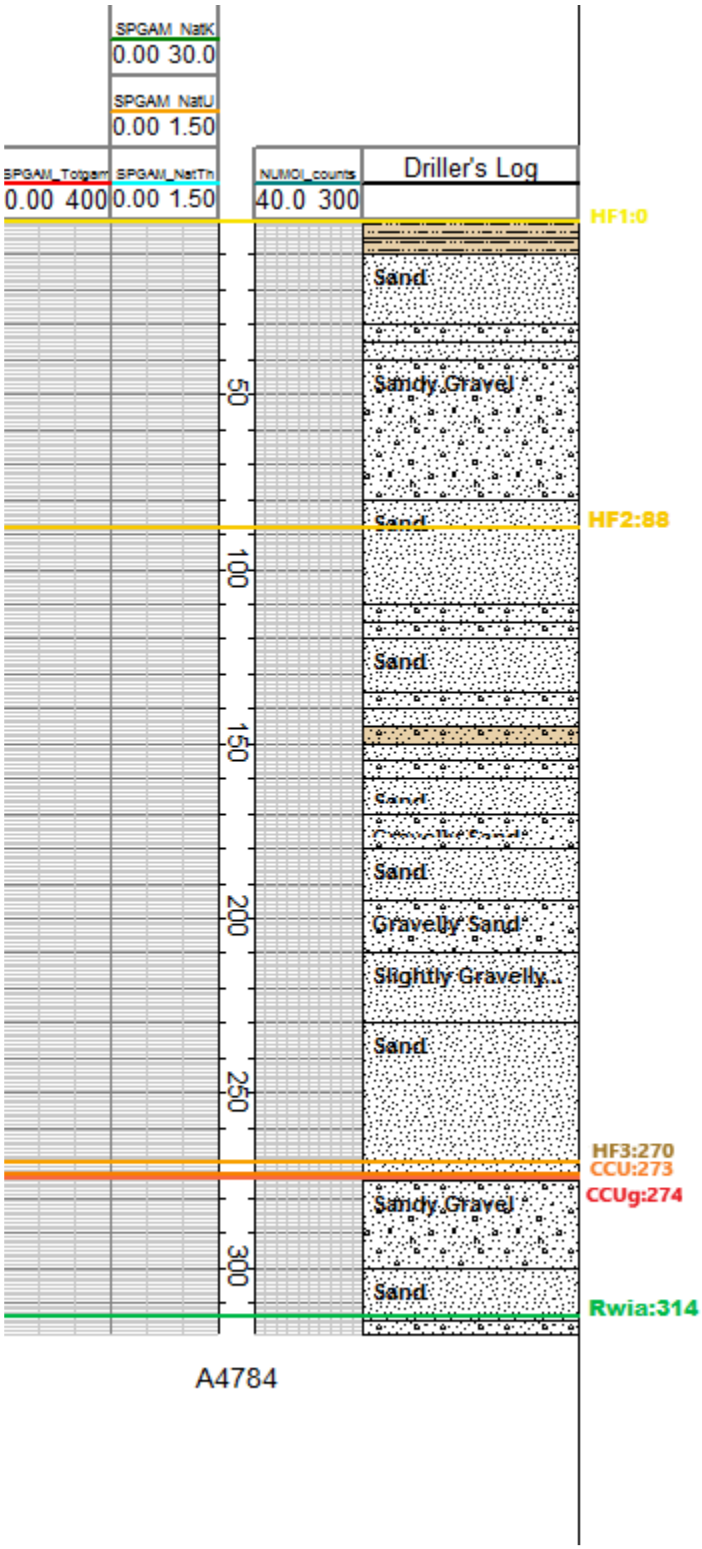
Driller's Log
Backfill
HF1:9
HF2:19
Sand and Gravel
Sand and Silt
Sand
Sand and Gravel
Sand
Sand and Gravel
Sand
HF3:201
Gravel and Sand
CCU:234
CCUg:236
Sand and Gravel
Sand and Gravel
Rwia:279
Gravel and Sand
20
40
60
80
100
120
140
160
180
200
220
240
260
280
A4788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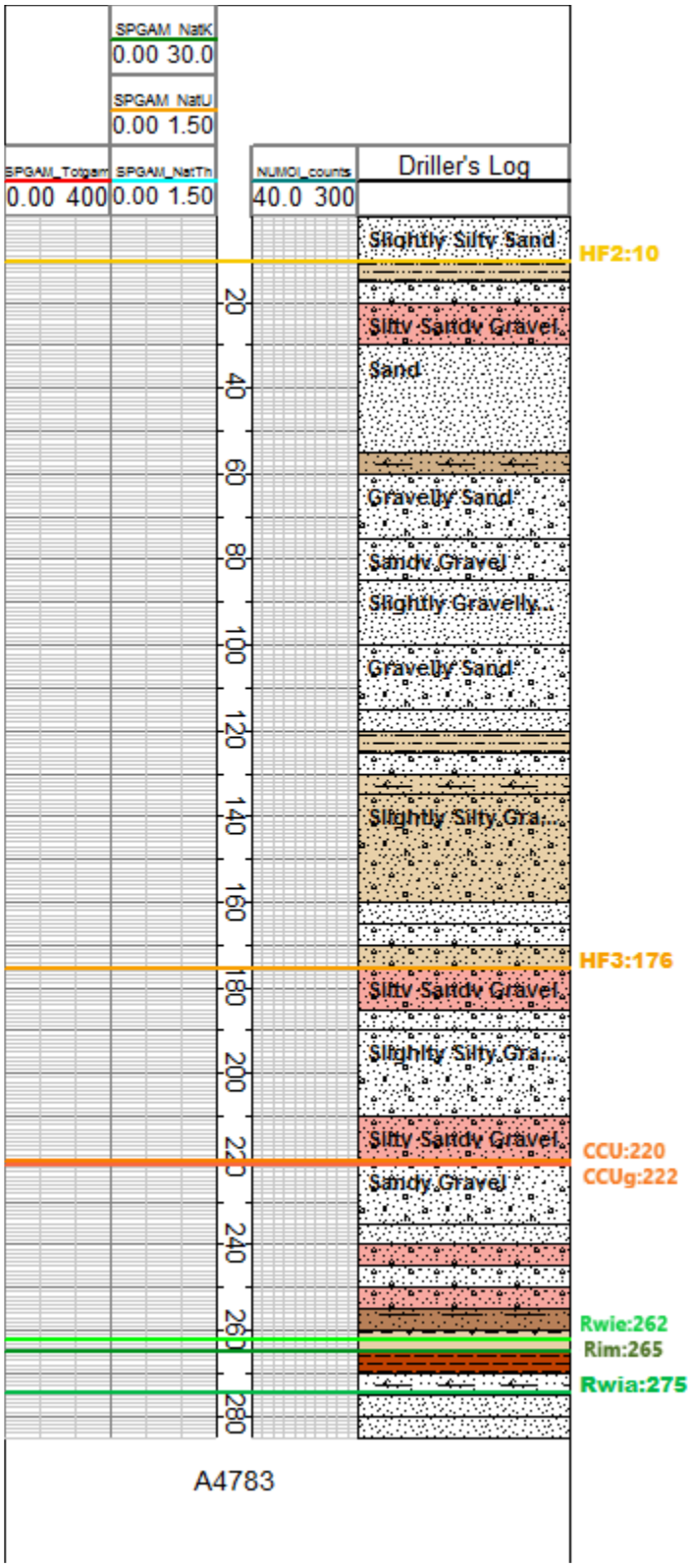
Driller's Log
HF1:0
Sand
Sandy Gravel
HF2:88
Sand
Sand
Sand
Gravelly Sand
Slightly Gravelly...
Sand
HF3:270
CCU:273
CCUg:274
Sandy Gravel
Sand
Rwia:314
50
100
150
200
250
300

A4784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Driller's Log
Slightly Silty Sand
HF2:10
Silty Sandy Gravel
Sand
Gravelly Sand
Sandy Gravel
Slightly Gravelly...
Gravelly Sand
Slightly Silty Gra...
HF3:176
Silty Sandy Gravel
Slightly Silty Gra...
Silty Sandy Gravel
CCU:220
CCUg:222
Sandy Gravel
Rwie:262
Rim:265
Rwia:275
20
40
60
80
100
120
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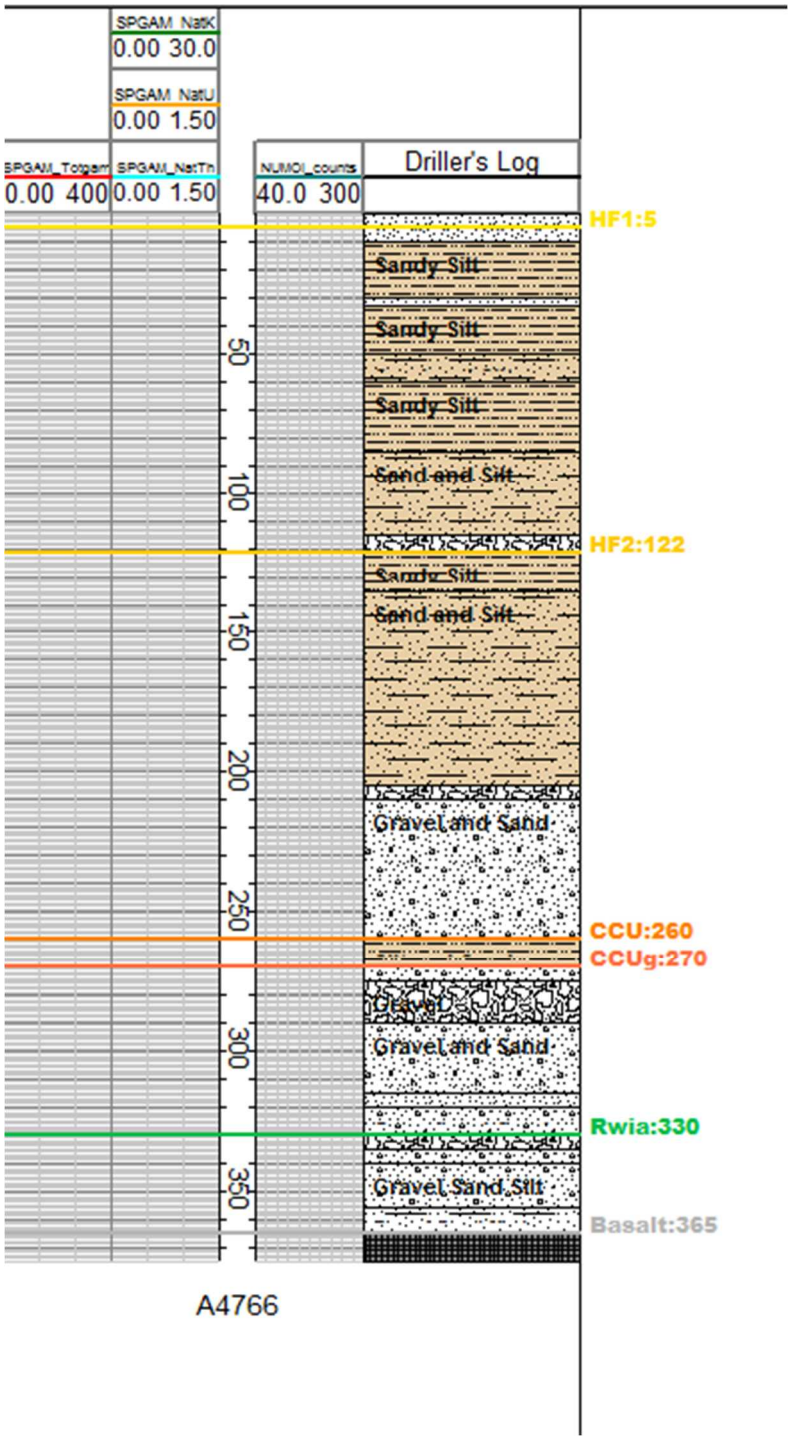
200
220
240
260
280
A4783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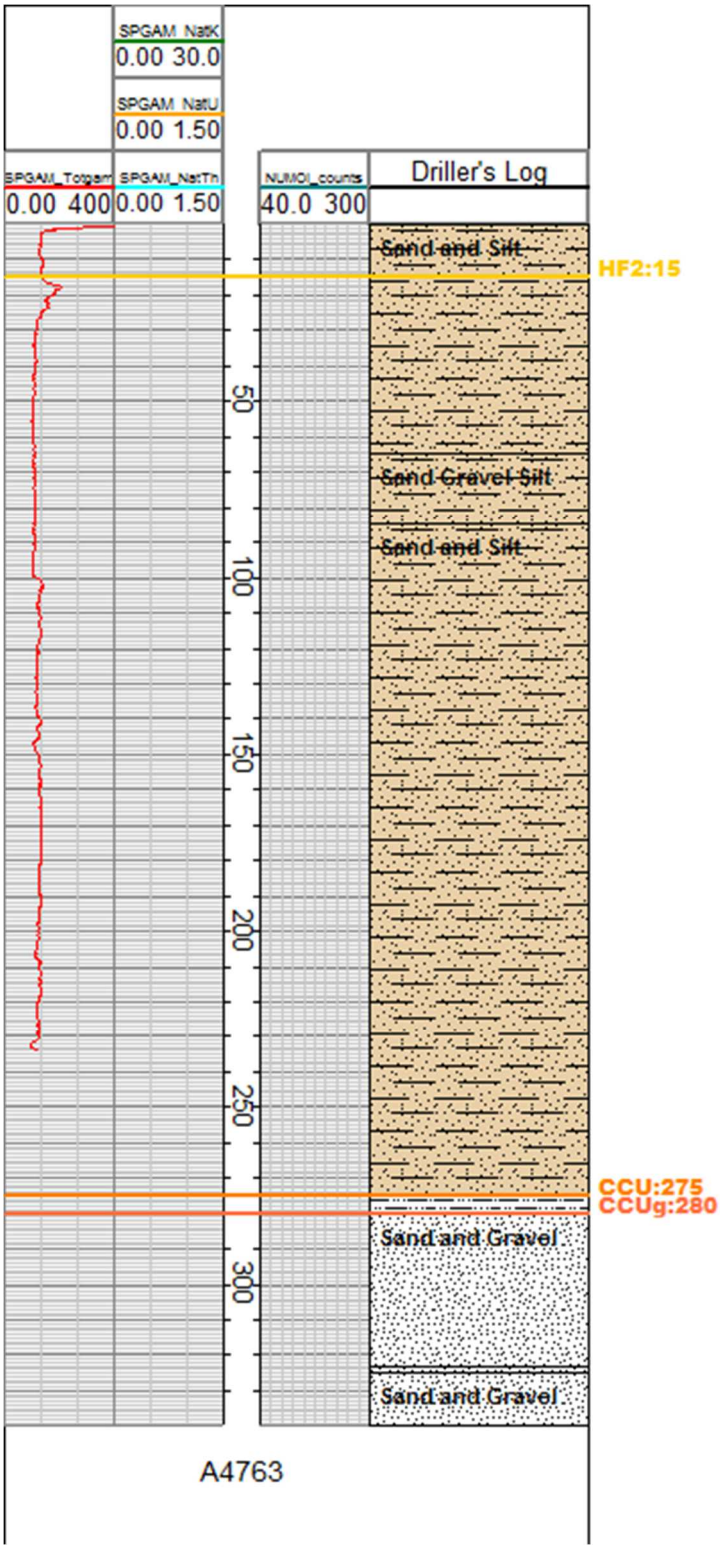
Driller's Log
HF1:5
Sandy Silt
Sandy Silt
Sandy Silt
Sand and Silt
HF2:122
Sandy Silt
Sand and Silt
Gravel and Sand
CCU:260
CCUg:270
Gravel
Gravel and Sand
Rwia:330
Gravel Sand Silt
Basalt:365
50
100
150
200
250
300
350
A4766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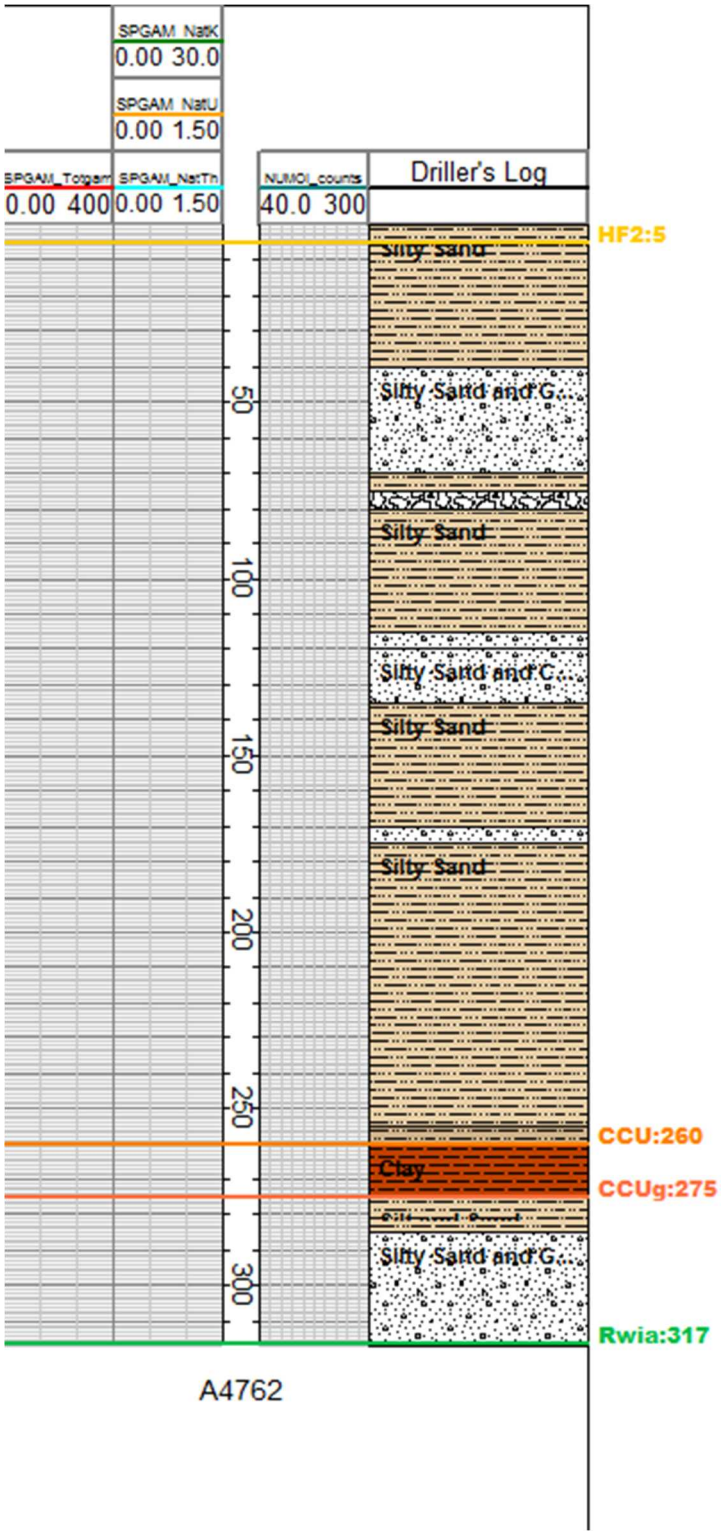
40.0 300
Driller's Log
Sand and Silt
HF2:15
Sand Gravel Silt
Sand and Silt
CCU:275
CCUg:280
Sand and Gravel
Sand and Gravel
50
100
150
200
250
300
A4763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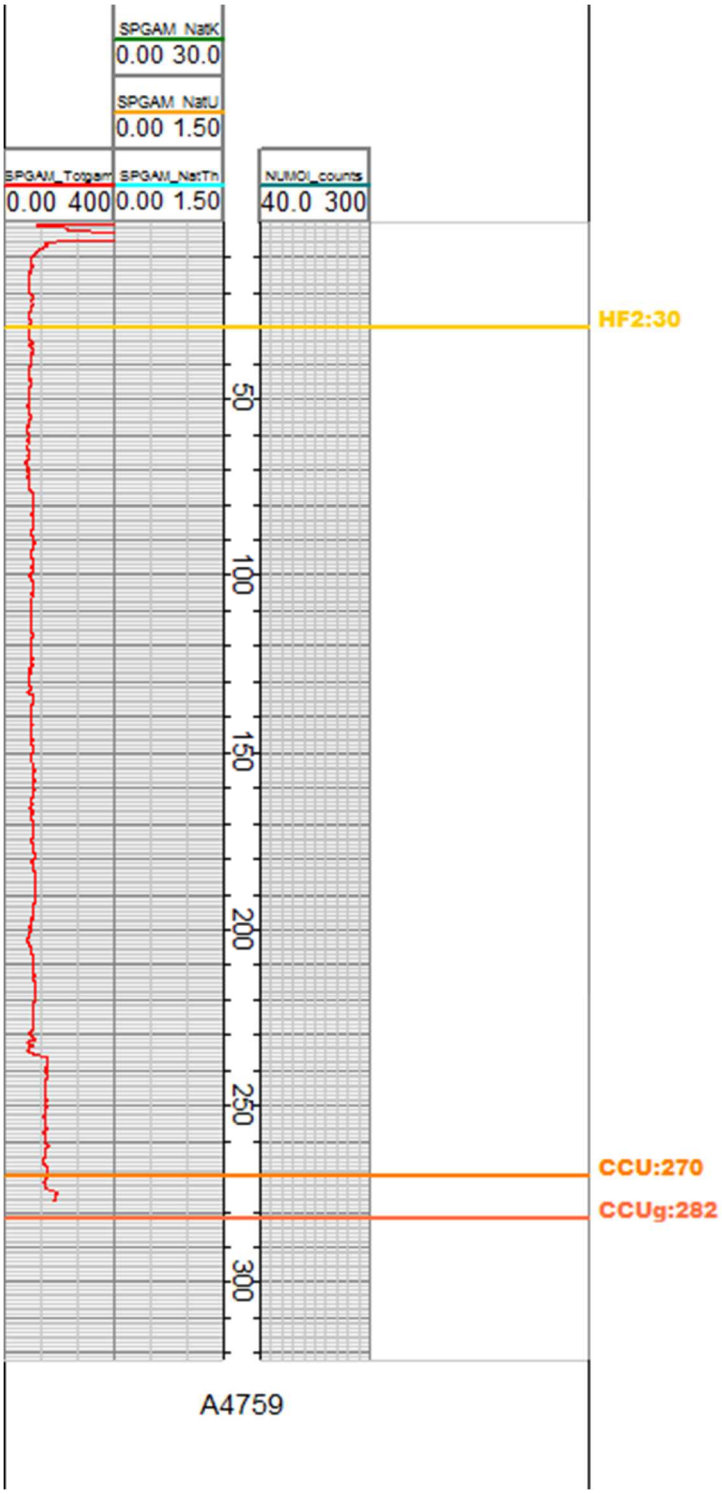
NUMOI_counts
40.0 300
Driller's Log
HF2:5
Silty Sand
Silty Sand and G...
Silty Sand
Silty Sand and C...
Silty Sand
Silty Sand
CCU:260
Clay
CCUg:275
Silty Sand and G...
Rwia:317
50
100
150
200
250
300
A4762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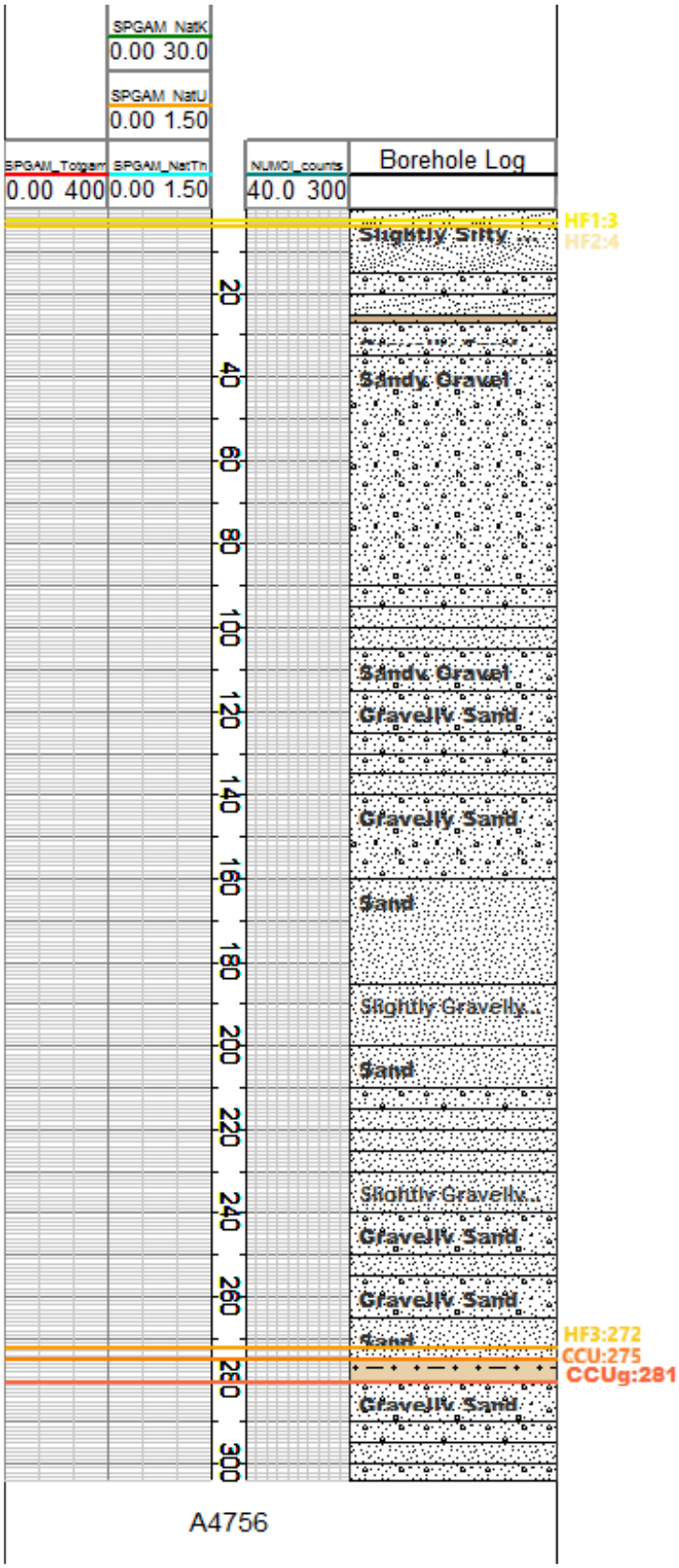
HF2:30
50
100
150
200
250
CCU:270
CCUg:282
300
A4759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SPGAM_NatTh
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NUMOI_counts
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Borehole Log
HF1:3
HF2:4
Slightly Silty ...
Sandy Gravel
Sandy Gravel
Gravelly Sand
Gravelly Sand
Sand
Slightly Gravelly...
Sand
Slightly Gravelly...
Gravelly Sand
Gravelly Sand
Sand
HF3:272
CCU:275
CCUg:281
Gravelly Sand
20
40
60
80
100
120
140
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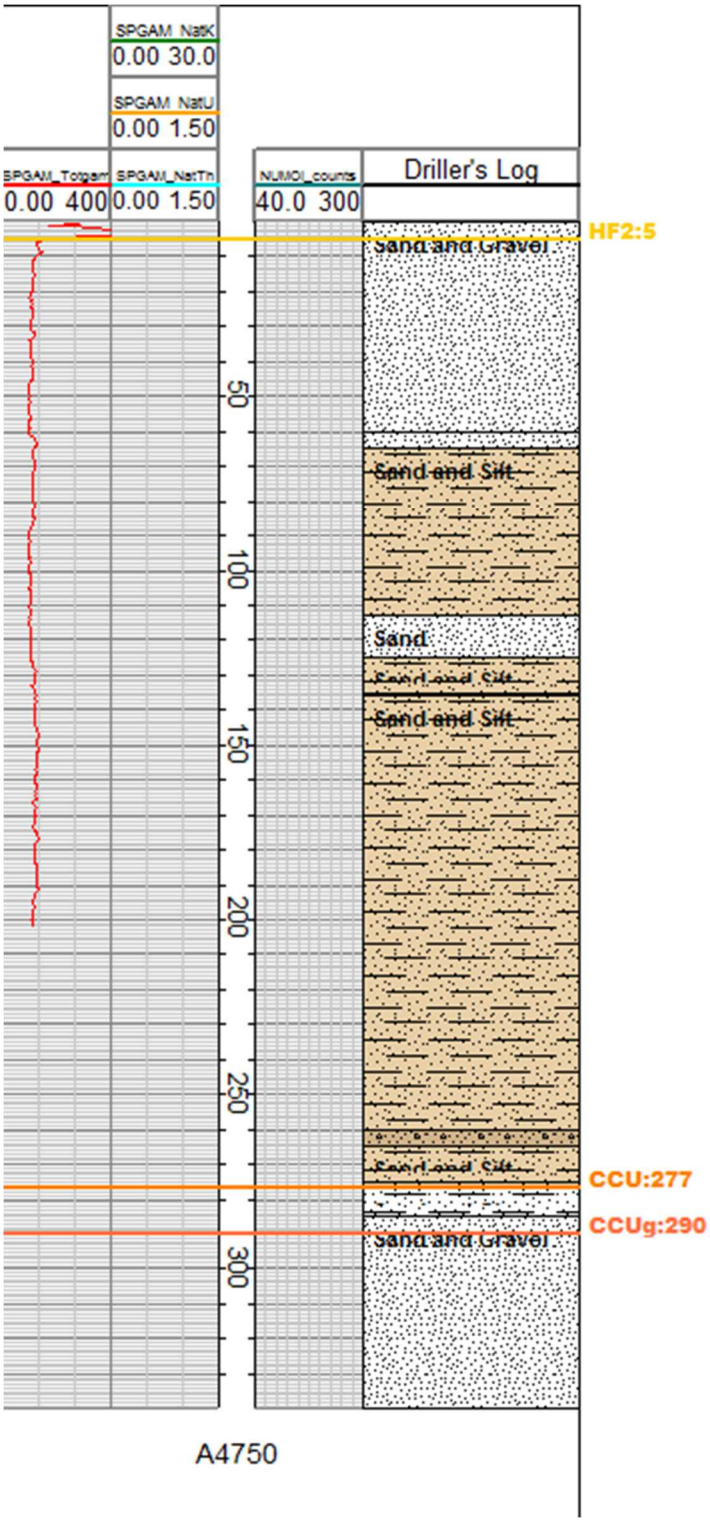
220
240
260
280
300
A4756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SPGAM_NatTh
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NUMOI_counts
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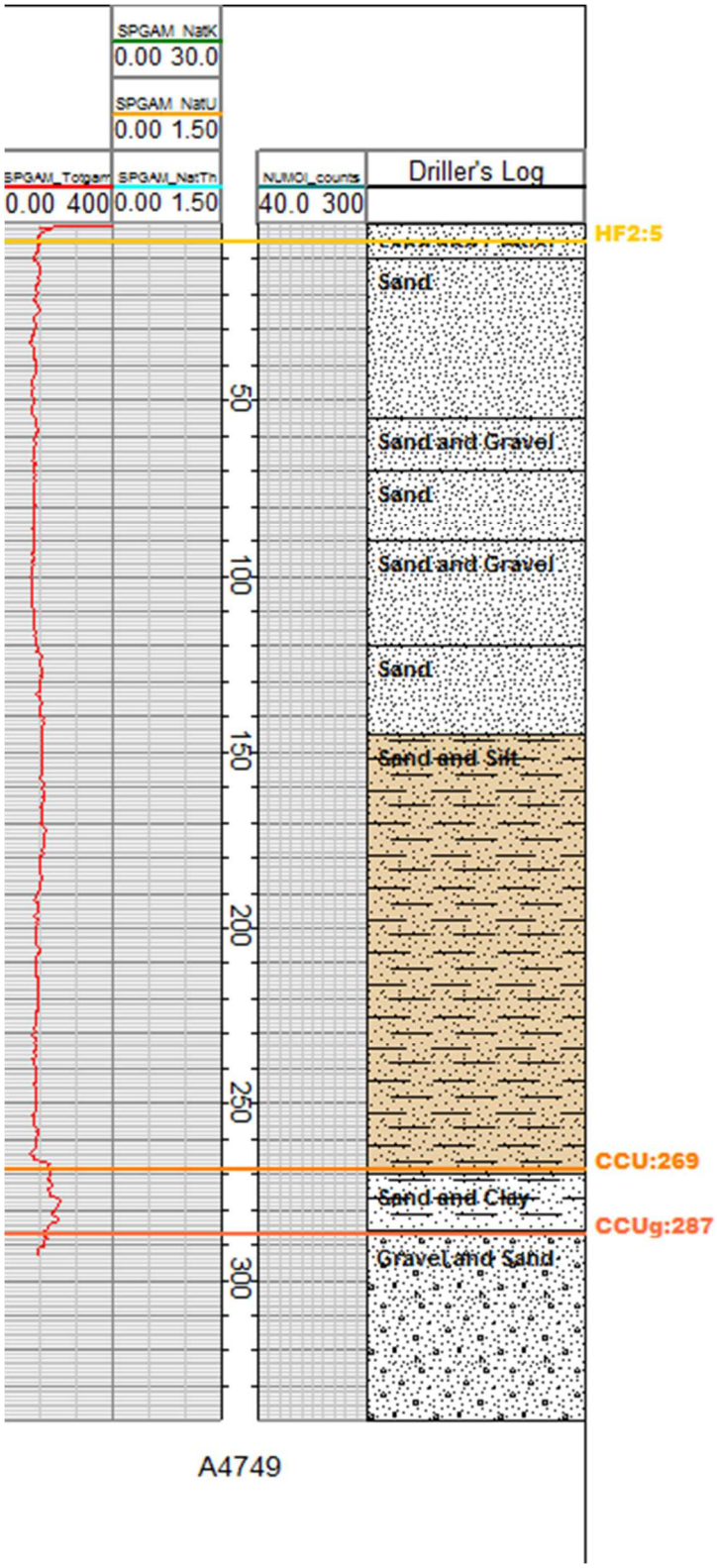
Driller's Log
HF2:5
Sand and Gravel
Sand and Silt
Sand
Sand and Silt
Sand and Silt
CCU:277
CCUg:290
Sand and Gravel
50
100
150
200
250
300
A4750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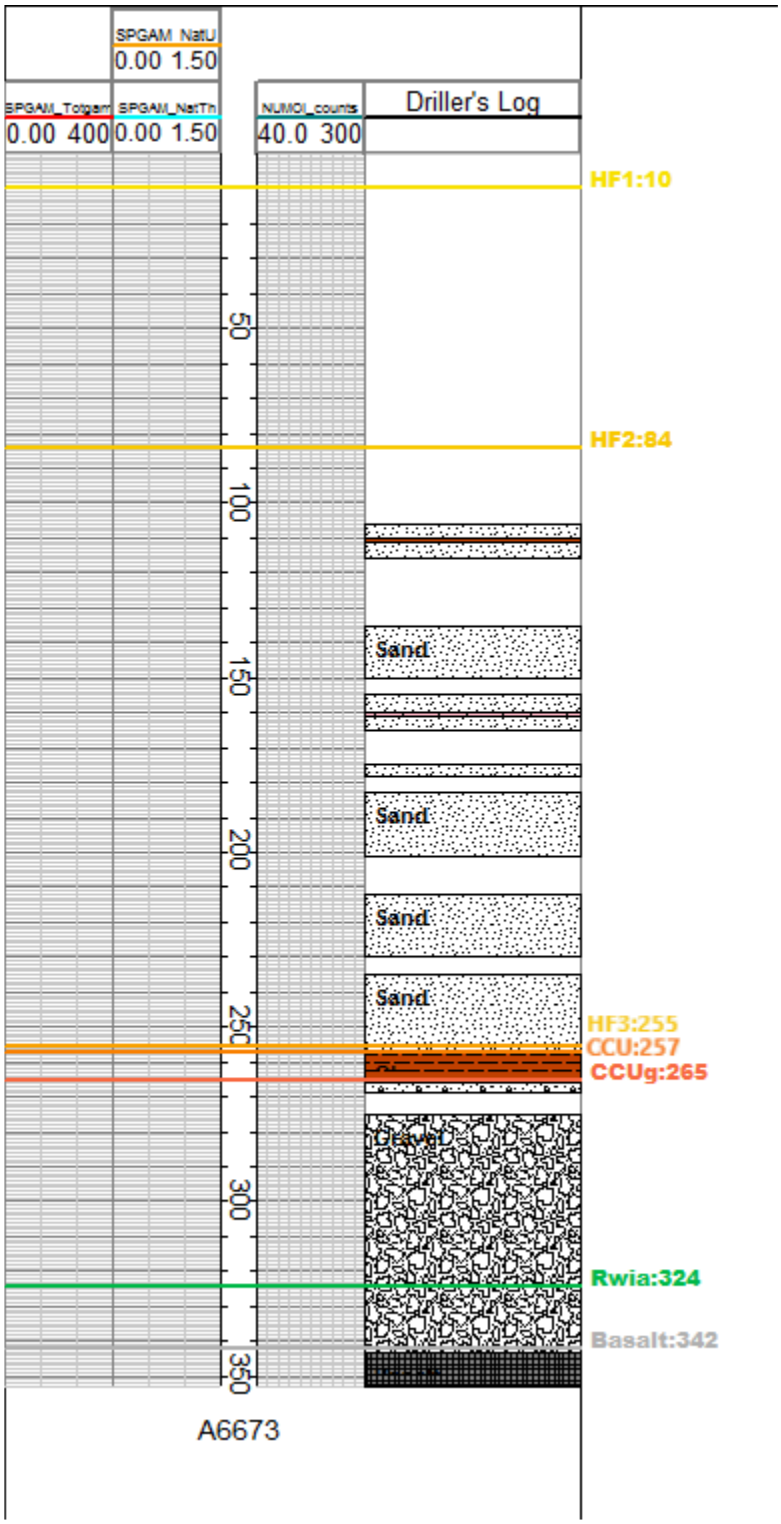
NUMOI_counts
40.0 300
Driller's Log
HF2:5
Sand
Sand and Gravel
Sand
Sand and Gravel
Sand
Sand and Silt
CCU:269
Sand and Clay
CCUg:287
Gravel and Sand
50
100
150
200
250
300
A4749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NUMOI_counts
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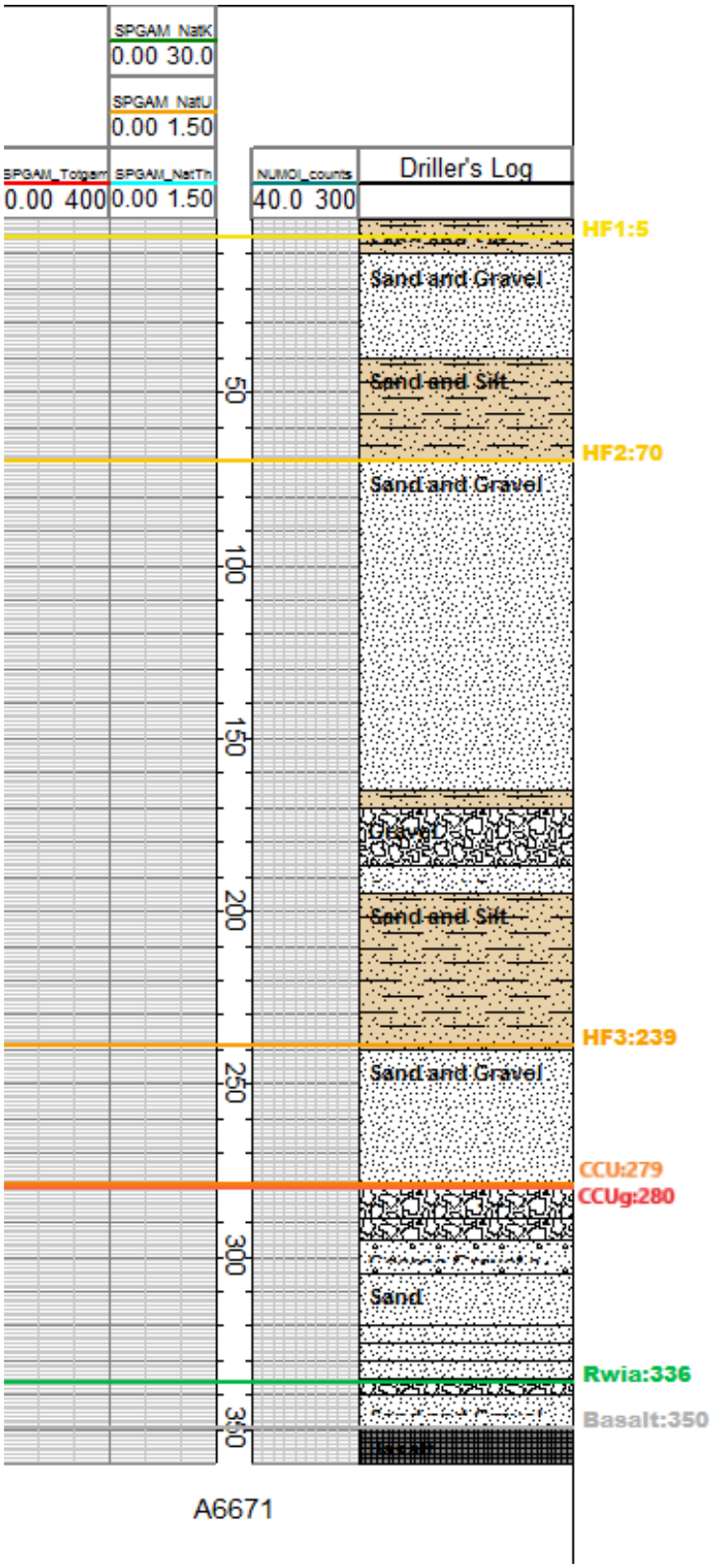
Driller's Log
HF1:10
HF2:84
Sand
Sand
Sand
Sand
HF3:255
CCU:257
CCUg:265
Gravel
Rwia:324
Basalt:342
50
100
150
200
250
300
350
A6673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NUMOI_counts
40.0 300
Driller's Log
HF1:5
Sand and Gravel
Sand and Silt
HF2:70
Sand and Gravel
Gravel
Sand and Silt
HF3:239
Sand and Gravel
CCU:279
CCUg:280
Sand
Rwia:336
Basalt:350
50
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150
200
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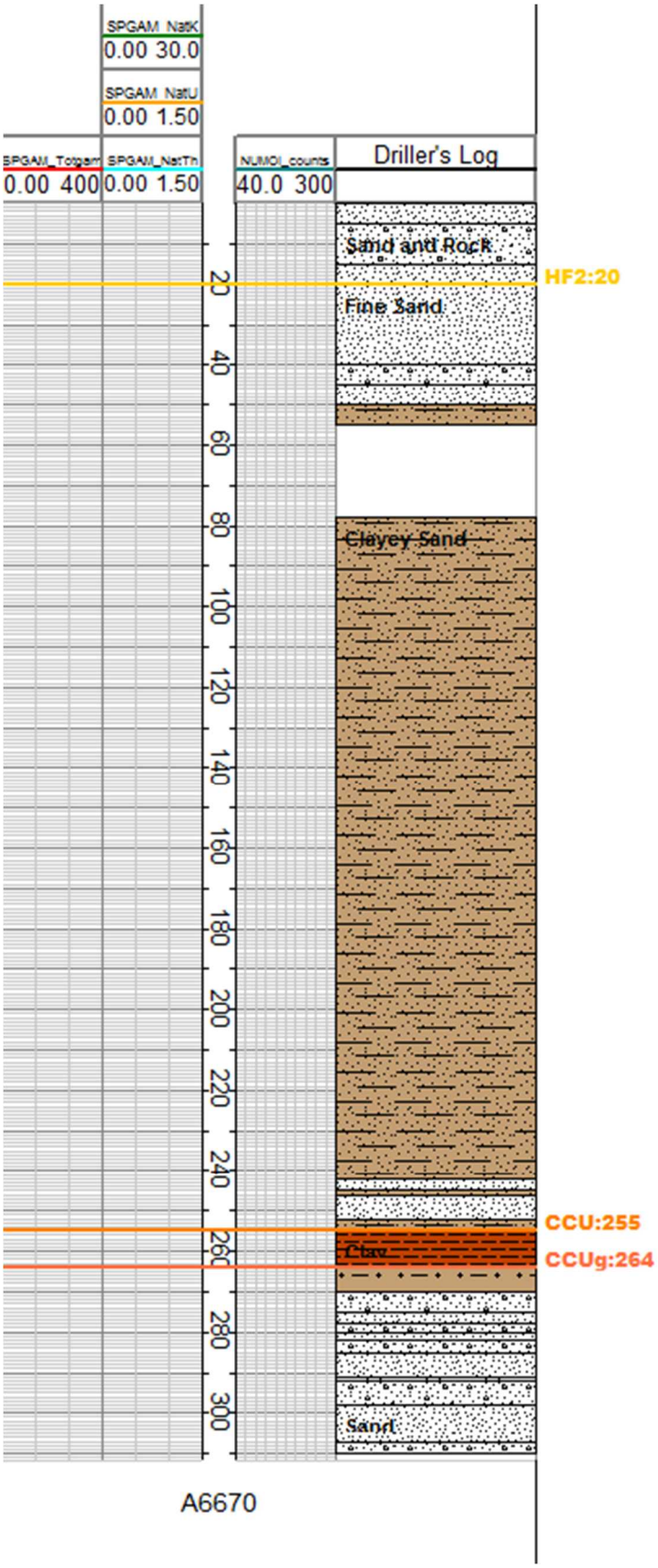
300
350
A6671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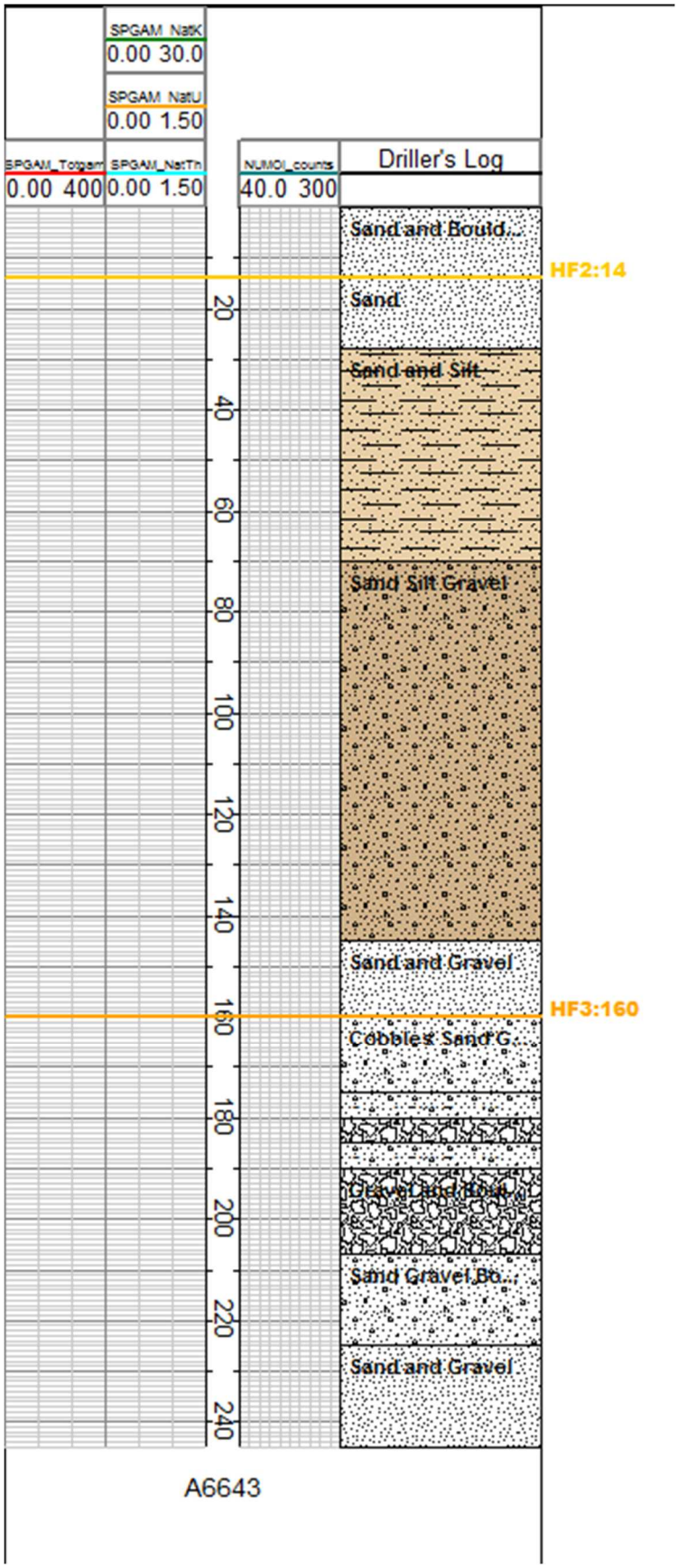
SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Driller's Log
Sand and Rock
HF2:20
Fine Sand
Clayey Sand
CCU:255
Clay
CCUg:264
Sand
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
A6670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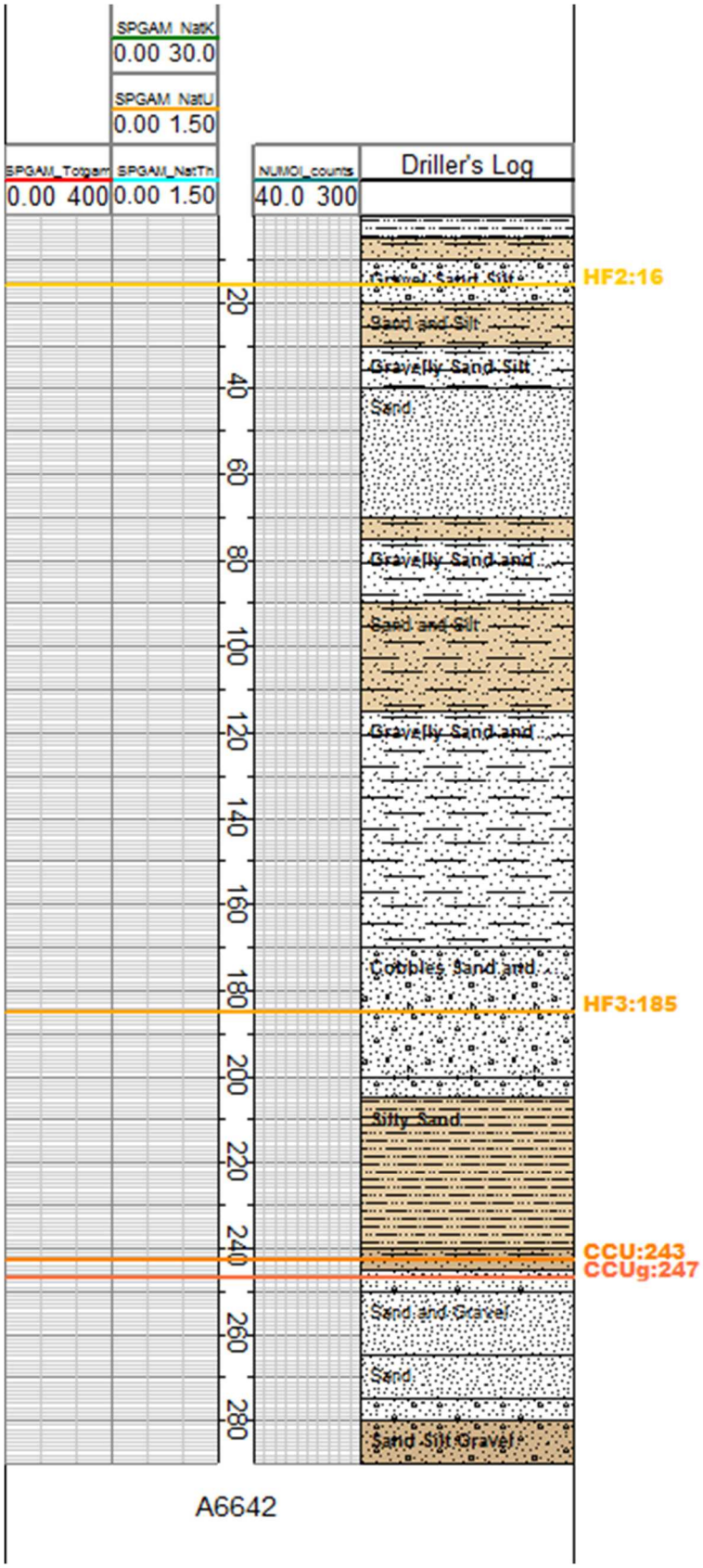
NUMOI_counts
40.0 300
Driller's Log
Sand and Bould...
HF2:14
Sand
Sand and Silt
Sand Silt Gravel
Sand and Gravel
HF3:160
Cobbles Sand G...
Gravel and Boul...
Sand Gravel Bo...
Sand and Gravel
20
40
60
80
100
120
140
160
180
200
220
240
A6643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NUMOI_counts
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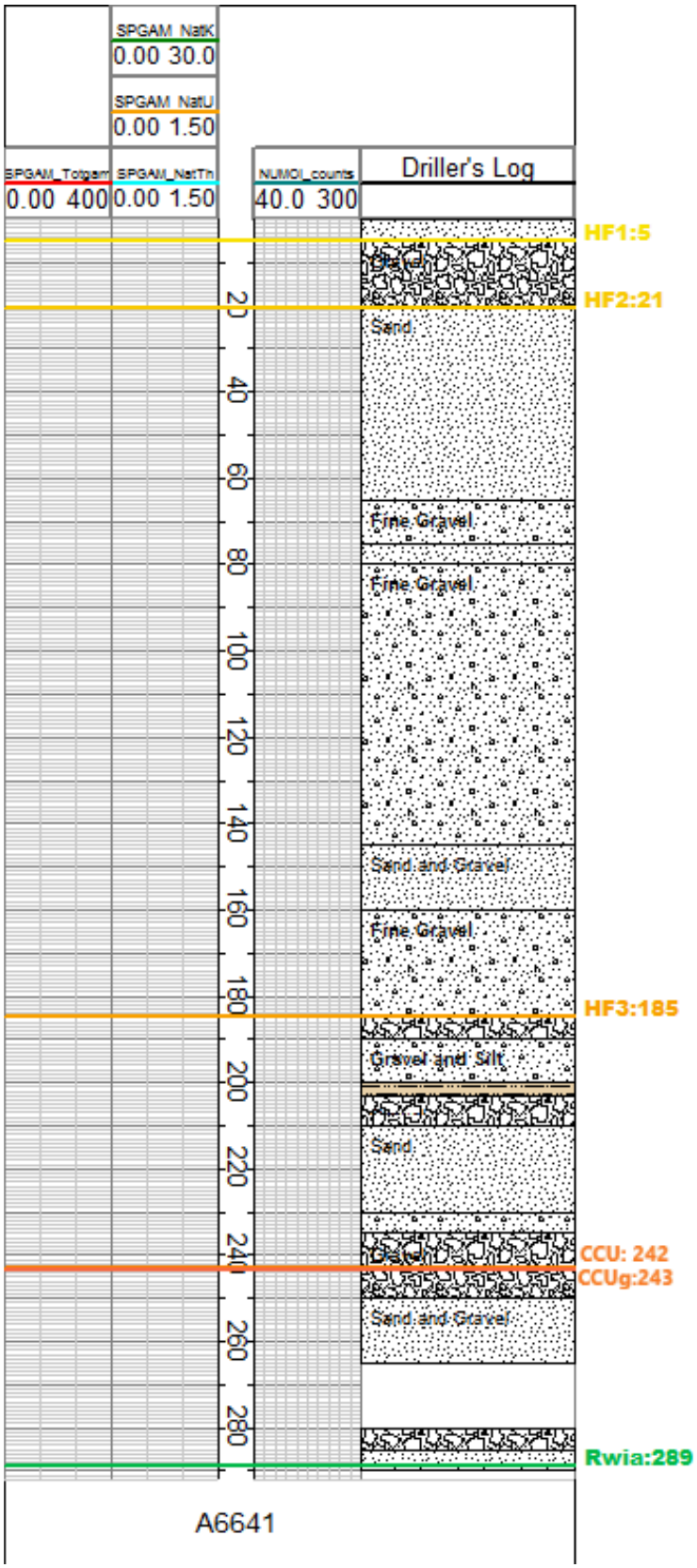
Driller's Log
HF2:16
Gravel, Sand, Silt
Sand and Silt
Gravelly Sand, Silt
Sand
Gravelly Sand and
Sand and Silt
Gravelly Sand and
Cobbles, Sand and
HF3:185
Silty Sand
CCU:243
CCUg:247
Sand and Gravel
Sand
Sand, Silt, Gravel
20
40
60
80
100
120
140
160
180
200
220
240
260
280
A6642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SPGAM_NatTh
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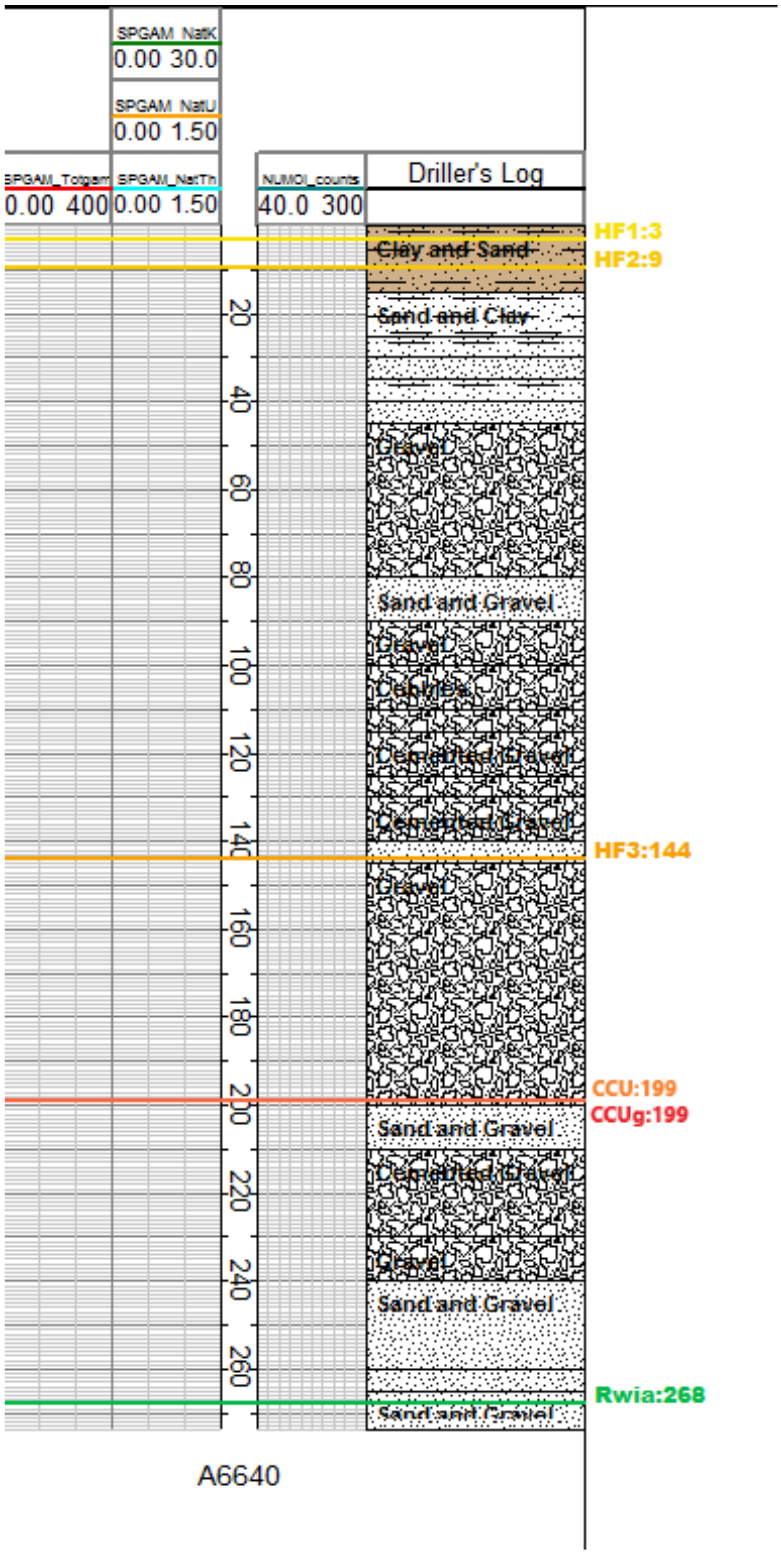
NUMOI_counts
40.0 300
Driller's Log
HF1:5
HF2:21
Sand
Fine Gravel
Fine Gravel
Sand and Gravel
Fine Gravel
HF3:185
Gravel and Silt
Sand
Gravel
CCU: 242
CCUg:243
Sand and Gravel
Rwia:289
20
40
60
80
100
120
140
160
180
200
220
240
260
280
A6641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NUMOI_counts
40.0 300
Driller's Log
HF1:3
HF2:9
Clay and Sand
Sand and Clay
Gravel
Sand and Gravel
Gravel
Cobbles
Cemented Gravel
Cemented Gravel
HF3:144
Gravel
CCU:199
CCUg:199
Sand and Gravel
Cemented Gravel
Gravel
Sand and Gravel
Rwia:268
Sand and Gravel
20
40
60
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100
120
140
160
180
200
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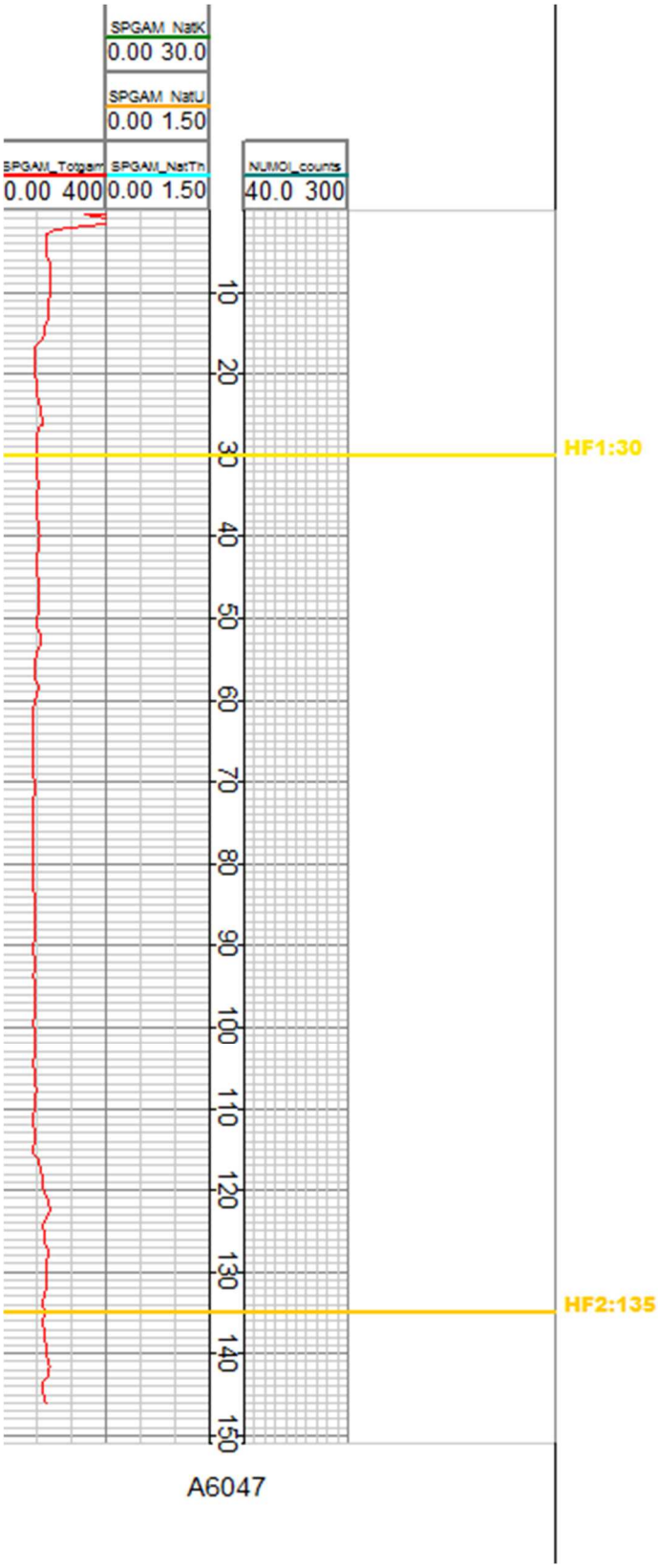
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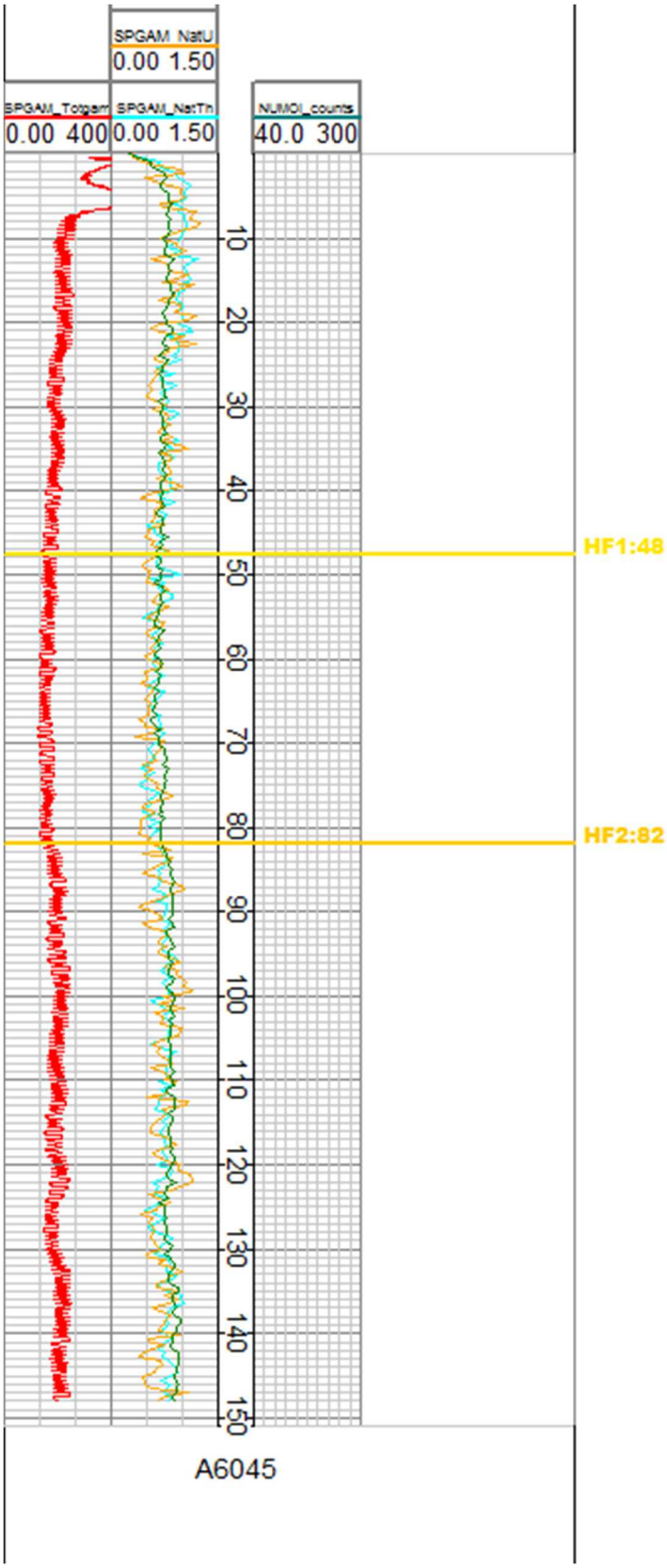
40.0 300
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
HF1:30
HF2:135
A6047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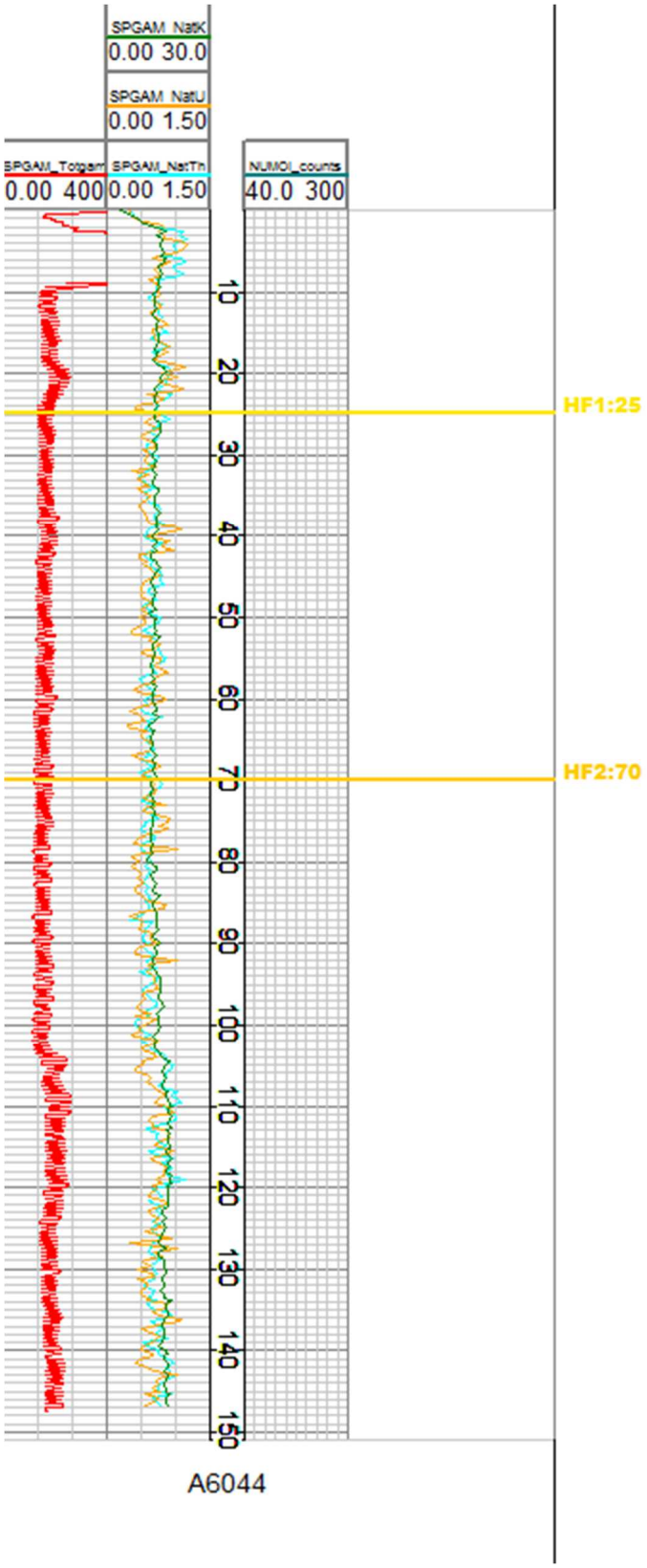
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
HF1:48
HF2:82
A6045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10
20
30
40
50
60
70
80
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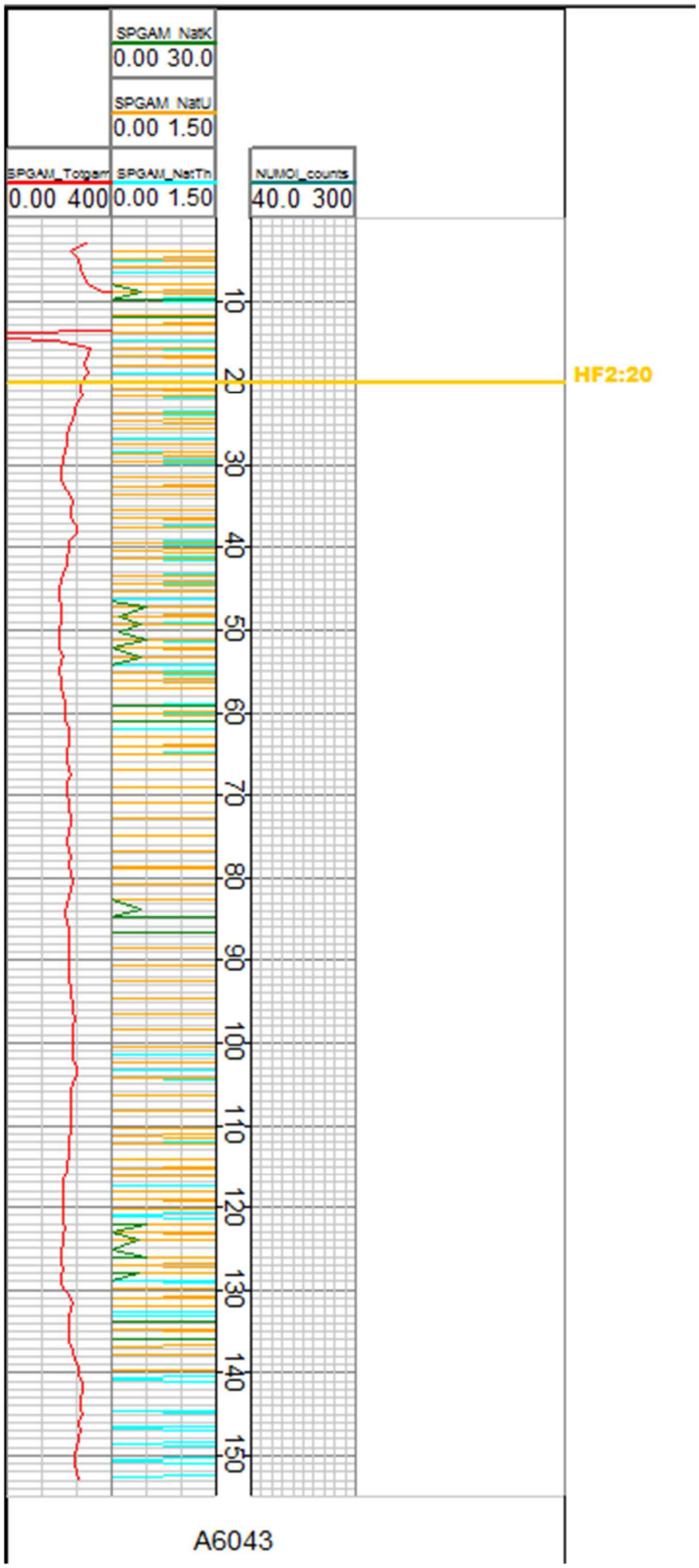
130
140
150
HF1:25
HF2:70
A6044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SPGAM_NatTh
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NUMOI_counts
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10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
HF2:20
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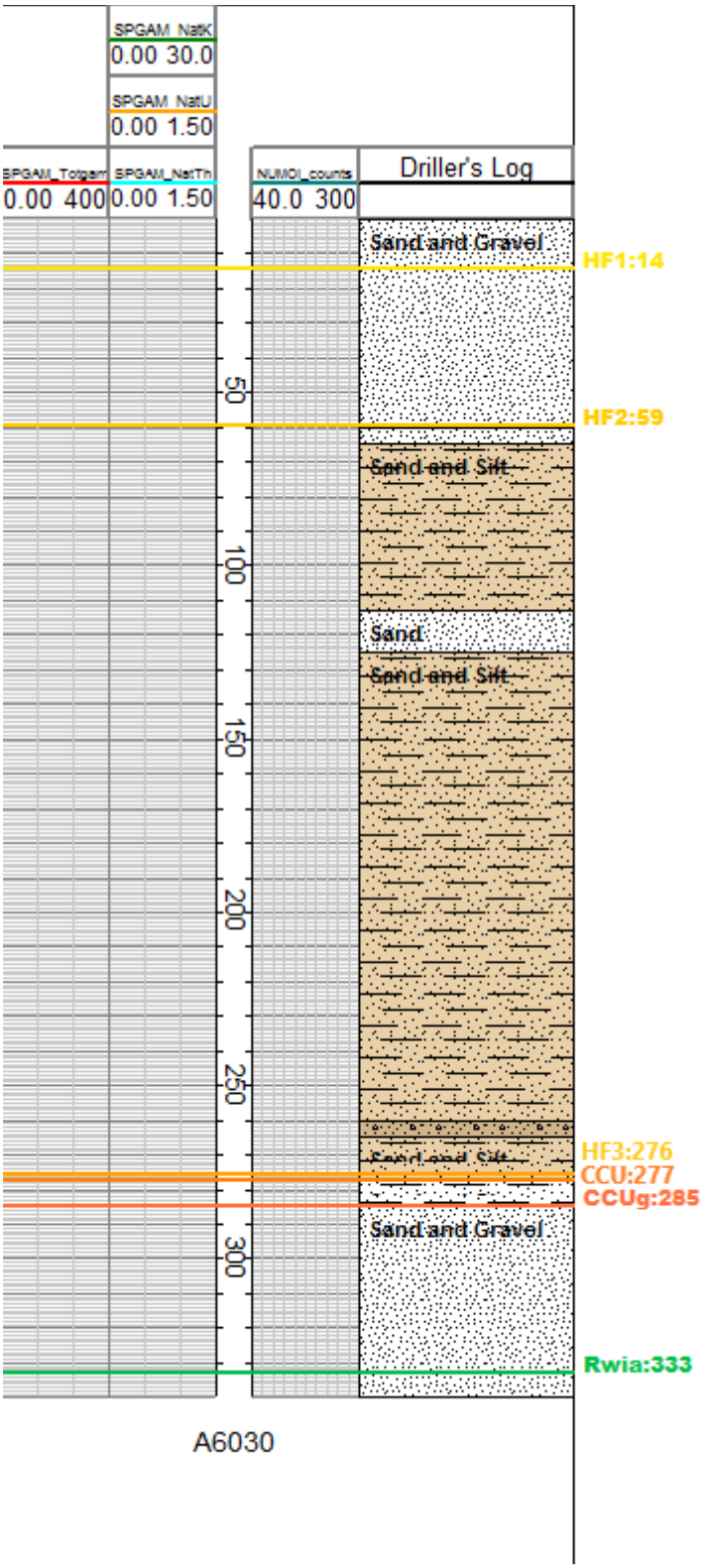
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0.00 1.50
SPGAM_Totgam
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SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Driller's Log
Sand and Gravel
HF1:14
HF2:59
Sand and Silt
Sand
Sand and Silt
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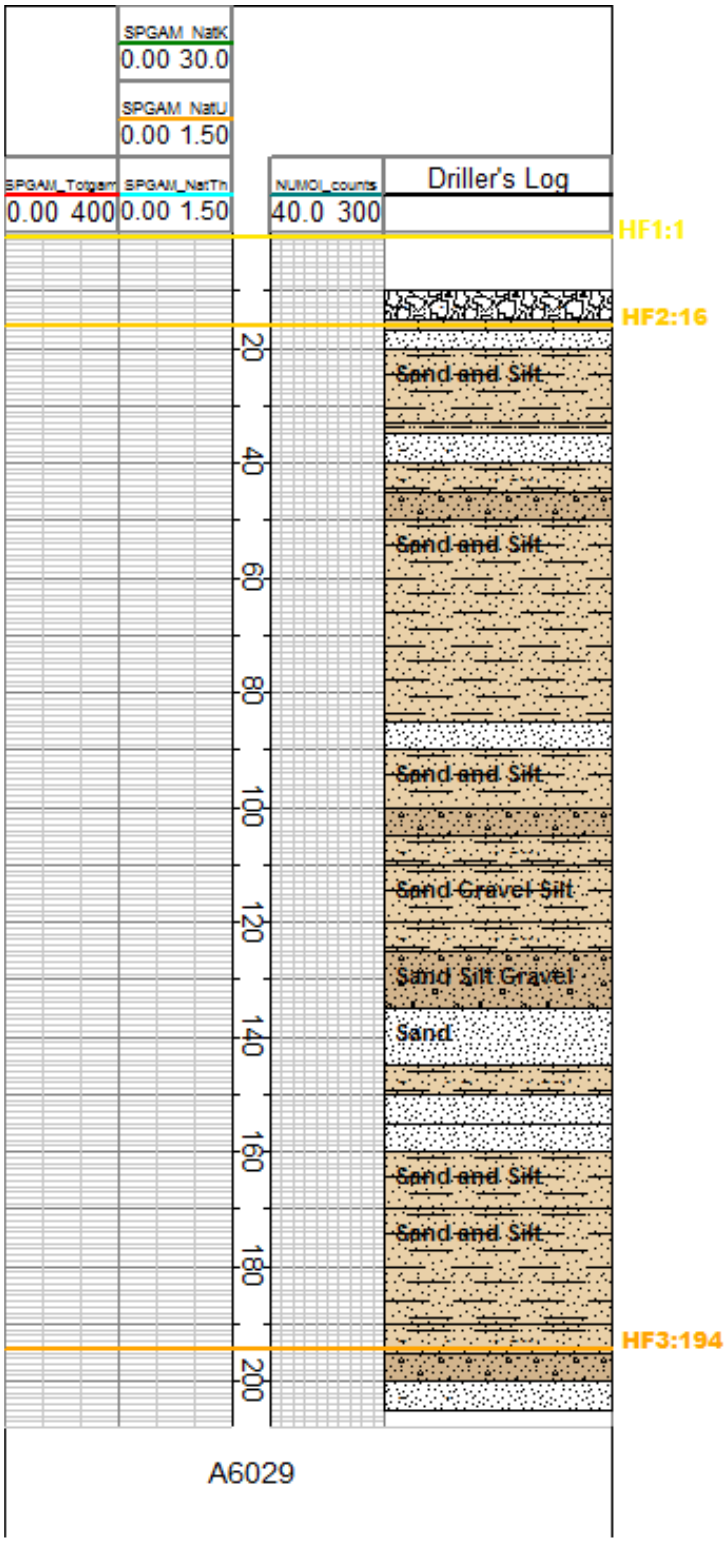
CCU:277
CCUg:285
Sand and Gravel
Rwia:333
50
100
150
200
250
300
A6030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Driller's Log
HF1:1
HF2:16
HF3:194
20
40
60
80
100
120
140
160
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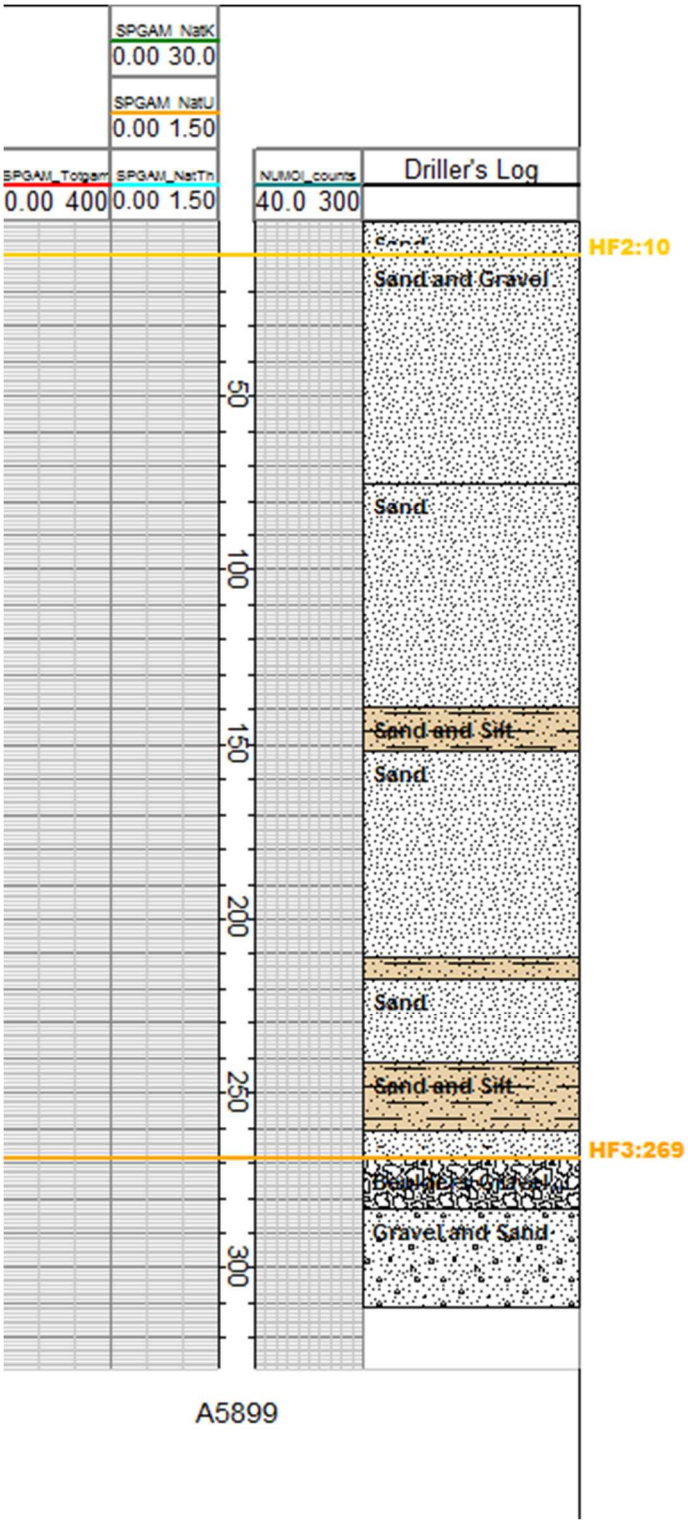
Sand and Silt
Sand and Silt
Sand and Silt
Sand Gravel Silt
Sand Silt Gravel
Sand
Sand and Silt
Sand and Silt
A6029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Driller's Log
HF2:10
Sand and Gravel
Sand
Sand and Silt
Sand
Sand
Sand and Silt
HF3:269
Gravel and Sand
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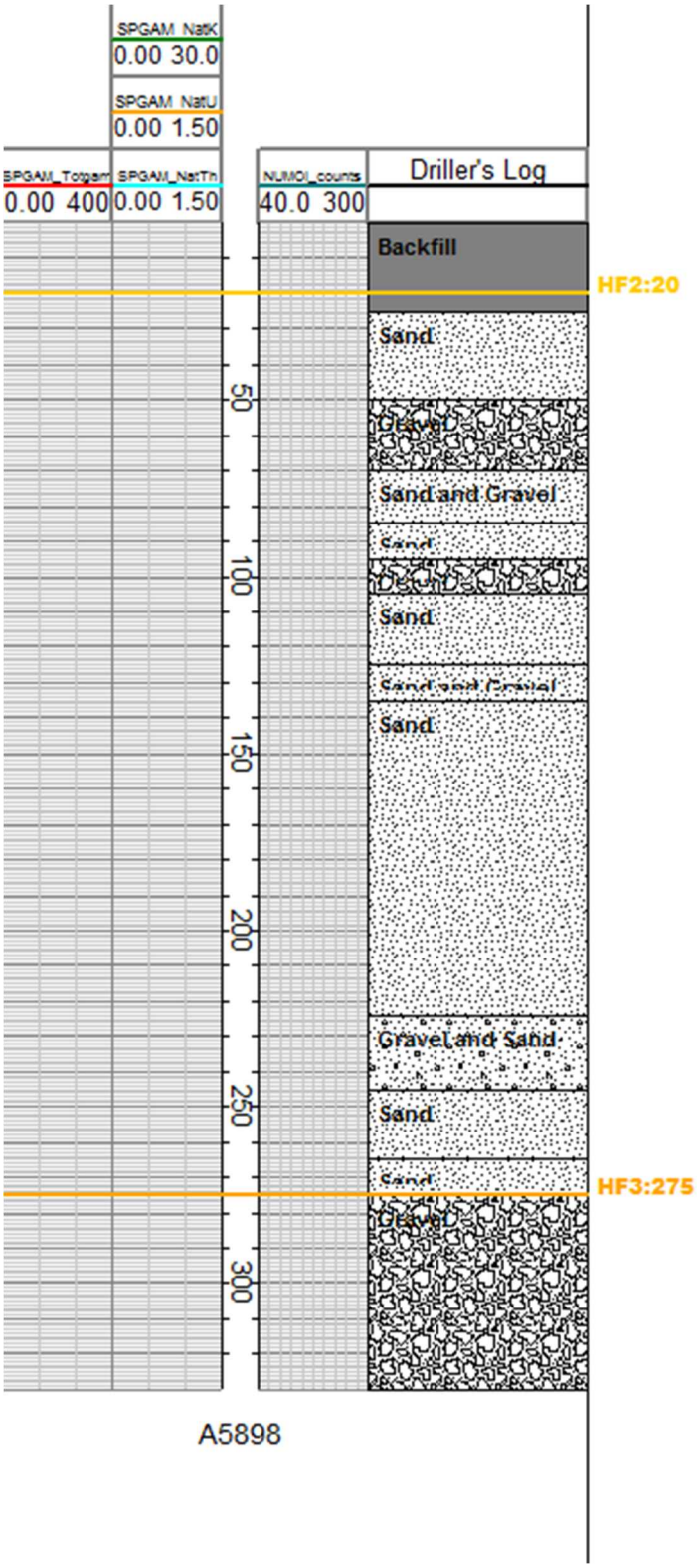
100
150
200
250
300
A5899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40.0 300
Driller's Log
Backfill
HF2:20
Sand
Gravel
Sand and Gravel
Sand
Gravel
Sand
Sand and Gravel
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150
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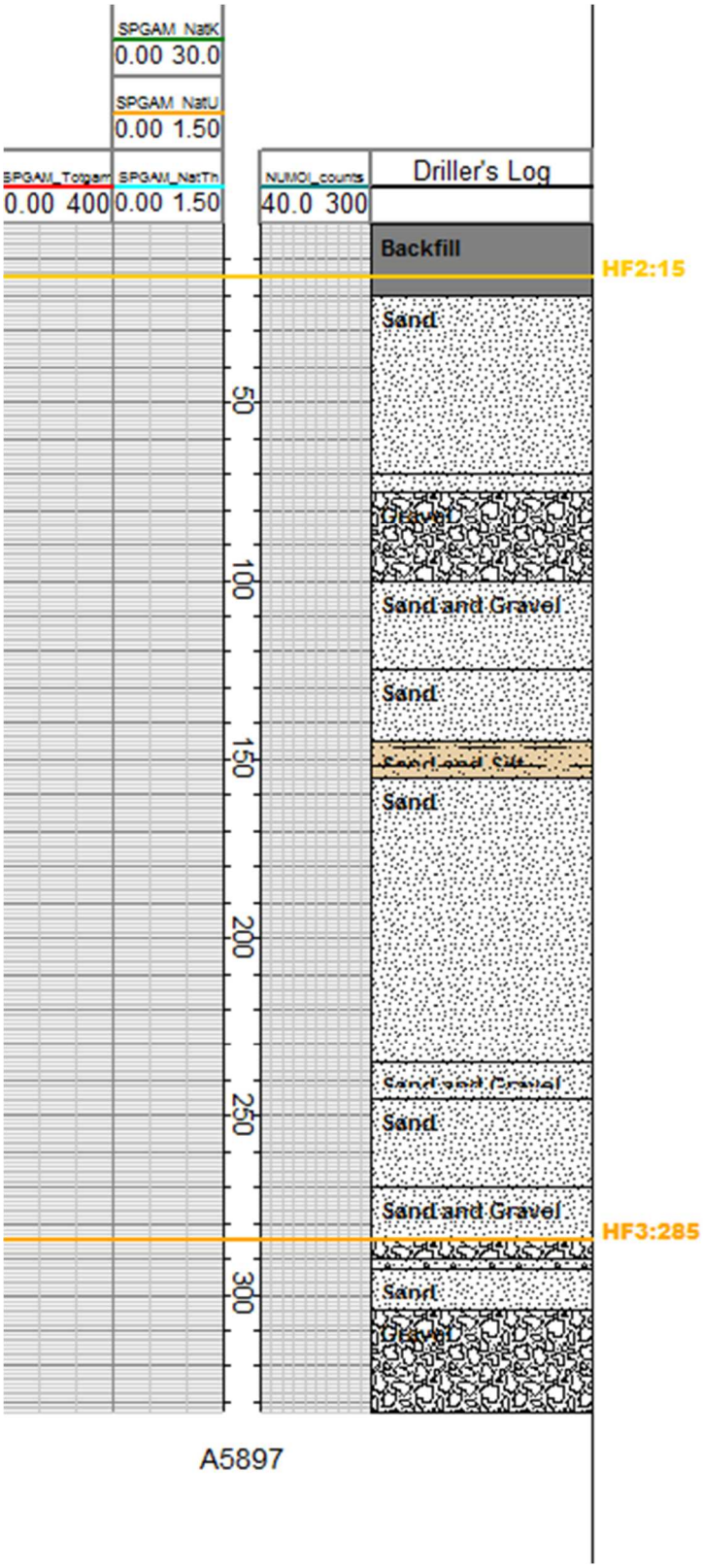
250
300
A5898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40.0 300
Driller's Log
Backfill
HF2:15
Sand
Gravel
Sand and Gravel
Sand
Sand
Sand
Sand and Gravel
Sand
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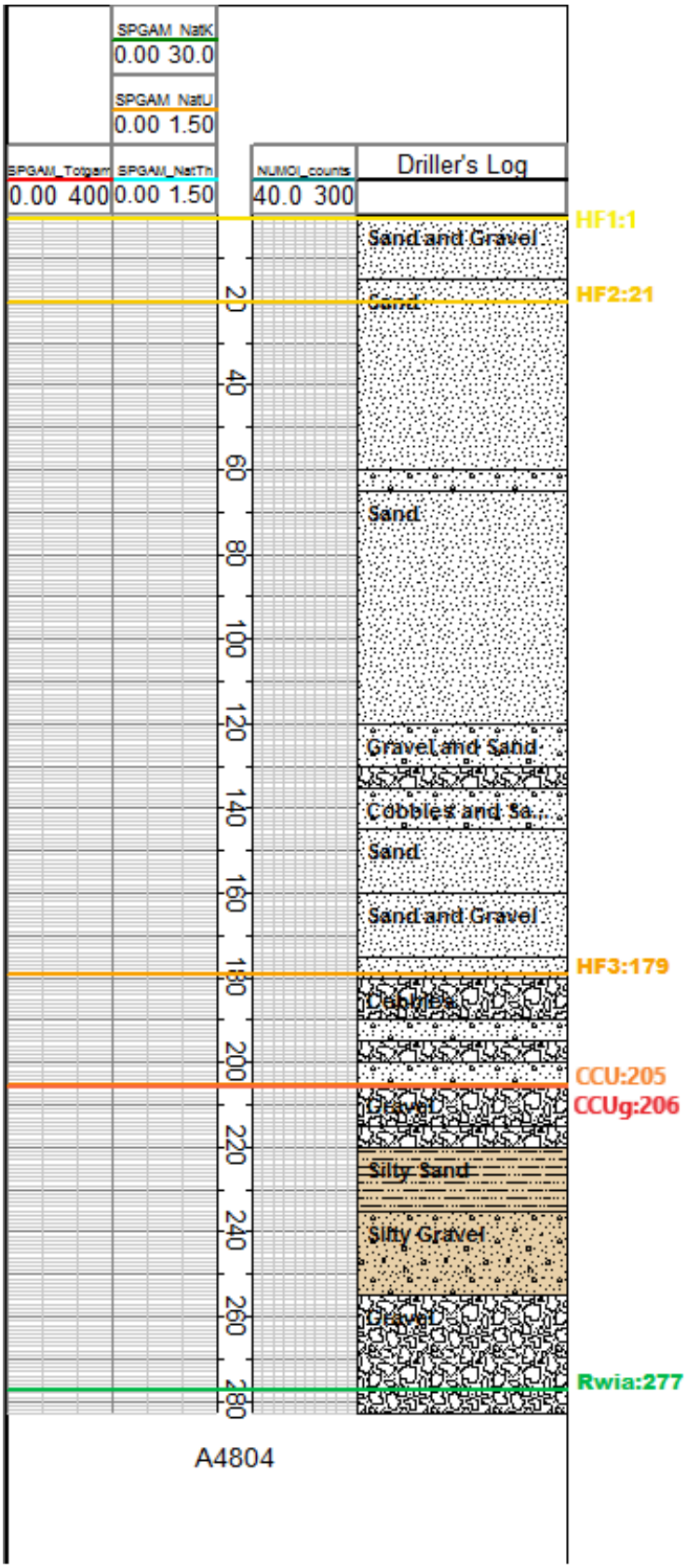
100
150
200
250
300
A5897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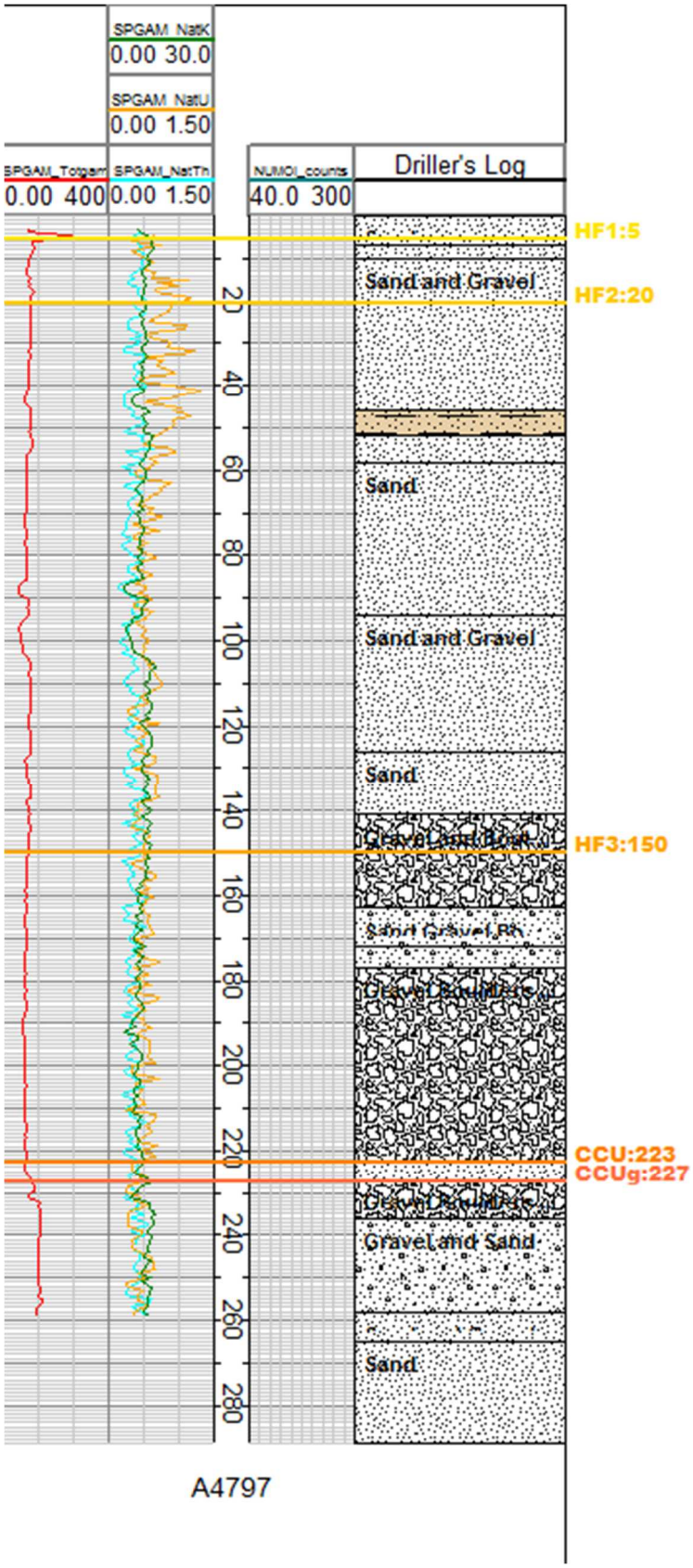
SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Driller's Log
HF1:1
Sand and Gravel
HF2:21
Sand
Gravel and Sand
Cobbles and Sa...
Sand
Sand and Gravel
HF3:179
Cobbles
CCU:205
CCUg:206
Gravel
Silty Sand
Silty Gravel
Gravel
Rwia:277
20
40
60
80
100
120
140
160
180
200
220
240
260
280
A4804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NUMOI_counts
40.0 300
Driller's Log
HF1:5
Sand and Gravel
HF2:20
Sand
Sand and Gravel
Sand
HF3:150
CCU:223
CCUg:227
Gravel and Sand
Sand
20
40
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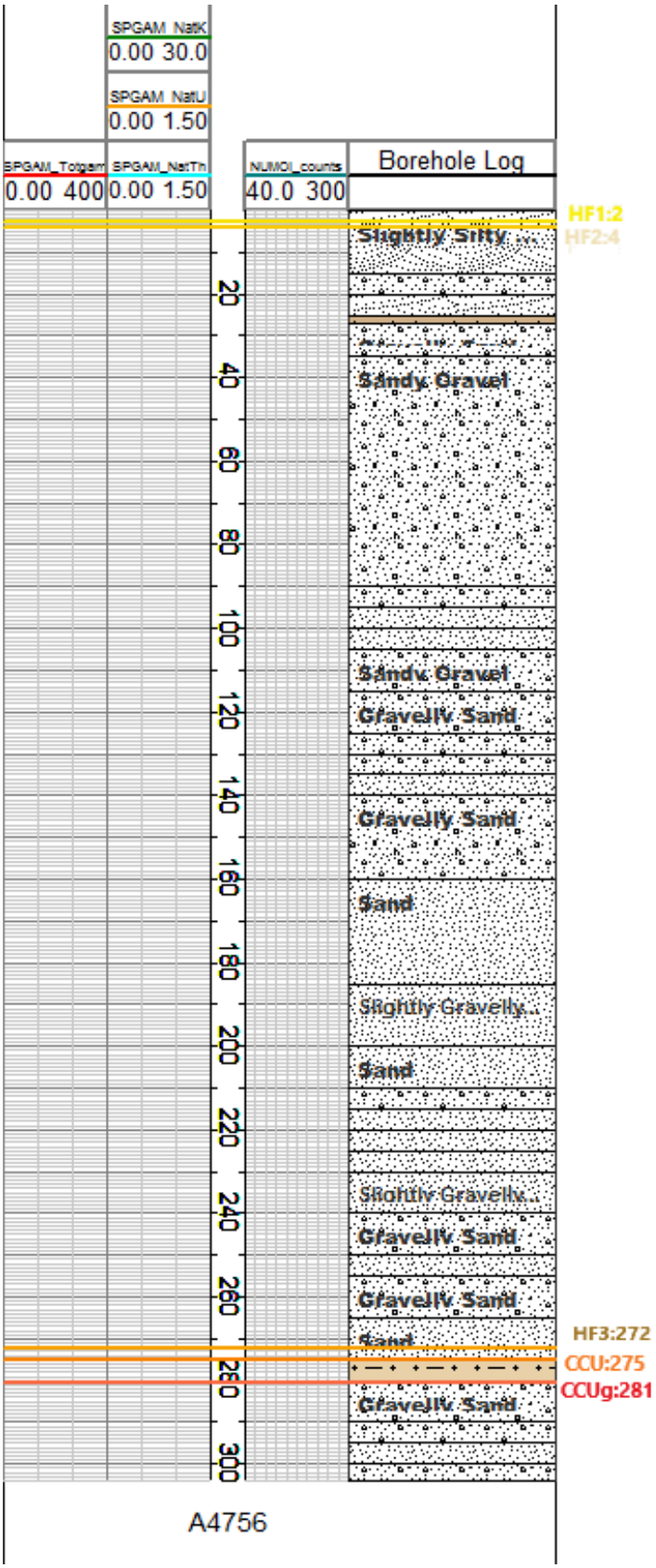
80
100
120
140
160
180
200
220
240
260
280
A4797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SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
HF1:2
HF2:4
Slightly Silty ...
Sandy Gravel
Sandy Gravel
Gravelly Sand
Gravelly Sand
Sand
Slightly Gravelly...
Sand
Slightly Gravelly...
Gravelly Sand
Gravelly Sand
Sand
HF3:272
CCU:275
CCUg:281
Gravelly Sand
20
40
60
80
100
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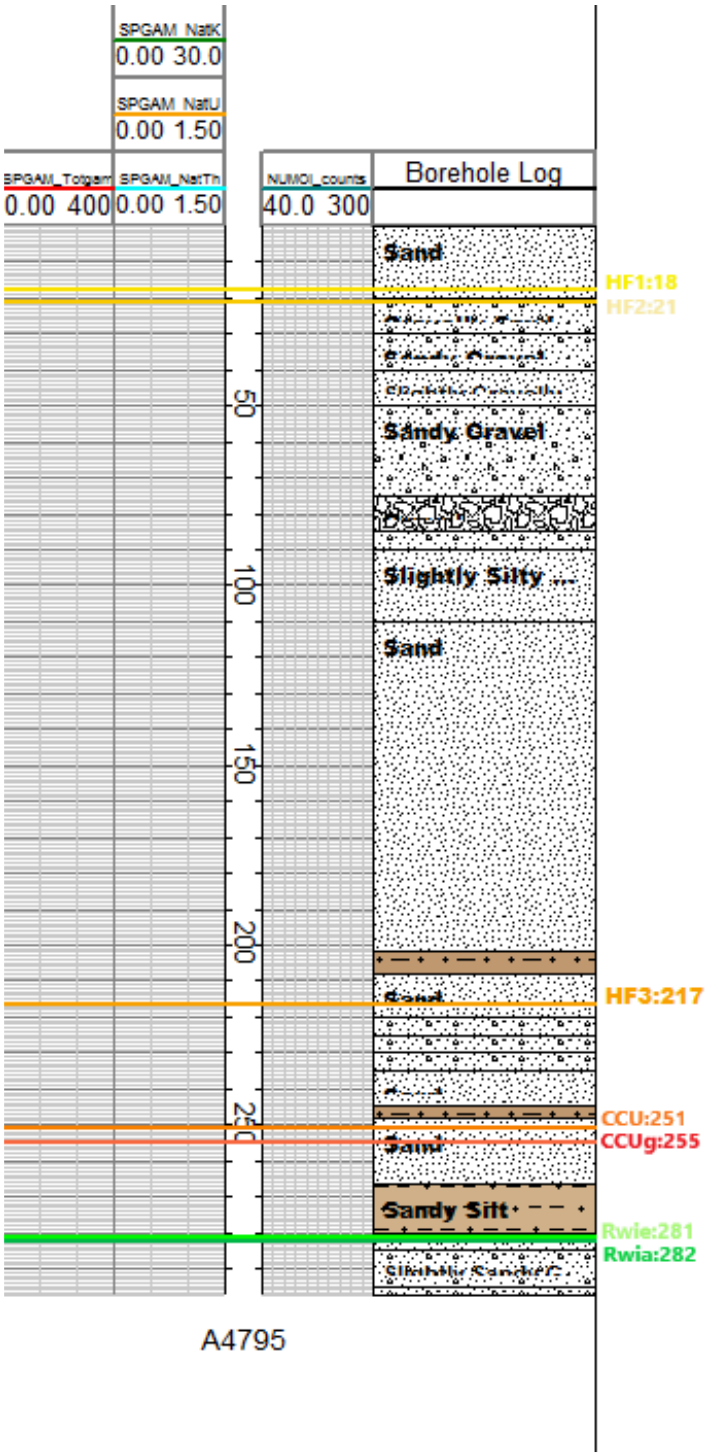
220
240
260
280
300
A4756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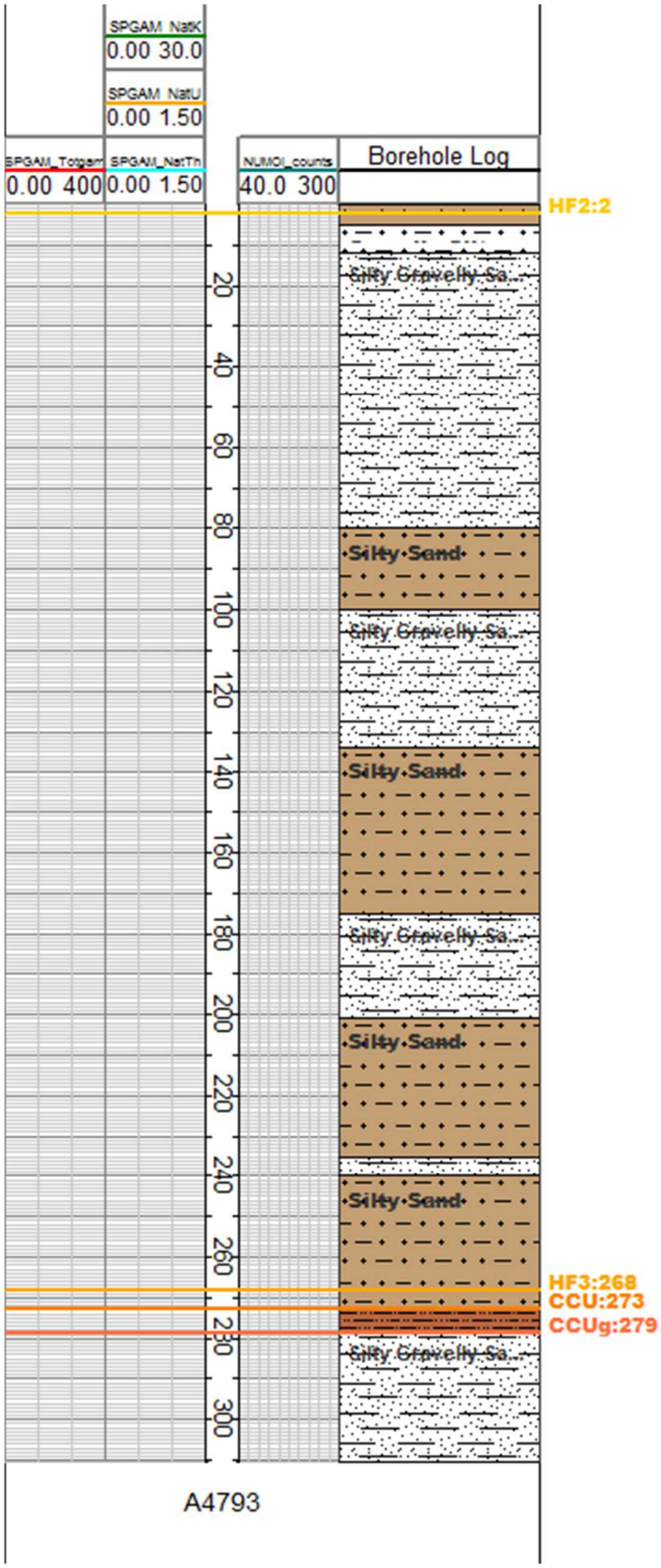
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
Sand
HF1:18
HF2:21
Sandy Gravel
Slightly Silty ...
Sand
HF3:217
CCU:251
CCUg:255
Sandy Silt
Rwie:281
Rwia:282
50
100
150
200
250
A4795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NUMOI_counts
40.0 300
Borehole Log
HF2:2
Silty Gravelly Sa...
Silty Sand
HF3:268
CCU:273
CCUg:279
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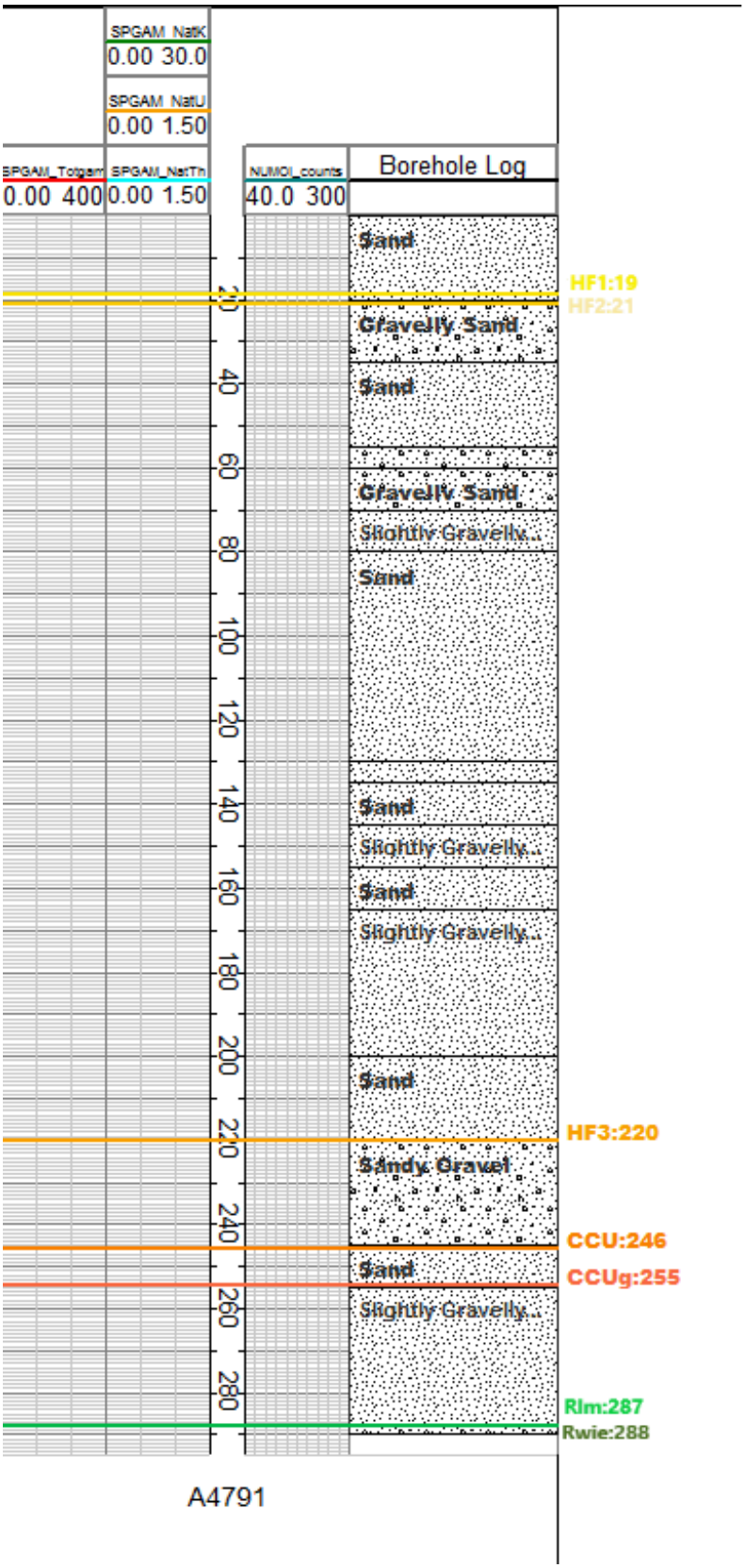
220
240
260
280
300
A4793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SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
Sand
Gravelly Sand
Sand
Gravelly Sand
Slightly Gravelly...
Sand
Sand
Slightly Gravelly...
Sand
Slightly Gravelly...
Sand
Sandy Gravel
Sand
Slightly Gravelly...
20
40
60
80
100
120
140
160
180
200
220
240
260
280
HF1:19
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HF3:220
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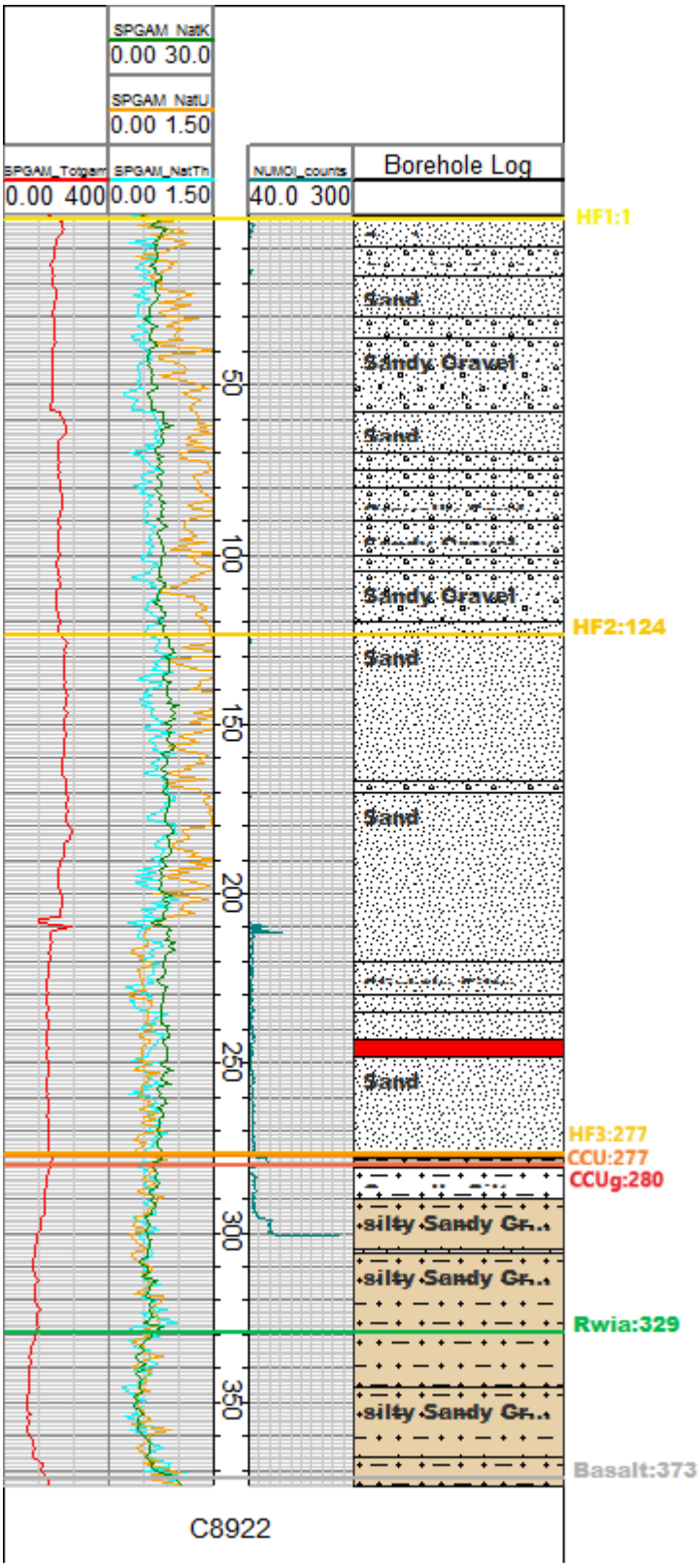
CCUg:255
Rlm:287
Rwie:288
A4791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NUMOI_counts
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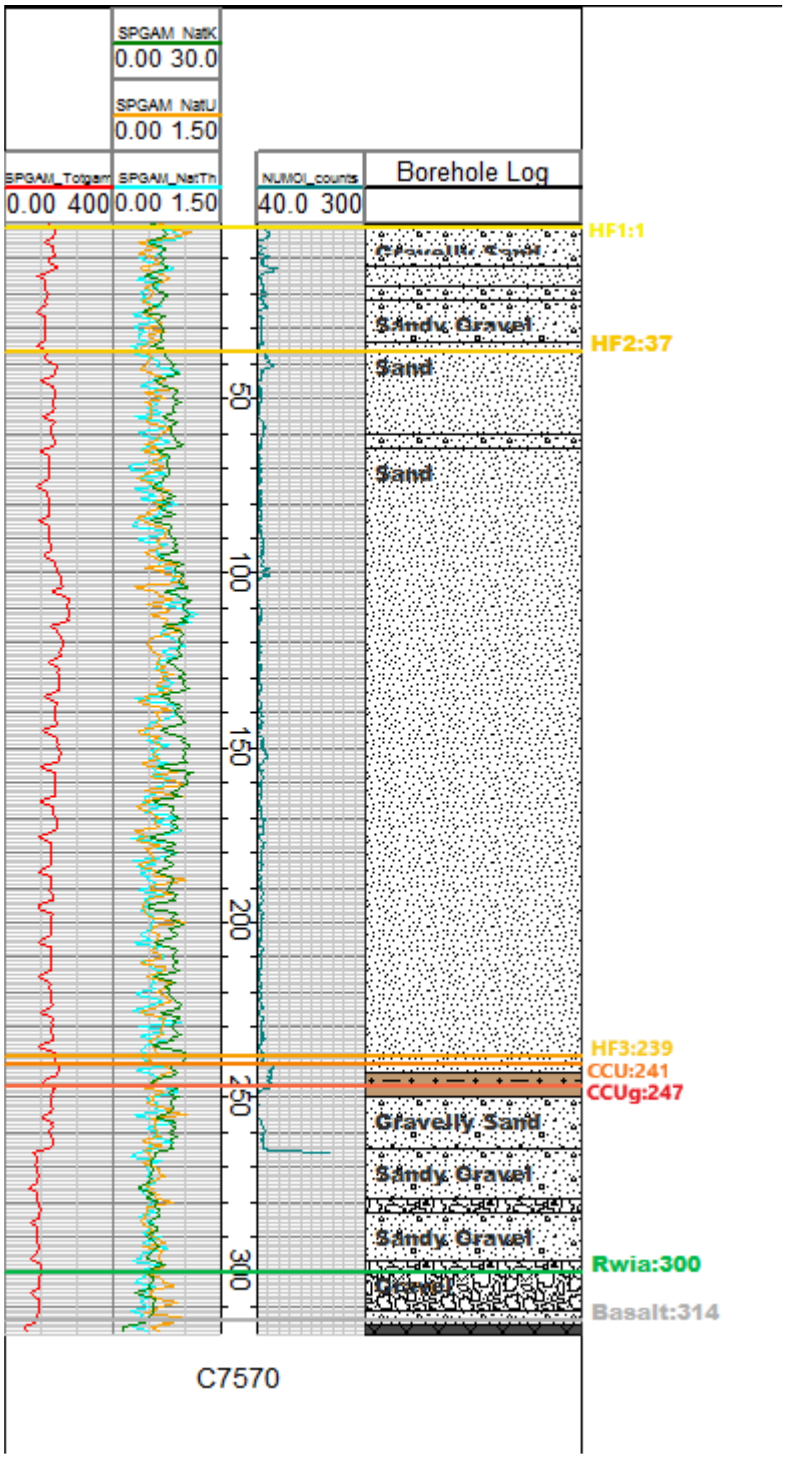
Borehole Log
HF1:1
Sand
Sandy Gravel
Sand
Sandy Gravel
HF2:124
Sand
Sand
Sand
HF3:277
CCU:277
CCUg:280
silty Sandy Gr...
silty Sandy Gr...
Rwia:329
silty Sandy Gr...
Basalt:373
50
100
150
200
250
300
350
C8922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SPGAM_NatTh
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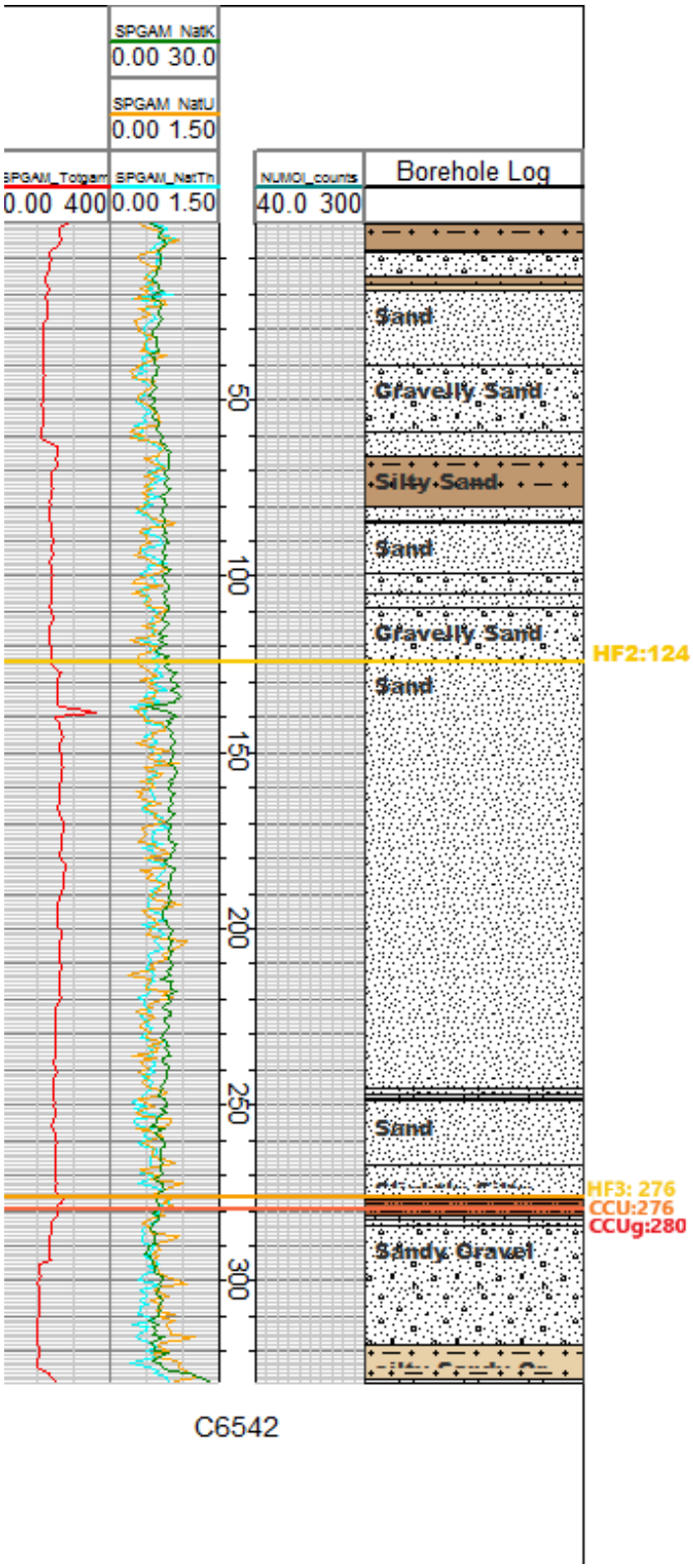
NUMOI_counts
40.0 300
Borehole Log
HF1:1
Sandy Gravel
HF2:37
Sand
Sand
HF3:239
CCU:241
CCUg:247
Gravelly Sand
Sandy Gravel
Sandy Gravel
Rwia:300
Basalt:314
50
100
150
200
250
300
C7570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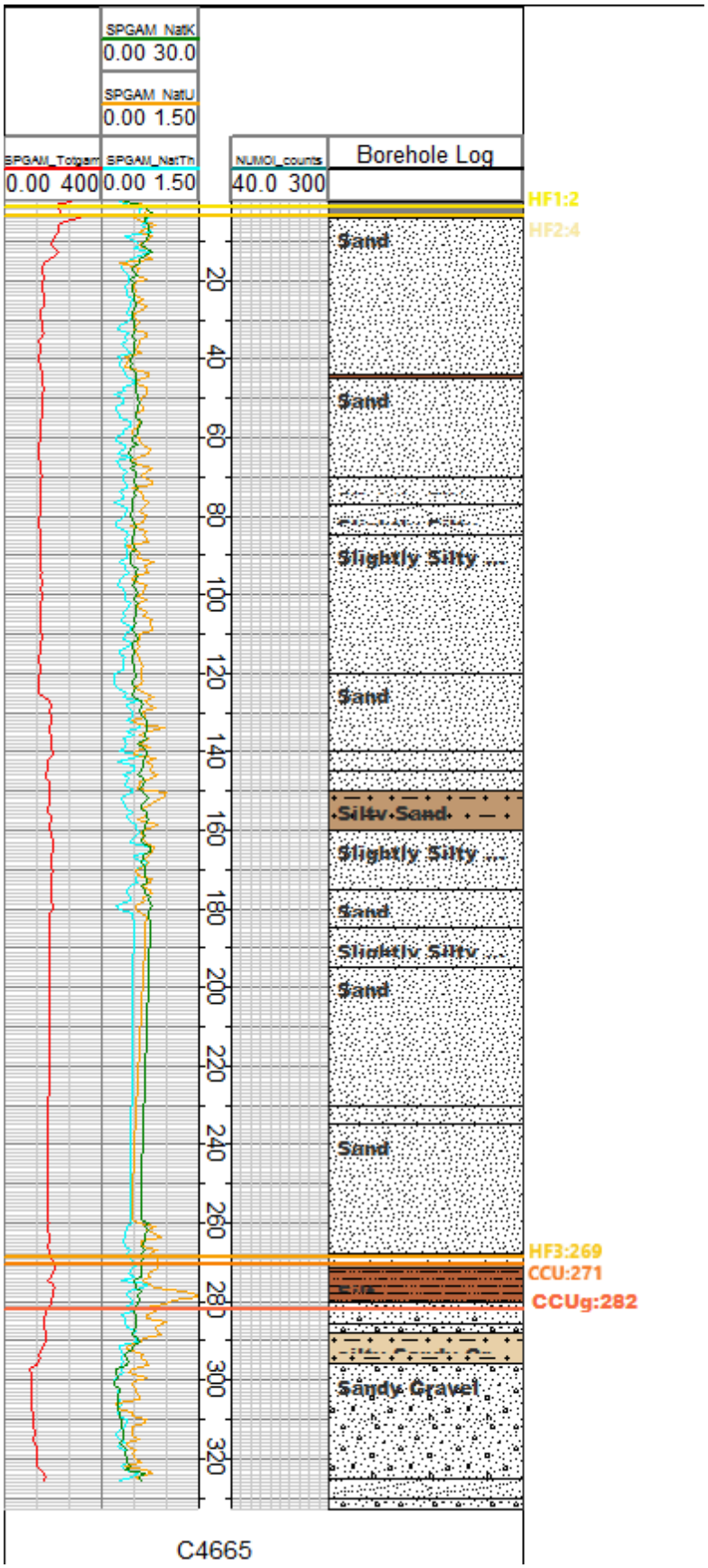
SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
Sand
Gravelly Sand
Silty Sand
Sand
Gravelly Sand
Sand
Sand
Sandy Gravel
50
100
150
200
250
300
HF2:124
HF3: 276
CCU:276
CCUg:280
C6542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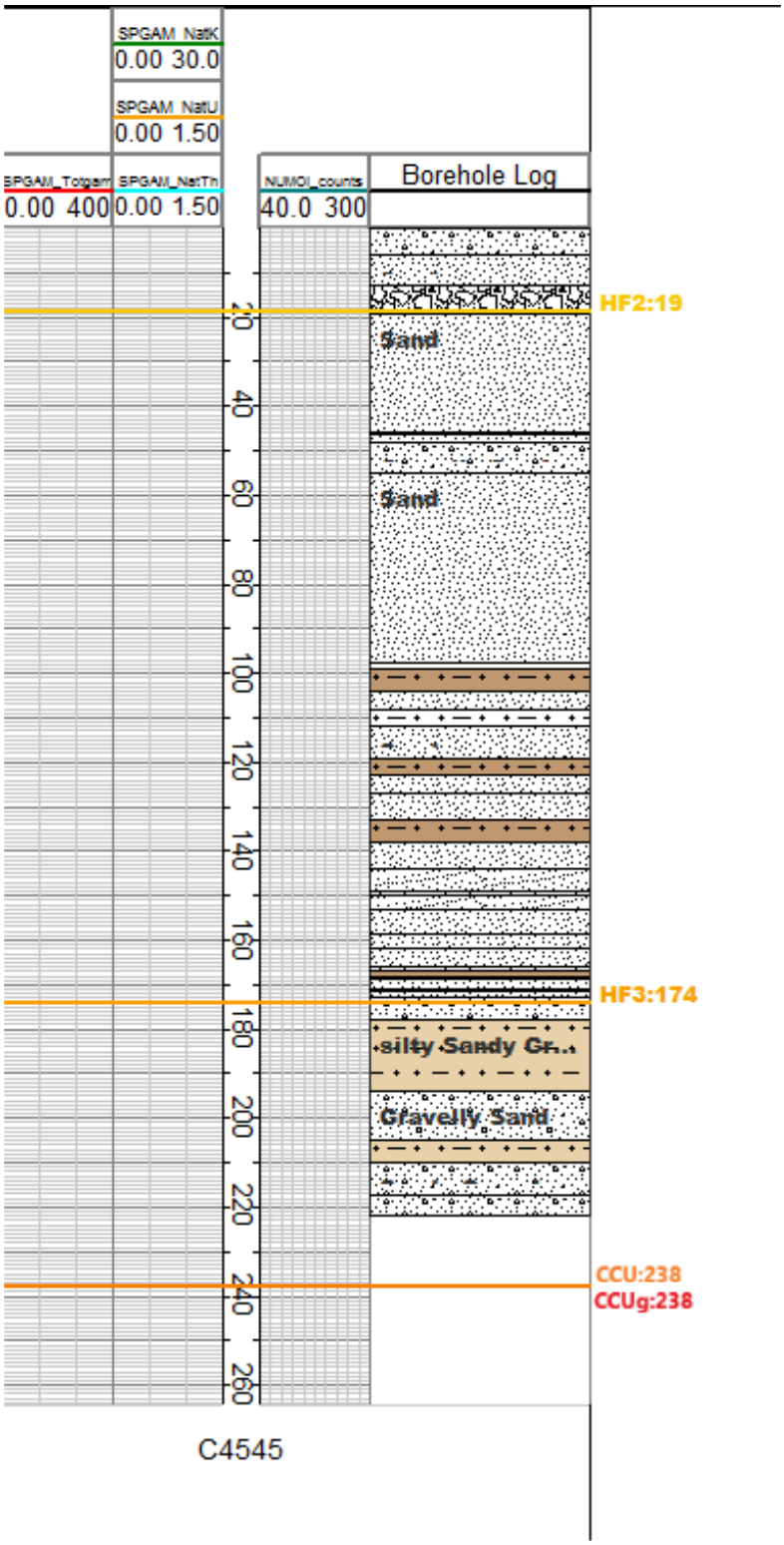
SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
HF1:2
HF2:4
Sand
Sand
Slightly Silty ...
Sand
Silty Sand
Slightly Silty ...
Sand
Slightly Silty ...
Sand
Sand
HF3:269
CCU:271
CCUg:282
Sandy Gravel
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
C4665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NUMOI_counts
40.0 300
Borehole Log
HF2:19
Sand
Sand
HF3:174
silty Sandy Gr...
Gravelly Sand
CCU:238
CCUg:238
20
40
60
80
100
120
140
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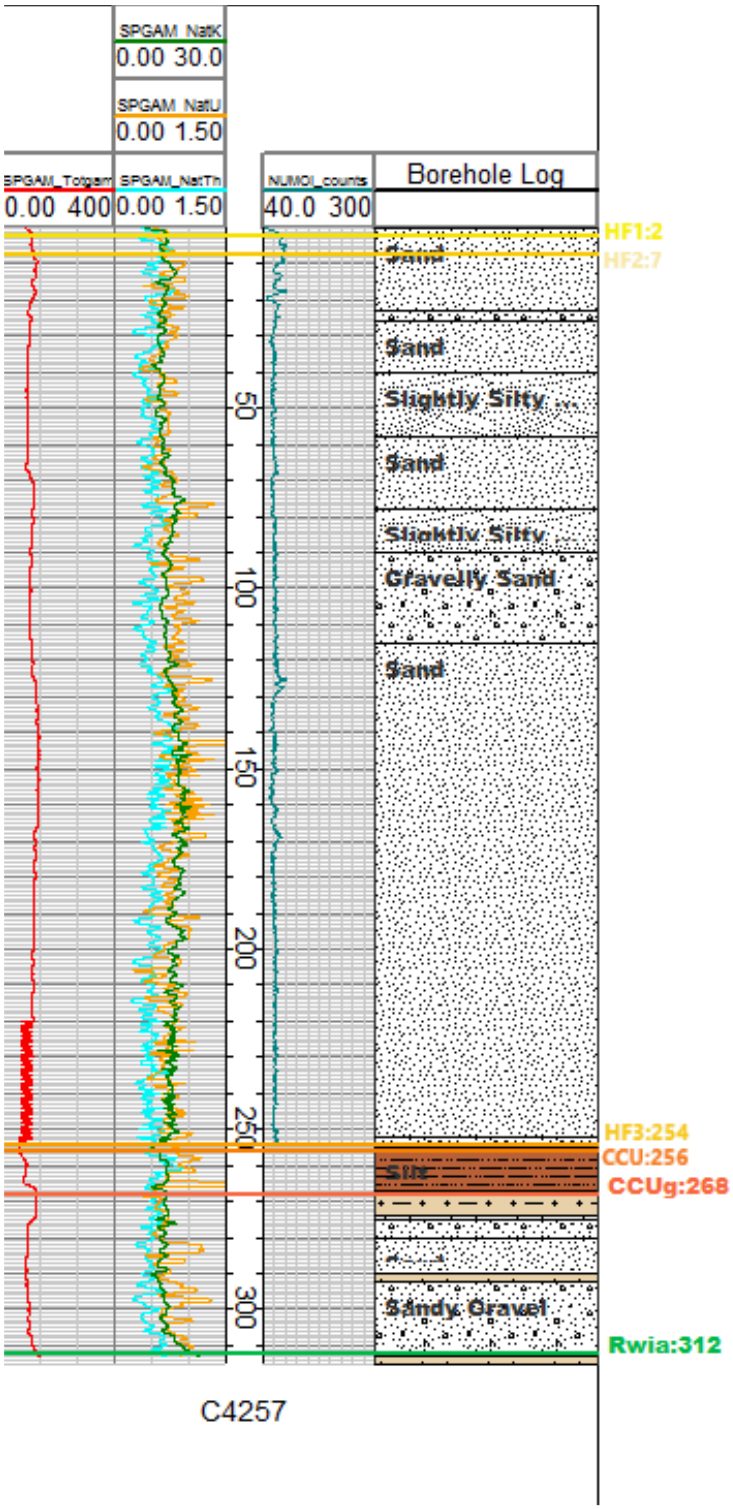
240
260
C4545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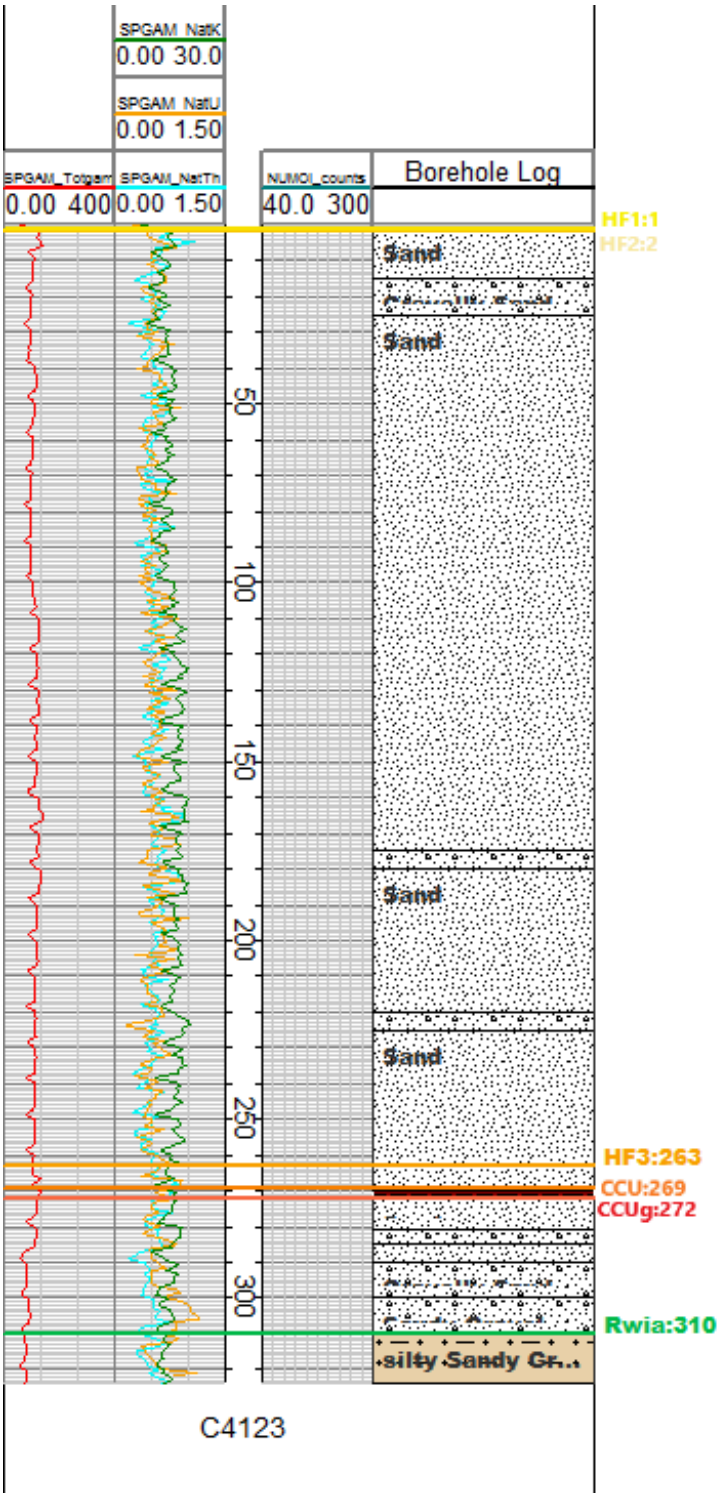
NUMOI_counts
40.0 300
Borehole Log
HF1:2
HF2:7
Sand
Slightly Silty
Gravelly Sand
HF3:254
CCU:256
CCUg:268
Silt
Sandy Gravel
Rwia:312
50
100
150
200
250
300
C4257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SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
HF1:1
HF2:2
Sand
Sand
Sand
Sand
HF3:263
CCU:269
CCUg:272
Rwia:310
silty Sandy Gr...
50
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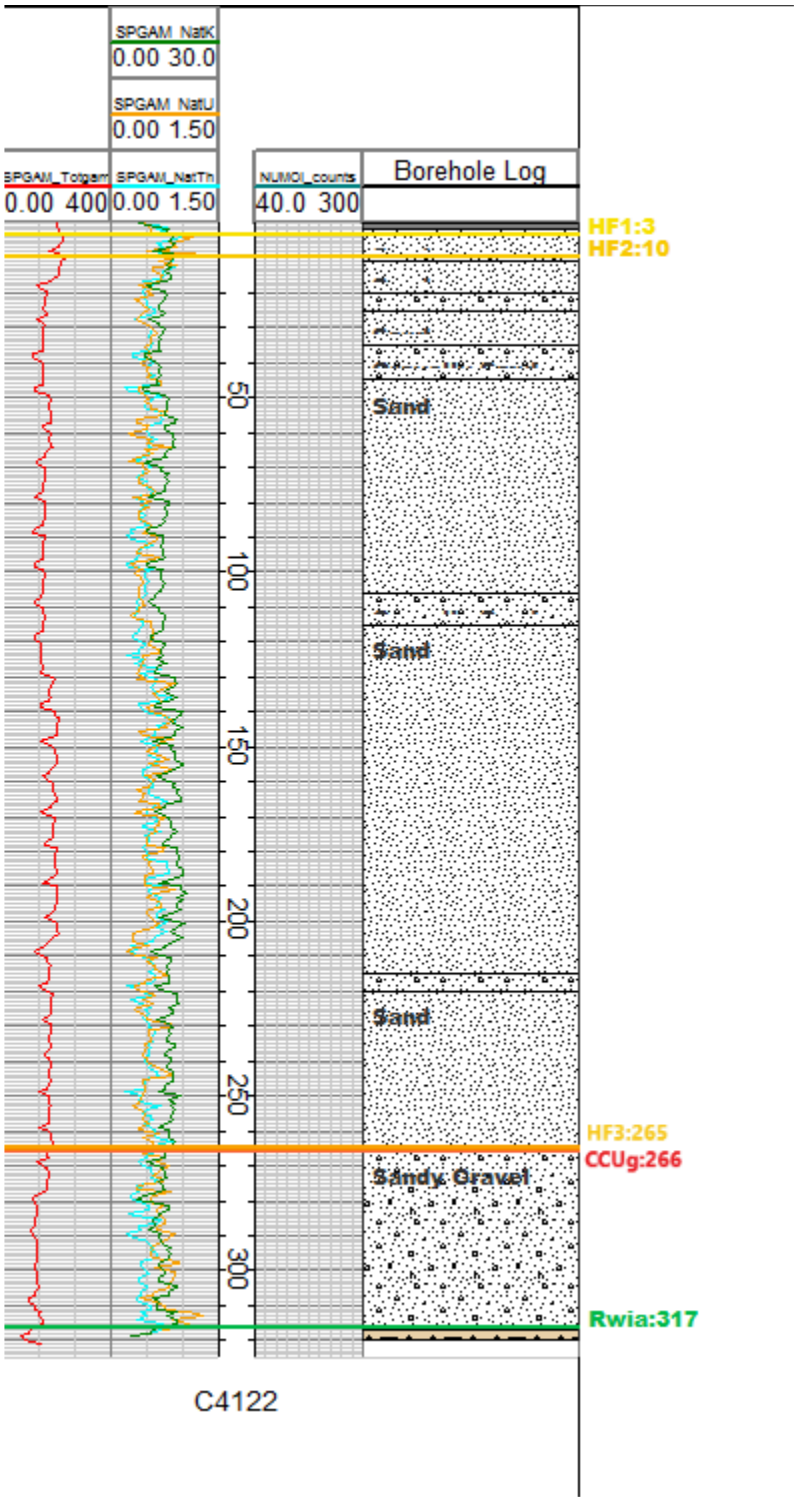
200
250
300
C4123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SPGAM_Totgam
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SPGAM_NatTh
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NUMOI_counts
40.0 300
Borehole Log
HF1:3
HF2:10
Sand
Sand
Sand
HF3:265
CCUg:266
Sandy Gravel
Rwia:317
50
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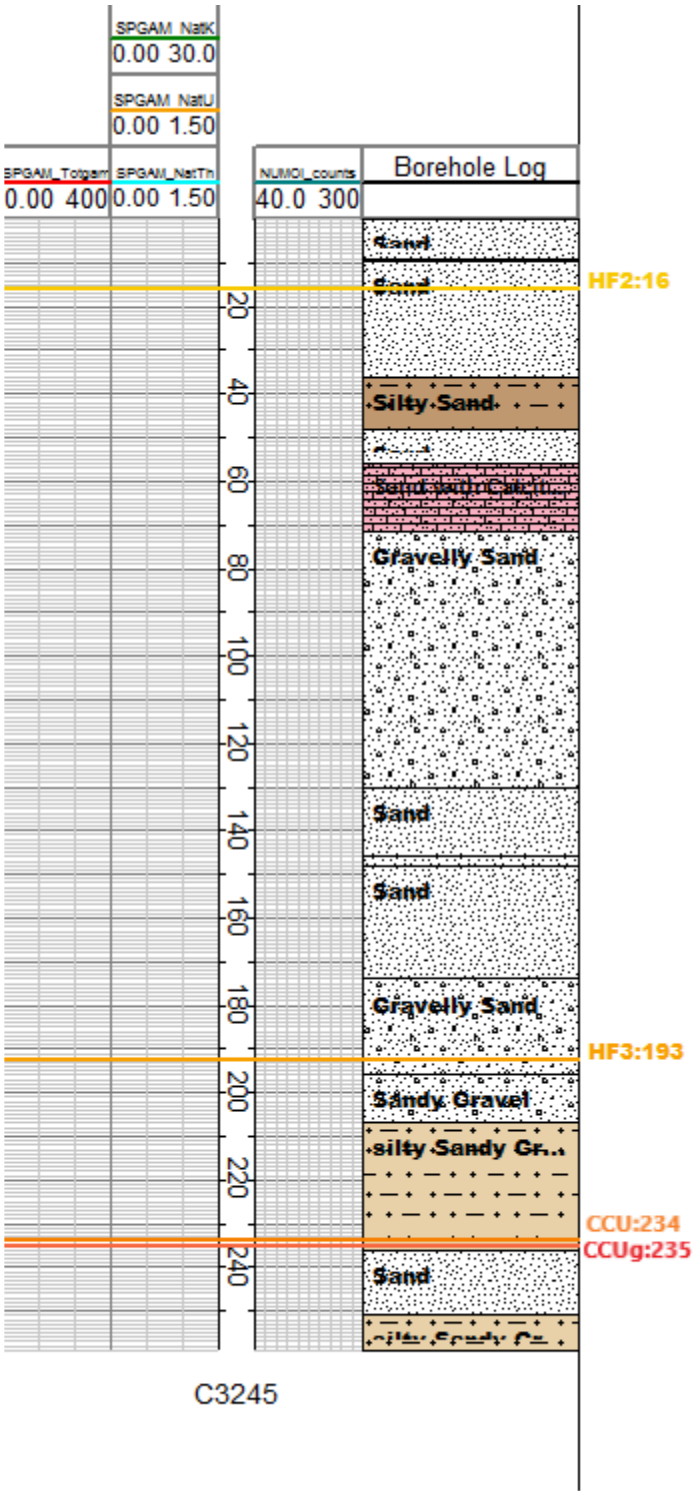
200
250
300
C4122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SPGAM_Totgam
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SPGAM_NatTh
0.00 1.50
NUMOI_counts
40.0 300
Borehole Log
Sand
Sand
HF2:16
20
40
Silty Sand
60
80
Gravelly Sand
100
120
Sand
140
Sand
160
180
Gravelly Sand
HF3:193
200
Sandy Gravel
silty Sandy Gr...
220
CCU:234
CCUg:235
240
Sand
C3245

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Attachment C

Interpolation of Stratigraphic Unit Surfaces Using the Kingdom®[11] Geology Software

[11] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.

Interpolation of Stratigraphic Unit Surfaces

Stratigraphic unit tops data interpreted from borehole geologic, drillers', and geophysical logs (Attachment B) were used in the interpolation of elevation grid surfaces representing the upper extents of each of the stratigraphic units. This process was undertaken using the Kingdom® Geology software employing its interpolation algorithms. Specific steps in the sequence of stratigraphic unit surface interpolation in Kingdom® are as follows.

1. *Import borehole location and tops data into Kingdom®*. Unit tops are imported by selecting Tops→Import→File. Then browse to file and select. Import formation top data in line order and assign appropriate column names to the appropriate columns, then import.

    a. Unit tops can be imported in either measured depth or elevation. For this project, the option to work in x = meters, y = meters, and z = feet was chosen because drilling and borehole logs are recorded in feet rather than meters.

    b. Upon importation, unit tops can be viewed in context of geologic and geophysical logs, with boreholes automatically posted with accurate elevations. This enables easy exchange between elevation and depth below ground surface and eliminates ground surface elevation issues. A first-pass formation, top-quality check was conducted visually to see if unit tops were appropriately located within their respective boreholes. These visual checks were also used to assess conformity of unit tops with borehole log descriptions and geophysical log curves. The next check was to examine the unit tops in relation to prior interpretations and to neighboring borehole unit tops.

    c. Once the interpreter is satisfied with the state of the unit tops in the selected boreholes, a first round of unit-surface interpolation can occur.

2. *Run interpolation algorithm*. In the Kingdom® Geology software, the "Flex Gridding" algorithm available in the Dynamic Map Update Modeling module was selected for interpolation. Dynamic Map Update is activated by selecting View→Toolbars→Dynamic Depth Conversion and Map Update. Next select "Edit Model" from the Dynamic Map Update toolbar and under the "Manage" tab, select "New" to start a new model.

    a. A new model is set up by defining the different layers to be modeled and which input data should be used to create those layers. When discussing the setup of a dynamically updated model, stratigraphic units are referred to as "layers." Once the model is run, the module produces gridded surfaces that represent those model layers. The gridded surfaces are the products exported from Kingdom® to be used as inputs elsewhere. The layers should be organized in stratigraphic order. Existing polygons (or newly digitized polygons) can be used to define the domain of the overall model and choose an appropriate xy cell size (10 m for the Waste Management Area [WMA] A-AX geologic framework models [GFMs]) for the model. In the case of the WMA A-AX GFMs, each unit layer interpolated used a constraining polygon except for the Ringold Formation Wooded Island Unit A (Rwia). Settings for each model layer are presented in Table C-1.

Table C-1. Kingdom® Dynamic Map Update Modeling Module Settings Used in the Waste Management Area A-AX Geologic Framework Models.

Layer	Input depth data	Framework Rules	Onlap	Constraints
1	HF1 Tops	Conform to Surface Below	Yes	None
2	HF2 Tops	Non-Conformable	No	Polygon
3	HF3 Tops	Conform to Surface Below	Yes	Polygon
4	CCUu Tops	Conform to Surface Below	Yes	Polygon
5	CCUg Tops	Conform to Surface Below	Yes	Polygon
6	Rwie Tops	Conform to Surface Below	Yes	Polygon
7	Rlm Tops	Non-Conformable	Yes	Polygon
8	Rwia Tops	Conform to Surface Below	Yes	None

Note: Settings apply to both Waste Management Area A-AX Alternative Conceptual Model 1 and Alternative Conceptual Model 2. The gridding algorithm employed in the Dynamic Map Update module is called Flex Gridding, which is a form of a class 2 mathematical modeling algorithm. Class 2 algorithms first fit some form of mathematical surface to the data values and then interpolate by finding the value of the surface passing through the desired location. The definition of flex gridding explained in the IHS Kingdom® Help Manual: "Flex gridding uses a system of differential equations whose solution yields the values of grid nodes that meet the following two criteria: (1) the interpolated surface must pass through or at least very close to the data in the XYZ space and (2) as much as possible without violating criterion 1, the surface must fit a mathematical criterion selected by the user."

CCUg = Cold Creek Unit gravels
CCUu = Cold Creek Unit undifferentiated
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.

b. Specific framework rules were also used as guidelines in areas of the model where borehole formation data are scarce. In Kingdom® settings, the user can select either onlap or non-onlap. This determines how a surface is truncated by other unconformities. Because changing relief in the top of basalt (TOB) surface often controls the deposition of the stratigraphic (suprabasalt sediment) units above, most of the layers in our model have the onlap setting checked. This enables depositional units to pinch-out on the layers below it.

c. Available fitting criteria in Kingdom® include minimum tension or rubber sheet, minimum curvature or as smooth as possible, and a blend of minimum tension and minimum curvature. The midway point (blend of minimum tension and minimum curvature) was used in surface interpolation for the WMA A-AX GFMs because it was observed to best honor the data points without causing slope discontinuities at each data point location.

3. *Assess unit tops in the context of gridded surfaces*. Gridded surfaces were assessed for continuity or discontinuity according to their presence or absence in boreholes by location. In areas where boreholes were too shallow to encounter deeper stratigraphic units, checks

were done to ensure that the deep stratigraphic units were interpolated through consistently. At this stage, control points could be added to force the stratigraphic unit surfaces to better comply with extents determined by presence or absence in boreholes by location and/or by professional judgment of the interpreter of the geologic setting. Because of the ample amount of borehole data for the relatively small WMA A-AX GFMs domain, no control points were needed.

4. *Export Surfaces*. Once the model is satisfactorily complete, the software user can lock it for editing and turn off the dynamic update function. One of the automatic protocols in the Dynamic Map Update module is to produce a gridded surface for each model layer. Each of those surfaces is available in the grid menu of the Kingdom® project tree. It is then possible to right-click on each surface and export as an XYZ *.dat file for input to other tools.

    a. The *.dat surfaces exported from Kingdom® are in text format and needed to be converted to a format usable by Tecplot®[12]. Therefore, a Python script (rasta.py, Attachment D) developed for this purpose was employed. After converting the *.dat files to *.asc for importation into Tecplot®, the conversion with rasta.py was checked by comparing the unit tops data values at their respective locations within both the *.dat and *.asc files. In addition to the borehole data, surface elevations were checked at random points between borehole data locations for further evaluation of the quality of the conversion. Tolerances were set at a difference of one meter as this distance was considered a conservative estimator of the quality of the conversion. The results of these tolerance checks suggest the following.

    b. The converted *.dat surfaces matched exactly with their corresponding *.asc conversions. This was done by point sampling each grid point location in each file and comparing the elevations at each corresponding sampled grid point.

    c. Most borehole data fell within the 1-m tolerance limit with a few exceptions (Table C-2 and Table C-3). These exceptions are readily explainable and do not reflect model defects that result in inaccurate representations of the modeled stratigraphic unit surfaces.

Figure 4-2 through Figure 4-9 show the structure contour maps of the checked, finished stratigraphic unit surfaces and Figure 4-10 through Figure 4-16 are isopach maps showing unit thicknesses based on each surface and the surfaces immediately below them.

[12] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

Table C-2. Alternative Conceptual Model 1 Borehole Data Versus Interpolated Surfaces Tolerance Violations. Only Boreholes that had Tolerance Violations are Included.

Borehole	X	Y	HF1 Difference	HF2 Difference	HF3 Difference	CCUu Difference	CCUg Difference	Rwie Difference	Rlm Difference	Rwia Difference	Comments
299-E25-14	575667.76	136166.55	1.29	1.35	1.22	—	—	—	—	—	Onlap framework interpolation rules causing upper surface to conform to the surface below.
299-E25-46	575359.73	135963.50	—	11.12	0.55	0.20	-0.03	—	—	—	Borehole value > surface value due to adjacent data of lower elevation.
299-E25-42	575622.80	135887.60	-0.04	-0.34	0.44	0.61	0.34	120.51	120.45	-0.29	Rwie and Rlm surface extents truncate due to polygon constraints resulting in borehole being outside of surface extents. Onlap framework interpolation rules causing upper surface to conform to the surface below.
299-E25-48	575623.85	135815.69	-0.38	-0.18	-0.08	0.21	0.03	122.37	—	-0.10	Rwie surface extents truncate due to polygon constraints resulting in borehole being outside of surface extents. Onlap framework interpolation rules causing upper surface to conform to the surface below.

CCUg = Cold Creek Unit gravels
CCUu = Cold Creek Unit undifferentiated
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Table C-3. Alternative Conceptual Model 2 Borehole Data Versus Interpolated Surfaces Tolerance Violations. Only Boreholes that had Tolerance Violations are Included.

Borehole	X	Y	HF1 Difference	HF2 Difference	HF3 Difference	CCUu Difference	CCUg Difference	Rwie Difference	Rlm Difference	Rwia Difference	Comments
299-E27-6	575245.06	136332.48	4.94	2.30	-0.71	-0.38	-0.13	—	—	0.020	Borehole value > surface value due to adjacent data of lower elevation and Onlap framework interpolation rules causing upper surface to conform to the surface below for HF1. Borehole value > surface value due to adjacent data of lower elevation only for HF2.
299-E24-13	575300.61	136037.32	—	1.23	—	0.75	0.19	—	—	—	Borehole value > surface value due to adjacent data of lower elevation.
299-E24-14	575323.85	136018.81	—	8.16	—	0.02	-0.80	—	—	—	Borehole value > surface value due to adjacent data of lower elevation.
299-E25-41	575466.06	136145.92	—	2.48	0.85	-0.05	-0.01	—	—	—	Borehole value > surface value due to adjacent data of lower elevation.
299-E25-46	575359.73	135963.50	—	12.16	0.38	0.17	-0.03	—	—	—	Borehole value > surface value due to adjacent data of lower elevation.
299-E25-58	575402.68	136029.42	0.00	1.53	—	—	—	—	—	—	Surface projected slightly below data point at this location from interpolation lag effect resulting from much higher adjacent data values.
299-E25-14	575667.76	136166.55	0.85	0.89	1.76	—	—	—	—	—	Adjacent borehole (E25-6) has HF3 data at a higher elevation resulting in a slightly lower surface value at this location because of interpolation lag effect.
299-E25-6	575683.76	136163.97	-0.57	-0.38	1.47	-0.30	-0.38	—	—	-0.021	Borehole value > surface value due to adjacent data (E25-14) of lower elevation. Onlap framework interpolation rules appear to not be a factor in the borehole/surface offset at this location.
299-E25-42	575622.80	135887.60	0.28	0.00	0.43	0.61	0.34	120.51	120.45	-0.295	Rwie and Rlm surface extents truncate due to polygon constraints resulting in borehole being outside of surface extents. Onlap framework interpolation rules causing upper surface to conform to the surface below.
299-E25-48	575623.85	135815.69	-0.42	-0.21	-0.07	0.21	0.03	122.37	—	-0.103	Rwie surface extents truncate due to polygon constraints resulting in borehole being outside of surface extents. Onlap framework interpolation rules causing upper surface to conform to the surface below.

CCUg = Cold Creek Unit gravels
CCUu = Cold Creek Unit undifferentiated
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Attachment D

Python Scripts for Converting Kingdom®[13] Exported Data Files into Raster Format Usable by Tecplot®[14]

[13] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.
[14] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

Python Scripts for Converting Kingdom® Exported Data Files into Raster Format Usable by Tecplot®

Two scripts are contained within this Attachment. The first is a batch file (convert-em.bat) that allows batch-processing of multiple Kingdom® data files by invoking and executing the conversion script (rasta.py). The second script contained in this attachment is the conversion script rast.py. Quality control testing of the script's performance is discussed in Appendix C of this document. These scripts were written by M. Williams at INTERA, Inc., Richland, Washington.

Convert-em.bat:

```
python rasta.py WMA_A_AX_ACM 1_04272017_CCUg.dat WMA_A_AX_ACM 1_04272017_CCUg.asc

python rasta.py WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.dat WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc

python rasta.py WMA_A_AX_ACM 1_04272017_HF1.dat WMA_A_AX_ACM 1_04272017_HF1.asc

python rasta.py WMA_A_AX_ACM 1_04272017_HF2.dat WMA_A_AX_ACM 1_04272017_HF2.asc

python rasta.py WMA_A_AX_ACM 1_04272017_HF3.dat WMA_A_AX_ACM 1_04272017_HF3.asc

python rasta.py WMA_A_AX_ACM 1_04272017_Rlm.dat WMA_A_AX_ACM 1_04272017_Rlm.asc

python rasta.py WMA_A_AX_ACM 1_04272017_Rwie.dat WMA_A_AX_ACM 1_04272017_Rwie.asc

python rasta.py WMA_A_AX_ACM2_04272017_CCUg.dat WMA_A_AX_ACM2_04272017_CCUg.asc

python rasta.py WMA_A_AX_ACM2_04272017_Cold_Creek_Unit.dat WMA_A_AX_ACM2_04272017_Cold_Creek_Unit.asc

python rasta.py WMA_A_AX_ACM2_04272017_HF1.dat WMA_A_AX_ACM2_04272017_HF1.asc

python rasta.py WMA_A_AX_ACM2_04272017_HF2.dat WMA_A_AX_ACM2_04272017_HF2.asc

python rasta.py WMA_A_AX_ACM2_04272017_HF3.dat WMA_A_AX_ACM2_04272017_HF3.asc

python rasta.py WMA_A_AX_ACM2_04272017_Rlm.dat WMA_A_AX_ACM2_04272017_Rlm.asc

python rasta.py WMA_A_AX_ACM2_04272017_Rwia.dat WMA_A_AX_ACM2_04272017_Rwia.asc

python rasta.py WMA_A_AX_ACM2_04272017_Rwie.dat WMA_A_AX_ACM2_04272017_Rwie.asc
```

rasta.py:

```
""" this script converts Kindgom point files of surfaces (geologic
    structure contour tops) to ascii raster file that Leapfrog can load.
    The Kingdom point files are x,y,z with a constant dx and dy
    and are sent to us by Sarah from CHPRC.

The Leapfrom ASCII raster (grid) file format is (example):
ncols        8500
nrows         120
xllcorner    568255.000000000000
yllcorner    132005.000000000000
cellsize     50.000000000000
NODATA_value  -99999

    MWilliams, Intera 12-12-2016

    Updated by MDWilliams. Intera, 1-25-2017
    Fixed bug - data is written out starting with the UL row and moving down

"""
import sys
import numpy as np

nodata = -99999
fnodata = float(nodata)

# two command line arguments: input-kingdom-file output-leapfrog-grid
print(sys.argv[1])
print(sys.argv[2])
```

```
# load csv file from kingdom
with open(sys.argv[1],"r") as fi:
        kingall = fi.read()

kinglines=kingall.split("\n")  # separate out lines into array
klen=len(kinglines)

# Points from Kingdom can come in irregular order or inconsistent rows
# and columns.  Scan file first to build max rectangular domain
xd = dict()
yd = dict()

for pline in kinglines[0:klen-1]:
        sxyz = pline.split(",")
        fx = float(sxyz[0])
        fy = float(sxyz[1])
        fz = float(sxyz[2])
        xd[fx] = 1
        yd[fy] = 1

# sort keys
nx=0
xl=[fnodata] * len(xd)
for fx in sorted(xd):
        xd[fx]=nx
        xl[nx]=fx
        nx+=1
```

```
ny=0
yl=[fnodata] * len(yd)
for fy in sorted(yd):
        yd[fy]=ny
        yl[ny]=fy
        ny+=1

print("nx,ny=",nx,ny)
zsize = nx*ny
z = []
for i in range(zsize):
        z.append(fnodata)
print("zlen=",len(z))
for pline in kinglines[0:klen-1]:
        sxyz = pline.split(",")
        fx = float(sxyz[0])
        fy = float(sxyz[1])
        fz = float(sxyz[2])
        i = xd[fx]
        j = yd[fy]
        zptr = (nx*j) + i
#       print("zptr=",zptr,i,j)
        z[zptr] = fz

# write out ASCII raster file for leapfrog
with open(sys.argv[2],"w") as fo:
        fo.write("ncols       %d\n" % nx)
        fo.write("nrows       %d\n" % ny)
```

```
fo.write("xllcorner    %f\n" % xl[0])
fo.write("yllcorner    %f\n" % yl[0])
fo.write("cellsize     %f\n" % (xl[1]-xl[0]))
fo.write("NODATA_value ");
fo.write("%d\n" % nodata)
# Patch - reversed order (jmax first) - mdw 1/25/2017
# for j in range(ny):
for j in reversed(range(ny)):
        for i in range(nx):
                zptr = (nx*j) + i
                if z[zptr] == fnodata:
                        fo.write("%d " % nodata)
                else:
                        fo.write("%f " % z[zptr])
        fo.write("\n")
```

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Attachment E

Software Installation and Checkout Form for Kingdom®[15] Geology

[15] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.

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):

[redacted]TKS101\Kingdom.exe

3. Executable Size (bytes): 822 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):

USDOES WF34759

7. Operating System (include version number):

Windows 7 Enterprise Service Pack 1

8. Open Problem Report? (•) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]Quality Assurance\ITC-1 06152017.pdf

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

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

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

Prepared By:

19. Software Owner (Signature)	WE Nichols Print	15 JUNE 2017 Date
20. Test Personnel: Sign	SD Springer Print	06-15-17 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

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

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Attachment F

Detailed Description of the Development of ACM 1 and ACM 2 Three-Dimensional Geologic Framework Models

F1 Development of Common Two-Dimensional Triangular Mesh for the Geologic Models

A common two-dimensional (2D) triangular finite element mesh (TFEM) was developed in order to interpolate the top of each stratigraphic unit from the surfaces given in Section 4.2.3.1 linearly. The development of the TFEM was necessary because not all of the surfaces provided in Section 4.2.3.1 had the same XY extent or the same grid resolution necessary to build a three-dimensional (3D) geologic model for the region of interest. This section describes the development of the TFEM.

The first step in this process was to create grids (shown in color in F-1[a]) over each tank farm's backfill areas (shown in light gray in Figure F-1[a]). The grid spacing for these grids is 4 × 4 m. This spacing is necessary to accurately capture the bottom of the backfill for a groundwater/ vadose zone model. Next, an expanded geologic model domain that is large enough for developing the flow and transport model (blue rectangle F-1[b]) was created. This expanded domain's extents are contained within the bounding coordinates X-min/Y-min 574555, 135305, and X-max/Y-max 576555, 137005. Following the creation of this expanded domain, a coarse grid (20 × 20) was superimposed on that domain (Figure F-1[b]). The areas of the finer grids (4 × 4) were blanked out to avoid overlap between the coarse and fine grids, and the boreholes within the domain were added (Figure F-1[b]). Once all the grid points from the fine and coarse grids were located, along with the boreholes, the triangulation routine within Tecplot 360®[16] was used to create a TFEM that will be used to build the geologic models for this expanded domain region.

Figure F-2(a) shows the final triangular mesh for the domain. It consists of 25,908 nodes and 51,444 elements.

Figure F-2(b) shows the finer mesh at Waste Management Area A-AX. The nodes are color coded to the grid from which they originated.

[16] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

Figure F-1. Fine (a) and Coarse (b) Grids Used to Create the Triangular Finite Element Mesh Used for the ACM 1 and ACM 2 Geologic Framework Models.

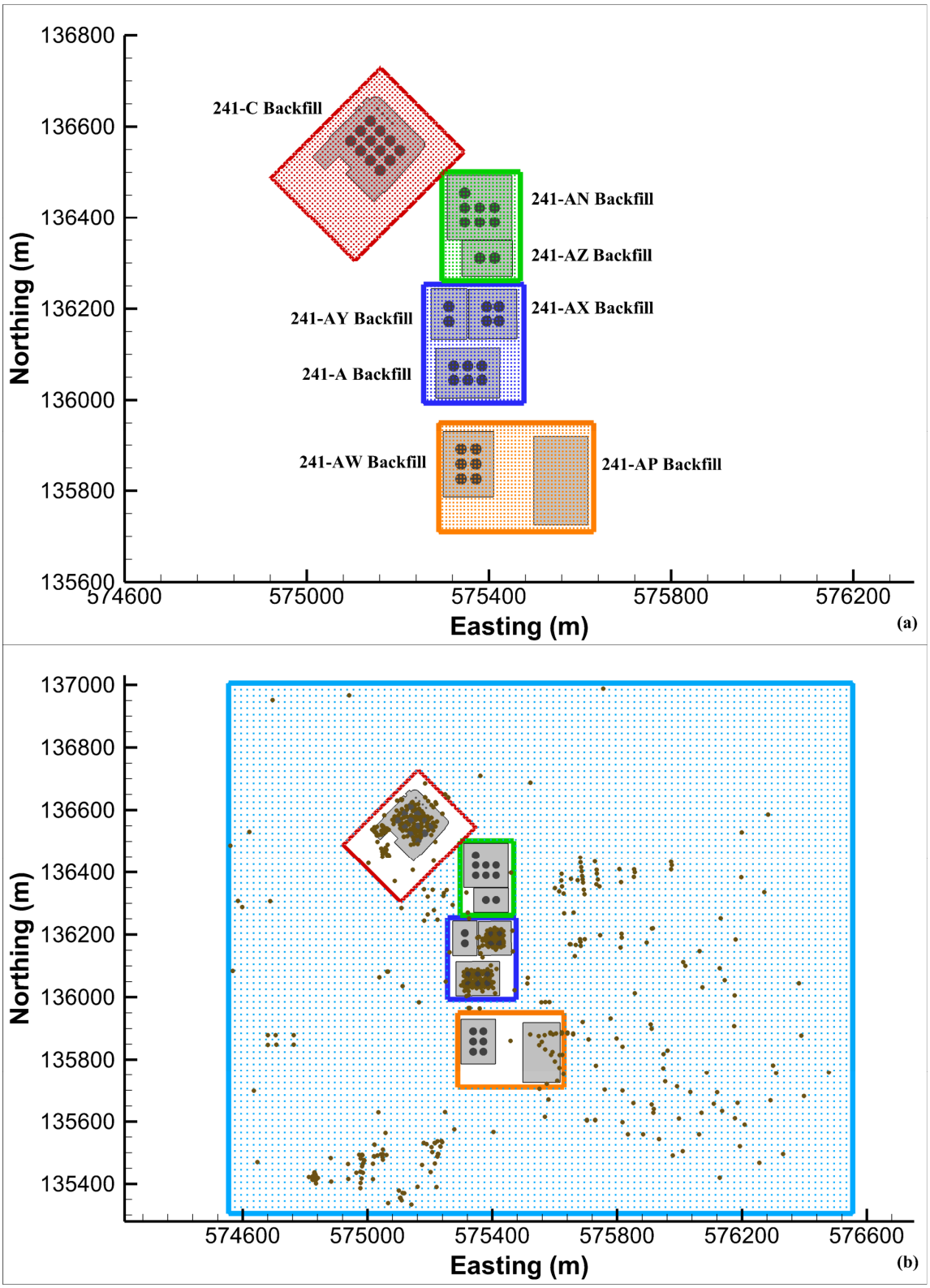
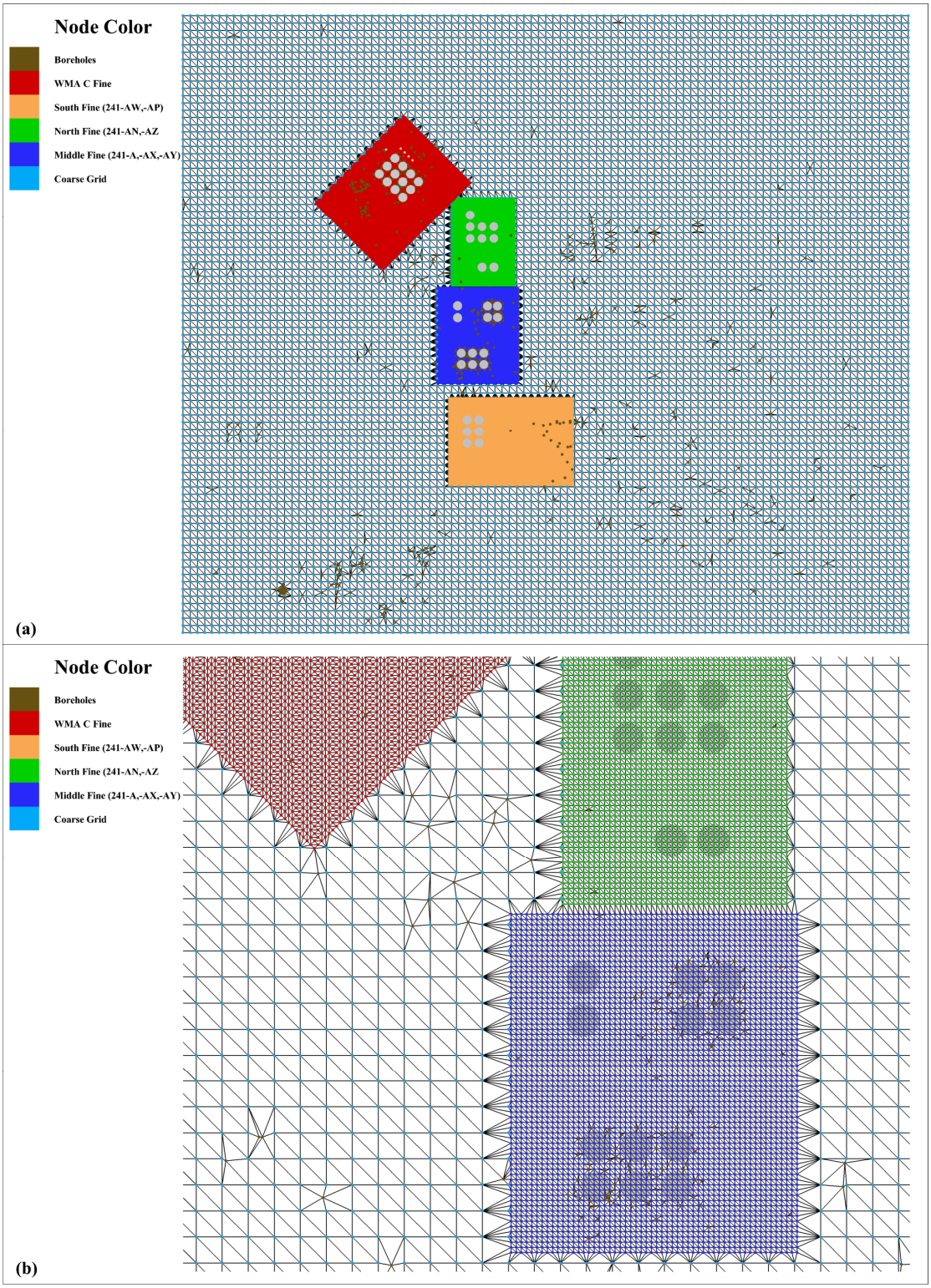


Figure F-2. Triangular Finite Element Mesh Used for the ACM 1 and ACM 2 Geologic Framework Models – Whole Domain (a) and Close-Up View around Waste Management Area A-AX (b).



WMA = Waste Management Area

F2 Building the ACM 1 and ACM 2 Geologic Framework Models

Building the geologic framework models (GFMs) required repeating a series of steps for each stratigraphic unit in the model from interpolation of surfaces to creating the volume zones defining each stratigraphic unit. Table F-1 lists the steps used to create each stratigraphic unit in each of the Alternative Conceptual Model (ACM) 1 GFM. For each unit, there are three major steps, the first step describes how the bottom the unit was defined, the second step describes how the top of the unit is defined, with the description for both these steps providing additional details, and the third step describes how the bottom and the top of the unit were joined together to create a volume for the unit.

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Base of Model	Triangular finite element mesh (TFEM)	Base of model is arbitrarily set to an elevation of 50 m NAVD88; Unit number is set to 1
TOB	TFEM	Top of Basalt linearly interpolated from TOB_20m_HS051016EXP.asc; Thickness = TOB - Base of Model (nodes and cell centers); Unit number is set to 1
Volume Basalt	Base of Model and TOB	Use Volume Add-On to join the two meshes together
Bottom of Rwia (saturated)	TOB	Bottom of Rwia = TOB
Top of Rwia (saturated)	TFEM	Top of Rwia linearly interpolated WMA_A_AX_ACM 1_04272017_Rwia.asc; Maximum (Top of Rwia [saturated], Top of Rwia [saturated]); Minimum (Top of Rwia [saturated], Water Table [121.66]); Thickness = Top of Rwia (saturated) - Bottom of Rwia (saturated) (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 2
Volume Rwia (saturated)	Bottom of Rwia (saturated) and Top of Rwia (saturated)	Use Volume Add-On to join the two meshes together
Bottom of Rwia (vadose)	TFEM	Bottom of Rwia (Vadose) = Water Table (121.66) set to constant elevation
Top of Rwia (vadose)	TFEM	Top of Rwia linearly interpolated WMA_A_AX_ACM 1_04272017_Rwia.asc; Maximum (Water Table [121.66], Top of Rwia [vadose]); Thickness = Top of Rwia (vadose) - Bottom of Rwia (vadose) (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 3

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Volume Rwia (vadose)	Bottom of Rwia (vadose) and Top of Rwia (vadose)	Use Volume Add-On to join the two meshes together
Bottom of Rlm (saturated)	Top of Rwia (saturated)	Bottom of Rlm = Top of Rwia (saturated)
Top of Rlm (saturated)	TFEM	WMA_A_AX_ACM 1_04272017_Rlm.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_Rlm.asc,50) TFEM extends further to the North; set elevation to 50 for TFEM; Top of Rlm linearly interpolated WMA_A_AX_ACM 1_04272017_Rlm.asc; Maximum (Top of Rlm [saturated], Bottom of Rlm [saturated]); Minimum (Top of Rlm [saturated], Water Table [121.66]); Thickness = Top of Rlm (saturated) - Bottom of Rlm (saturated) (nodes and cell centers) Blank when cell center thickness = 0. Unit number is set to 4
Volume Rlm (saturated)	Bottom of Rlm (saturated) and Top of Rlm (saturated)	Use Volume Add-On to join the two meshes together
Bottom of Rlm (vadose)	Top of Rwia (vadose)	Bottom of Rlm = Top of Rwia (Vadose)
Top of Rlm (vadose)	TFEM	WMA_A_AX_ACM 1_04272017_Rlm.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_Rlm.asc,50) TFEM extends further to the North; set elevation to 50 for TFEM; Top of Rlm (vadose) linearly interpolated WMA_A_AX_ACM 1_04272017_Rlm.asc; Maximum (Top of Rlm [vadose], Bottom of Rlm [vadose]); Thickness = Top of Rlm (vadose) - Bottom of Rlm (vadose) (nodes and cell centers); Blank when cell center thickness = 0; Unit number is set to 5
Volume Rlm (vadose)	Bottom of Rlm (vadose) and Top of Rlm (vadose)	Use Volume Add-On to join the two meshes together
Bottom of Rwie (saturated)	Top of Rlm (saturated)	Bottom of Rwie (saturated) = Top of Rlm (saturated)

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Top of Rwie (saturated)	TFEM	WMA_A_AX_ACM 1_04272017_Rwie.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_Rwie.asc,50) TFEM extends further to the North; set elevation to 50 for TFEM; Top of Rwie linearly interpolated WMA_A_AX_ACM 1_04272017_Rwie.asc; Maximum (Top of Rwie [saturated], Bottom of Rwie [saturated]); Minimum (Top of Rwie [saturated], Water Table [121.66]); Thickness = Top of Rwie (saturated) - Bottom of Rwie (saturated) (nodes and cell centers); Blank when cell center thickness = 0; Unit number is set to 6
Volume Rwie (saturated)	Bottom of Rwie (saturated) and Top of Rwie (saturated)	Use Volume Add-On to join the two meshes together
Bottom of Rwie (vadose)	Top of Rlm (vadose)	Bottom of Rwie (vadose) = Top of Rlm (vadose)
Top of Rwie (vadose)	TFEM	WMA_A_AX_ACM 1_04272017_Rwie.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_Rwie.asc,50) TFEM extends further to the North; set elevation to 50 for TFEM; Top of Rwie (vadose) linearly interpolated WMA_A_AX_ACM 1_04272017_Rwie.asc; Maximum (Top of Rwie [vadose], Bottom of Rwie [vadose]); Thickness = Top of Rwie (vadose) - Bottom of Rwie (vadose) (nodes and cell centers); Blank when cell center thickness = 0; Unit number is set to 7
Volume Rwie (vadose)	Bottom of Rwie (vadose)and Top of Rwie (vadose)	Use Volume Add-On to join the two meshes together
Bottom of CCUg (saturated)	Top of Rwie (Saturated)	Bottom of CCUg (saturated) = Top of Rwie (saturated)

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Top of CCUg (saturated)	TFEM	Top of CCUg = WMA_A_AX_ACM 1_04272017_CCUg.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_CCUg.asc,50); Had spike depression at location 575979.925,135488.5, averaged to nodes around it Top of CCUg linearly interpolated WMA_A_AX_ACM 1_04272017_CCUg.asc; Maximum (Top of CCUg [saturated], Bottom of CCUg [saturated]); Minimum (Top of CCUg [saturated], Water Table [121.66]); Thickness = Top of CCUg (saturated) - Bottom of CCUg (saturated) (nodes and cell centers) Blank when cell center thickness = 0; Unit number is set to 8
Volume CCUg (saturated)	Bottom of CCUg (saturated) and Top of CCUg (saturated)	Use Volume Add-On to join the two meshes together
Bottom of CCUg (vadose)	Top of Rwie (vadose)	Bottom of CCUg (vadose) = Top of Rwie (vadose)
Top of CCUg (vadose)	TFEM	WMA_A_AX_ACM 1_04272017_CCUg.asc has null values (-99999); Take Maximum (WMA_A_AX_ACM 1_04272017_CCUg.asc,50); Had spike depression at location 575979.925,135488.5, averaged to nodes around it; Top of CCUg (vadose) linearly interpolated WMA_A_AX_ACM 1_04272017_CCUg.asc; Maximum (Top of CCUg [vadose], Bottom of CCUg [vadose]); Maximum (Top of CCUg [vadose], Water Table [121.66]) Thickness = Top of CCUg (vadose) - Bottom of CCUg (vadose) (nodes and cell centers) Blank when cell center thickness = 0. Unit number is set to 9
Volume CCUg (vadose)	Bottom of CCUg (vadose) and Top of CCUg (vadose)	Use Volume Add-On to join the two meshes together
Bottom of CCUsandsilt	Top of CCUg (vadose)	Bottom of CCUsandsilt = Top of CCUg (vadose)

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Top of CCUsandsilt	TFEM	WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc had spike depression at location 575979.925,135488.5, averaged to nodes around it; Top of CCUsandsilt linearly interpolated WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc; Subtracting 0.0001 mm from Z to ensure correct blanking on thickness. Difference between top and bottom was often less than 4E-5, did the subtraction to ensure it is 0 or less Maximum (Top of CCUsandsilt, Bottom of CCUsandsilt); Thickness = Top of CCUsandsilt - Bottom of CCUsandsilt (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 10
Volume CCUsandsilt	Bottom of CCUsandsilt and Top of CCUsandsilt	Use Volume Add-On to join the two meshes together
Bottom of HF3	Top of CCUsandsilt	Bottom of HF3 = Top of CCUsandsilt
Top of HF3	TFEM	WMA_A_AX_ACM 1_04272017_HF3.asc had spike depression at location 575979.925,135488.5, averaged to nodes around it; Top of HF3 linearly interpolated WMA_A_AX_ACM 1_04272017_HF3.asc; Thickness = Top of HF3 - Bottom of HF3 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 11
Volume HF3	Bottom of HF3 and Top of HF3	Use Volume Add-On to join the two meshes together
Lidar Land Surface - Excavation	Lidar Land Surface	Linearly interpolate Z values from backfill from single-shell tank farms 241-A, 241-AX, and 241-C, as well as double-shell tank farms 241-AN, 241-AP, 241-AW, 241-AY, and 241-AZ onto Lidar Land surface; take minimum (Lidar Land Surface, Lidar Land Surface - Excavation); Outside points = Do not change
Bottom of HF2	Top of HF3	Bottom of HF2 = Top of HF3
Top of HF2	TFEM	Top of HF2 linearly interpolated WMA_A_AX_ACM 1_04272017_HF2.asc; Minimum (Top of HF2, Lidar Land Surface - Excavation) Thickness = Top of HF2 - Bottom of HF2 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 12
Volume HF2	Bottom of HF2 and Top of HF2	Use Volume Add-On to join the two meshes together
Bottom of HF1	Top of HF2	Bottom of HF1 = Top of HF2

Table F-1. Steps for Building Each Surface and Volume for Stratigraphic Units in ACM 1. (6 sheets)

Title	Mesh(s) Used	Description
Top of HF1	TFEM	Top of HF1 linearly interpolated WMA_A_AX_ACM 1_04272017_HF1.asc; Minimum (Top of HF1, Lidar Land Surface - Excavation) Maximum (Top of HF1, Bottom of HF1) Thickness = Top of HF1 - Bottom of HF1 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 13
Volume HF1	Bottom of HF1 and Top of HF1	Use Volume Add-On to join the two meshes together
Bottom of Eolian	Top of HF1	Bottom of Eolian = Top of HF1
Top of Eolian	Lidar Land Surface - Backfill	Top of Eolian = Lidar Land Surface - Excavation; Thickness = Top of Eolian - Bottom of Eolian (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 14
Volume Eolian	Bottom of Eolian and Top of Eolian	Use Volume Add-On to join the two meshes together
Bottom of Backfill	Lidar Land Elevation - Backfill	Lidar Land Elevation - Backfill
Top of Backfill	Lidar Land Surface	Thickness = Lidar Land Surface (mesh) - (Lidar Land Surface - Backfill [mesh]) Blank when cell center thickness = 0 Unit number is set to 15
Volume Backfill	Bottom of Backfill and Top of Backfill	Use Volume Add-On to join the two meshes together

CCUg = Cold Creek Unit gravels
HF1 = Hanford Formation Unit 1
HF2 = Hanford Formation Unit 2
HF3 = Hanford Formation Unit 3
Lidar = light detection and ranging
NAVD88 = North American Vertical Datum of 1988
TOB = top of basalt
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

For the ACM 2 GFM, the source raster file grids (i.e., WMA_A_AX_ACM 1_*.asc) given in Table F-1 were replaced with those listed on the right side of Table F-2. A major difference was for the Cold Creek Unit silt (CCUz), for which a raster file grid of the thickness and extent of the unit was provided. The first step was to take the null value (area in which there is no CCUz) and set it to thickness of 0. The next step was to linearly interpolate the thickness of the unit onto the TFEM mesh with the points located outside the range of the raster file grid set to 0. This TFEM mesh was then added to the top of the Cold Creek Unit gravels (CCUg) to come up with the top of the CCUz. The thickness between was calculated by subtracting the top of the CCUg from the CCUz and blanking areas where the elevations coincide (i.e., areas of zero thickness). This is the major difference in the building of ACM 2 over ACM 1; otherwise, the steps listed in Table F-1

are the same for both models below the Cold Creek Silt. The difference in steps from the Cold Creek Silt to land surface are given in Table F-3, starting with the Cold Creek silt.

Table F-2. List of Raster Files Used to Develop Both Geologic Framework Models.

Alternative Conceptual Model 1	Alternative Conceptual Model 2
WMA_A_AX_ACM 1_04272017_Rwia.asc	WMA_A_AX_ACM2_04272017_Rwia.asc
WMA_A_AX_ACM 1_04272017_Rlm.asc	WMA_A_AX_ACM2_04272017_Rlm.asc
WMA_A_AX_ACM 1_04272017_Rwie.asc	WMA_A_AX_ACM2_04272017_Rwie.asc
WMA_A_AX_ACM 1_04272017_CCUg.asc	WMA_A_AX_ACM2_04272017_CCUg.asc
WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc	ccuz_95_thcknss.asc*
	WMA_A_AX_ACM 1_04272017_Cold_Creek_Unit.asc
WMA_A_AX_ACM 1_04272017_HF3.asc	WMA_A_AX_ACM2_04272017_HF3.asc
WMA_A_AX_ACM 1_04272017_HF2.asc	WMA_A_AX_ACM2_04272017_HF2.asc
WMA_A_AX_ACM 1_04272017_HF1.asc	WMA_A_AX_ACM2_04272017_HF1.asc

* In the case of Cold Creek Unit silt (CCUz) for Alternative Conceptual Model (ACM) 2, a thickness and extent of unit were provided instead of the top of the unit. This thickness was added to the top of the underlying unit to come up with a top for CCUz. The top of the CCUz in ACM 2 is the bottom of Cold Creek Unit sand.

F3 Comparison of Interpolation Results Using Kingdom® and Tecplot 360®

The Kingdom®[17] software was used to generate raster file grids of the top surface of all stratigraphic units except for CCUz in ACM 2; for that unit, the lateral extent and thickness of the unit was provided. These raster file grids were used to linearly interpolate the values from the raster file grids onto a Tecplot 360® TFEM. This raises the question: does the linear interpolation onto the triangular element mesh match the values of the Kingdom® software?

To answer this question, a contour map of the top of the HF2 stratigraphic unit (from ACM 1) was created from both Kingdom® raster file grids and then from the Tecplot 360® TFEM mesh after linear interpolation, and overlain to determine any differences (Figure F-3). In Figure F-3, the HF2 surface contour lines generated by the Kingdom® raster file grids are shown as solid red lines, while the dashed blue contour lines are from Tecplot 360® TFEM. In addition to the visual comparison of contour lines, the top of the HF2 unit was linearly interpolated to borehole locations within the model domain using both the Kingdom® grid and the Tecplot 360® TFEM (see Table F-4 for results). The difference in the top of the HF2 stratigraphic unit between the two grids shows that linear interpolation using Tecplot 360® provided very reasonable representation of results generated using the Kingdom® software with differences ranging from -1.2 mm to 3.1 mm over the model domain.

[17] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.

Table F-3. Steps for Building Surfaces and Volumes for Stratigraphic Units in ACM 2 that are Different from the Steps for ACM 1 Given in Table F-1. (2 sheets)

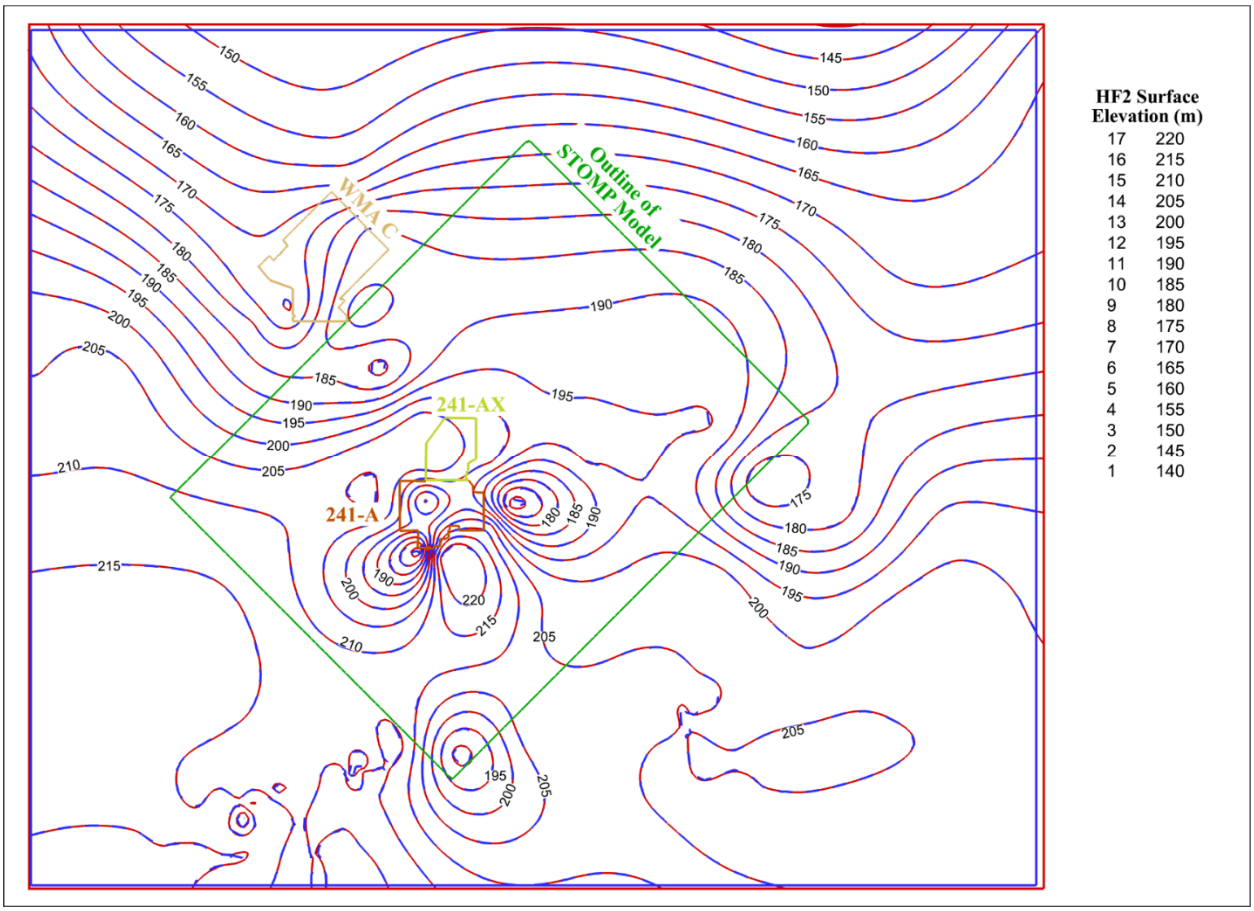
Title	Mesh(s) Used	Description
Top of CCUsilt	Triangular finite element mesh (TFEM)	Take raster file grid ccuz_95_thcknss; (thickness of Cold Creek silt) set null values (-99999) to 0 by taking maximum (ccuz_95_thcknss,0) Linearly interpolated thickness from ccuz_95_thcknss onto TFEM, and set outside points to 0 Add interpolated thickness to the elevation of the bottom of the CCUz mesh. This is now the top of CCUz; Thickness = Top of CCUz - Bottom of CCUz (nodes and cell centers) Blank when cell center thickness = 0; Unit number is set to 10
Bottom of CCUsand	Top of CCUsilt	Bottom of CCUsand =Top of CCUsilt
Top of CCUsand	TFEM	Top of CCUsand = WMA_A_AX_ACM2_04272017_Cold_Creek_Unit.asc had spike depression at location 575979.925,135488.5, averaged to nodes around it; Top of CCUsand linearly interpolated WMA_A_AX_ACM2_04272017_Cold_Creek_Unit.asc; Subtracting 0.0001 mm from Z to ensure correct blanking on thickness. Difference between top and bottom was often less than 4E-5, did the subtraction to ensure it is 0 or less Maximum (Top of CCUsand, Bottom of CCUsand); Thickness = Top of CCUsand - Bottom of CCUsand (nodes and cell centers) Blank when cell center thickness = 0; Unit number is set to 11
Volume CCUsand	Bottom of CCUsand and Top of CCUsand	Use Volume Add-On to join the two meshes together
Bottom of HF3	Top of CCUsand	Bottom of HF3 =Top of CCUsand
Top of HF3	TFEM	Top of HF3 = WMA_A_AX_ACM2_04272017_HF3.asc had spike depression at location 575979.925,135488.5, averaged to nodes around it; Top of HF3 linearly interpolated WMA_A_AX_ACM2_04272017_HF3.asc; Thickness = Top of HF3 - Bottom of HF3 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 12

Table F-3. Steps for Building Surfaces and Volumes for Stratigraphic Units in ACM 2 that are Different from the Steps for ACM 1 Given in Table F-1. (2 sheets)

Title	Mesh(s) Used	Description
Top of HF2	TFEM	Top of HF2 linearly interpolated WMA_A_AX_ACM2_04272017_HF2.asc; minimum (Top of HF2, Lidar Land Surface - Excavation) Thickness = Top of HF2 - Bottom of HF2 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 13
Top of HF1	TFEM	Top of HF1 linearly interpolated WMA_A_AX_ACM2_04272017_HF1.asc; Minimum (Top of HF1, Lidar Land Surface - Excavation) Maximum (Top of HF1, Bottom of HF1) Thickness = Top of HF1 - Bottom of HF1 (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 14
Top of Eolian	Lidar Land Surface - Backfill	Top of Eolian = Lidar Land Surface - Excavation; Thickness = Top of Eolian - Bottom of Eolian (nodes and cell centers) Blank when cell center thickness = 0 Unit number is set to 15
Top of Backfill	Lidar Land Surface	Thickness = Lidar Land Surface(mesh) - (Lidar Land Surface - Backfill [mesh]) Blank when cell center thickness = 0 Unit number is set to 16

CCUz = Cold Creek Unit silt
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Lidar = light detection and ranging

Figure F-3. Comparison of HF2 Unit Surface Contours Created in Kingdom® and Tecplot 360®.



HF2 = Hanford formation Unit 2 WMA = Waste Management Area
Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.
Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.
Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

Table F-4. Comparison of the HF2 Unit Linearly Interpolating Kingdom® Grid to the Tecplot 360® Triangular Finite Element Mesh at Borehole Locations within the Waste Management Area A-AX Flow and Transport Model. (4 sheets)

Borehole	Kingdom® Grid (m NAVD88)	Tecplot® Triangular Finite Element Mesh (m NAVD88)	Difference (m)
299-E24-3	204.23003	204.23003	1.87E-06
299-E24-4	208.80649	208.80647	2.00E-05
299-E24-5	209.00206	209.00204	2.09E-05
299-E24-13	197.07728	197.07706	2.23E-04
299-E24-14	193.58787	193.58787	0.00E+00
299-E24-19	188.63044	188.63046	-1.99E-05

Table F-4. Comparison of the HF2 Unit Linearly Interpolating Kingdom® Grid to the Tecplot 360® Triangular Finite Element Mesh at Borehole Locations within the Waste Management Area A-AX Flow and Transport Model. (4 sheets)

Borehole	Kingdom® Grid (m NAVD88)	Tecplot® Triangular Finite Element Mesh (m NAVD88)	Difference (m)
299-E24-20	208.80836	208.80836	0.00E+00
299-E24-22	209.07598	209.07598	0.00E+00
299-E24-33	203.71208	203.71208	0.00E+00
299-E24-67	194.12581	194.12583	-1.84E-05
299-E24-68	195.32140	195.32142	-2.12E-05
299-E24-70	194.01086	194.01023	6.31E-04
299-E24-71	195.12882	195.12888	-6.35E-05
299-E24-72	194.75940	194.75943	-2.91E-05
299-E24-73	191.45322	191.45318	4.66E-05
299-E25-1	192.34859	192.34861	-2.34E-05
299-E25-2	168.98824	168.98899	-7.48E-04
299-E25-4	196.12958	196.12954	3.88E-05
299-E25-5	197.06458	197.06456	2.04E-05
299-E25-6	195.92902	195.92903	-3.47E-06
299-E25-7	196.16586	196.16584	2.18E-05
299-E25-10	195.38583	195.38583	-4.77E-06
299-E25-13	207.52861	207.52860	1.63E-05
299-E25-14	197.87181	197.87181	0.00E+00
299-E25-15	200.86858	200.86846	1.21E-04
299-E25-16	193.60325	193.60325	-2.36E-06
299-E25-35	202.39429	202.39426	3.16E-05
299-E25-40	201.51882	201.51881	5.75E-06
299-E25-41	200.33343	200.33331	1.18E-04
299-E25-42	201.75472	201.75472	0.00E+00
299-E25-46	210.81073	210.80766	3.07E-03
299-E25-47	201.18258	201.18257	7.93E-06
299-E25-48	201.76662	201.76662	-9.50E-07
299-E25-54	174.67698	174.67817	-1.19E-03
299-E25-55	192.64171	192.64168	2.47E-05
299-E25-56	185.10560	185.10590	-3.08E-04
299-E25-57	198.86791	198.86793	-2.21E-05

Table F-4. Comparison of the HF2 Unit Linearly Interpolating Kingdom® Grid to the Tecplot 360® Triangular Finite Element Mesh at Borehole Locations within the Waste Management Area A-AX Flow and Transport Model. (4 sheets)

Borehole	Kingdom® Grid (m NAVD88)	Tecplot® Triangular Finite Element Mesh (m NAVD88)	Difference (m)
299-E25-58	204.27549	204.27550	-1.31E-05
299-E25-66	189.11310	189.11308	1.70E-05
299-E25-72	193.53882	193.53897	-1.52E-04
299-E25-73	196.11152	196.11156	-4.02E-05
299-E25-74	196.47464	196.47467	-3.68E-05
299-E25-77	193.29345	193.29345	6.90E-07
299-E25-79	198.98464	198.98457	7.55E-05
299-E25-81	202.19847	202.19847	-2.70E-07
299-E25-87	191.11354	191.11409	-5.55E-04
299-E25-89	186.91641	186.91661	-1.98E-04
299-E25-90	190.64328	190.64328	-1.98E-06
299-E25-92	192.13345	192.13348	-3.38E-05
299-E25-93	203.84595	203.84595	0.00E+00
299-E25-94	209.69871	209.69871	0.00E+00
299-E25-97	188.04010	188.04011	-1.16E-05
299-E25-99	203.29552	203.29551	1.23E-05
299-E25-100	203.10116	203.10115	2.37E-06
299-E25-101	203.56367	203.56367	1.30E-07
299-E25-102	204.31542	204.31541	1.32E-05
299-E25-103	205.06950	205.06950	2.90E-07
299-E25-104	205.19412	205.19412	-1.10E-06
299-E25-105	204.12970	204.12970	1.48E-06
299-E25-106	203.90252	203.90251	3.64E-06
299-E25-107	203.51360	203.51361	-7.77E-06
299-E25-108	203.75720	203.75720	-3.67E-06
299-E25-109	204.60506	204.60505	1.89E-05
299-E25-110	205.27886	205.27886	-5.93E-06
299-E25-111	205.56095	205.56095	-2.30E-06
299-E25-112	205.13787	205.13786	7.45E-06
299-E25-113	204.94877	204.94878	-3.87E-06
299-E25-114	205.87710	205.87710	5.60E-07

Table F-4. Comparison of the HF2 Unit Linearly Interpolating Kingdom® Grid to the Tecplot 360® Triangular Finite Element Mesh at Borehole Locations within the Waste Management Area A-AX Flow and Transport Model. (4 sheets)

Borehole	Kingdom® Grid (m NAVD88)	Tecplot® Triangular Finite Element Mesh (m NAVD88)	Difference (m)
299-E25-115	206.87085	206.87086	-5.79E-06
299-E25-116	206.94802	206.94801	6.74E-06
299-E25-117	206.25010	206.25010	0.00E+00
299-E25-118	205.45932	205.45928	4.50E-05
299-E25-119	206.12392	206.12391	6.88E-06
299-E25-120	205.79678	205.79676	1.80E-05
299-E25-122	207.47503	207.47502	4.83E-06
299-E25-123	207.54453	207.54448	4.39E-05
299-E25-124	206.83837	206.83835	1.88E-05
299-E25-127	205.33687	205.33686	3.62E-06
299-E25-170	191.84100	191.84100	0.00E+00
299-E25-236	173.80994	173.80994	0.00E+00
299-E26-4	191.61733	191.61736	-2.81E-05
299-E26-5	192.35520	192.35524	-4.80E-05
299-E26-6	191.31543	191.31543	-5.03E-06
299-E26-7	191.70026	191.70027	-2.37E-06
299-E26-8	175.66489	175.66488	6.11E-06
299-E27-2	179.48283	179.48316	-3.28E-04
299-E27-3	187.50829	187.50839	-9.82E-05
299-E27-6	179.14059	179.14102	-4.24E-04
299-E27-24	191.68637	191.68637	0.00E+00
C3245	195.28993	195.28989	3.97E-05
C4545	196.62110	196.62110	0.00E+00

HF2 = Hanford Formation Unit 2 NAVD88 = North American Vertical Datum of 1988

Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.
Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.

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Attachment G

Software Installation and Checkout Form for Tecplot 360 2013 R1 and Tecplot 360 EX 2017 R2

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: Tecplot 360 2013 Software Version No.: R1

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   Build 14.0.2.33360: [redacted]Tec360 2013R1\bin\Tec360.exe

3. Executable Size (bytes): 15,355 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   COTS executable provided

5. Operating System (include version number):

   COTS executable provided

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Company Property TecGeo Inc. Puget Systems Model Spirit Intel Computer Name:Puget-120734

7. Operating System (include version number):

   Windows Pro 10; Version 1607; OS Build 14393.1358

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   [redacted]Work\TecplotQA

10. Procedure(s):

    CHPRC-02806 Rev. 0, "Tecplot 360® INTEGRATED SOFTWARE MANAGEMENT PLAN"

11. Libraries:

    N/A

12. Input Files:

    1) atc-tecplot-1.dat
    2) Internally Created Grids
    3) Davis_2002_ArcGIS.png (compare results of Inverse Distance calculation to ARCGis)
    4) Davis_2002_krig_cropped.png (compare Krigging results)

13. Output Files:

    atc-tecplot-1_krig.lay
    atc-tecplot-1_krig.plt
    atc-tecplot-2_inv_dist.lay
    atc-tecplot-2_inv_dist.plt
    atc-tecplot-3_meters.lay
    atc-tecplot-3_krig_meters.plt
    atc-tecplot-5_unit_interpolation.lay
    atc-tecplot-5 unit interpolation.plt

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Tecplot 360 2013 Software Version No.: R1

14. Test Cases:

Case 1: Use Tecplot interpolation scheme krig (with default parameters) to interpolate points in atc-tecplot-1.dat onto internally created grid XMin: 500,500 XMax: 574,500; YMin: 4,150,500 YMax:4,248,000; I=149 J=196
Case 2: Use Tecplot interpolation scheme inverse distance (with parameters Minimum Distance = 0, Exponent = 2.0 Point Selection = 0) to interpolate points in atc-tecplot-1.dat onto internally created grid XMin: 500,500 XMax: 574,500; YMin: 4,150,500 YMax:4,248,000; I=149 J=196
Case 3: Use Tecplot Data Alteration to convert Case 1 results to meters and compare against feet
Case 4: Compare Maximum and Minimum of interpolated values for Case 1 against the maximum and minimum in original data file (atc-tecplot-1.dat)
Case 5: Create internally in Tecplot three 3-D grids with each having total of 8 nodes (2 in each direction). All three grids have XMin and YMin = 0, XMax and YMax = 9. Grid 1 has Z from 0 to 3, grid 2 has Z from 3 to 7, grid 3 has Z from 7 to 9. Create variable 4 = 0 in data alteration, then assign each grid variable 4 value, Grid 1 Var4 = 1; Grid 2, Var4 = 2, Grid 3 Var4 = 3. Create a 4th grid with I=4, J=4, K=4 and XMin,YMin,ZMin = 2, XMax,YMax,ZMax = 8. Use Tecplot's linear interpolation schemed to interpolate Var 4 values from grids 1 - 3 onto grid 4.

15. Test Case Results:

Results are documented in the following image files
atc-tecplot-1_krigComparison.png
atc-tecplot-2_inv_distComparison.png
atc-tecplot-3_krig_metersComparison.png
atc-tecplot-4_MinMaxComparison.png
atc-tecplot-5 unit interpolation.png

16. Test Performed By: Michael P Connelly.

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Installation added to HISI Entry 3882

Prepared By:

19.	Software Owner (Signature)	W. E. Nichols Print	28 NOV 2017 Date

20. Test Personnel:

Michael P. Connelly Digitally signed by Michael P Connelly Date: 2017.07.18 09:16:23 -06'00' Sign	Michael P. Connelly Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

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

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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: Tecplot 360 EX 2017 Software Version No.: R2

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   Build 17.2.0.79771: [redacted] Tecplot 360 EX 2017 R2\bin\tec360.exe

3. Executable Size (bytes): 5,851 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   COTS executable provided

5. Operating System (include version number):

   COTS executable provided

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Company Property TecGeo Inc. Puget Systems Laptop Travese Pro M560i 15 inch Computer Name:Puget-116138

7. Operating System (include version number):

   Windows Pro 10; Version 1607; OS Build 14393.1480

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   [redacted] Tecplot 360 EX 2017 R2\

10. Procedure(s):

    CHPRC-02806 Rev. 0, "Tecplot 360® INTEGRATED SOFTWARE MANAGEMENT PLAN"

11. Libraries:

    N/A

12. Input Files:

    1) atc-tecplot-1.dat
    2) Internally Created Grids
    3) Davis_2002_ArcGIS.png (compare results of Inverse Distance calculation to ARCGis)
    4) Davis_2002_krig_cropped.png (compare Krigging results)

13. Output Files:

    atc-tecplot-1_krig.lay
    atc-tecplot-1_krig.plt
    atc-tecplot-2_inv_dist.lay
    atc-tecplot-2_inv_dist.plt
    atc-tecplot-3_meters.lay
    atc-tecplot-3_krig_meters.plt
    atc-tecplot-5_unit_interpolation.lay
    atc-tecplot-5_unit_interpolation.plt

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Tecplot 360 EX 2017 Software Version No.: R2

14. Test Cases:

Case 1: Use Tecplot interpolation scheme krig (with default parameters) to interpolate points in atc-tecplot-1.dat onto internally created grid XMin: 500,500 XMax: 574,500; YMin: 4,150,500 YMax:4,248,000; I=149 J=196
Case 2: Use Tecplot interpolation scheme inverse distance (with parameters Minimum Distance = 0, Exponent = 2.0 Point Selection = 0) to interpolate points in atc-tecplot-1.dat onto internally created grid XMin: 500,500 XMax: 574,500; YMin: 4,150,500 YMax:4,248,000; I=149 J=196
Case 3: Use Tecplot Data Alteration to convert Case 1 results to meters and compare against feet
Case 4: Compare Maximum and Minimum of interpolated values for Case 1 against the maximum and minimum in original data file (atc-tecplot-1.dat)
Case 5: Create internally in Tecplot three 3-D grids with each having total of 8 nodes (2 in each direction). All three grids have XMin and YMin = 0, XMax and YMax = 9. Grid 1 has Z from 0 to 3, grid 2 has Z from 3 to 7, grid 3 has Z from 7 to 9. Create variable 4 = 0 in data alteration, then assign each grid variable 4 value, Grid 1 Var4 = 1; Grid 2, Var4 = 2, Grid 3 Var4 = 3. Create a 4th grid with I=4, J=4, K=4 and XMin,YMin,ZMin = 2, XMax,YMax,ZMax = 8. Use Tecplot's linear interpolation schemed to interpolate Var 4 values from grids 1 - 3 onto grid 4.

15. Test Case Results:

Results are documented in the following png files
atc-tecplot-1_krigComparison.png
atc-tecplot-2_inv_distComparison.png
atc-tecplot-3_krig_metersComparison.png
atc-tecplot-4_MinMaxComparison.png
atc-tecplot-5 unit interpolation.png

16. Test Performed By: Michael P Connelly.

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Installation added to HISI Entry 3882

Prepared By:

19.	Software Owner (Signature)	W. E. Nichols Print	28 NOV 2017 Date

20. Test Personnel:

Michael P. Connelly (Digitally signed by Michael P Connelly Date: 2017.07.18 16:04:34 -06'00')	Michael P. Connelly	
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

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

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Attachment H

Verification and Checking of Three-Dimensional Geologic Framework Models (ACM 1 and ACM 2)

As stated in Section 4, building a geologic framework model (GFM) is a process of successive refinements made up of defining the model's domain and developing and building the internal surfaces. There are a number of ways that errors may be introduced into the constructed model surfaces for different stratigraphic units. One such potential source is the method(s) used for interpolation (construction) of individual stratigraphic unit surfaces. The purpose of Attachment H is to evaluate potential sources of error for the GFM representation of different stratigraphic units for Alternative Conceptual Model (ACM) 1 and ACM 2. Two different approaches were used to perform such an evaluation.

- Method 1. The first compared two sets of data consisting of individual stratigraphic unit elevations from the Tecplot®[18] GFMs and borehole elevations (geologic control points; 43 deep boreholes, Table 3-1 and Table 3-2). The comparison provides a check on the accuracy of observed borehole elevations and the GFM modeled elevations for different stratigraphic units in ACM 1 and ACM 2.

- Method 2. The second approach was to directly compare and cross-check individual stratigraphic unit surface elevations from the Tecplot® GFMs with stratigraphic unit top elevations for each borehole (geologic control points; Table 3-1 and Table 3-2) for ACM 1 and ACM 2.

For both methods, the respective ACM 1 and ACM 2 borehole individual stratigraphic unit surface elevations are presented in Table 3-1 and Table 3-2. Attachment F explains the procedure used to develop the Tecplot® three-dimensional (3D) GFMs using Kingdom®[19]-generated surfaces (Attachment D).

The Method 1 assessment of ACM 1 (presented in Figure H-1 through Figure H-6) illustrates the results of comparisons and linear regression analysis of the stratigraphic unit surface elevations. For Method 2, Figure H-7 through Figure H-35 illustrate the results of the comparison of the 29 boreholes for ACM 1. Similarly, for ACM 2, Figure H-36 through Figure H-41 illustrate, for Method 1, the results of comparison and linear regression analysis of the various stratigraphic units. Figure H-42 through Figure H-84 illustrate, for Method 2, the results of comparison for the 43 boreholes for ACM 2.

Overall, as the comparison and the accompanying regression analyses indicate, the predicted stratigraphic unit surface elevations for ACM 1 and ACM 2 GFMs are a close match (R^2=0.99) with the geologic control points (stratigraphic unit elevations from Table 3-1 and Table 3-2) (see Figure H-1 through Figure H-6 for ACM 1 and Figure H-36 through Figure H-41 for ACM 2). However, there were a few outliers for Hanford Formation Unit 1 (HF1) and Unit 2 (HF2) stratigraphic units that exceeded the tolerance value set for these GFMs ($\pm$ 1-m tolerance limit – see Section 5). Those wells are highlighted in the regression plots. The reason for exceedance of the tolerance limit for those individual stratigraphic unit surface elevations is directly related to the presence of backfill and eolian sand deposits. Both backfill and eolian sand deposits surfaces are generally accounted for in the GFMs as the difference between land surface and the top of Hanford formation (either HF1 or HF2 unit). This problem arose due to the version of

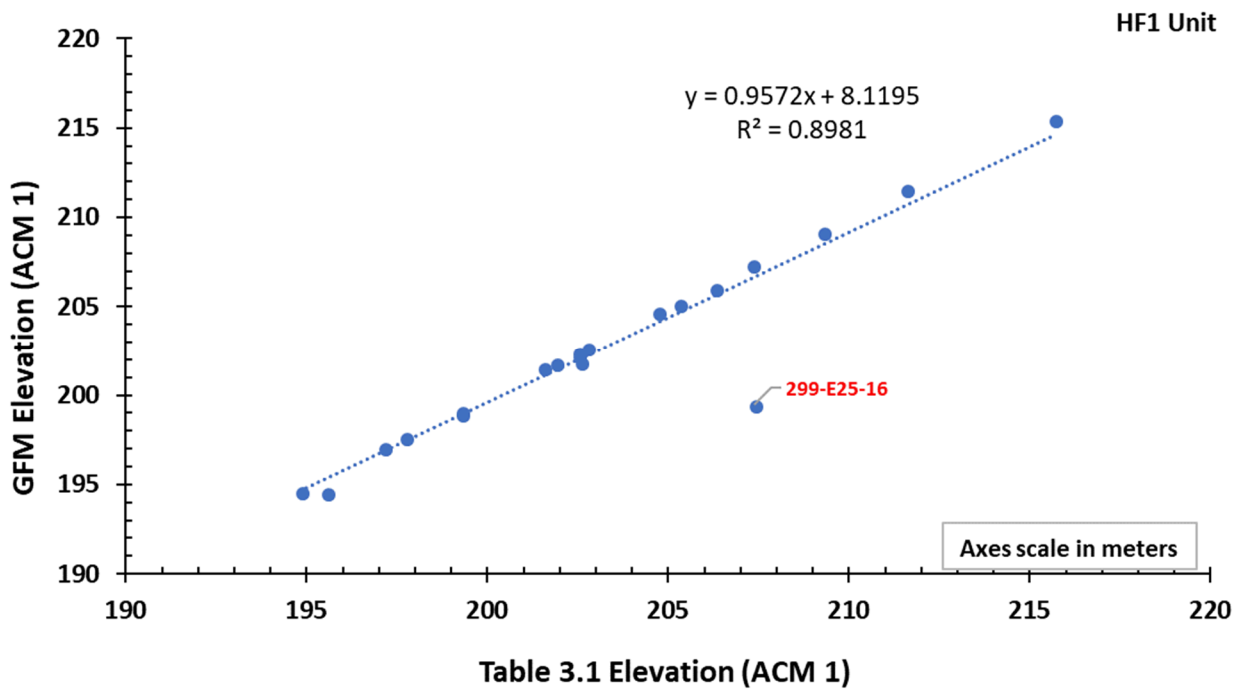
[18] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.
[19] Kingdom® is a registered trademark of IHS Markit, London, United Kingdom.

Kingdom® Geology used here to interpolate individual stratigraphic unit surfaces that only recognized the Hanford formation as the youngest stratigraphic unit present and did not account for the presence of either backfill or eolian sand. This resulted in a "gap" between the top of the uppermost Hanford formation unit and ground surface where either backfill materials or eolian sand deposits are present. For ACM 1 and ACM 2 GFMs, this issue was addressed in Tecplot® where both backfill materials and eolian sand were added in as additional stratigraphic unit surfaces.

Similar to Method 1, the Method 2 comparison shows excellent agreement for the two datasets within the ± 1-m tolerance limit (see Figure H-7 through Figure H-35 for ACM 1 and Figure H-36 through Figure H-41 for ACM 2). For the boreholes that exceeded the threshold tolerance, as was the case with Method 1, the deviations resulted from not accounting for the presence of backfill and eolian sands in Kingdom®.

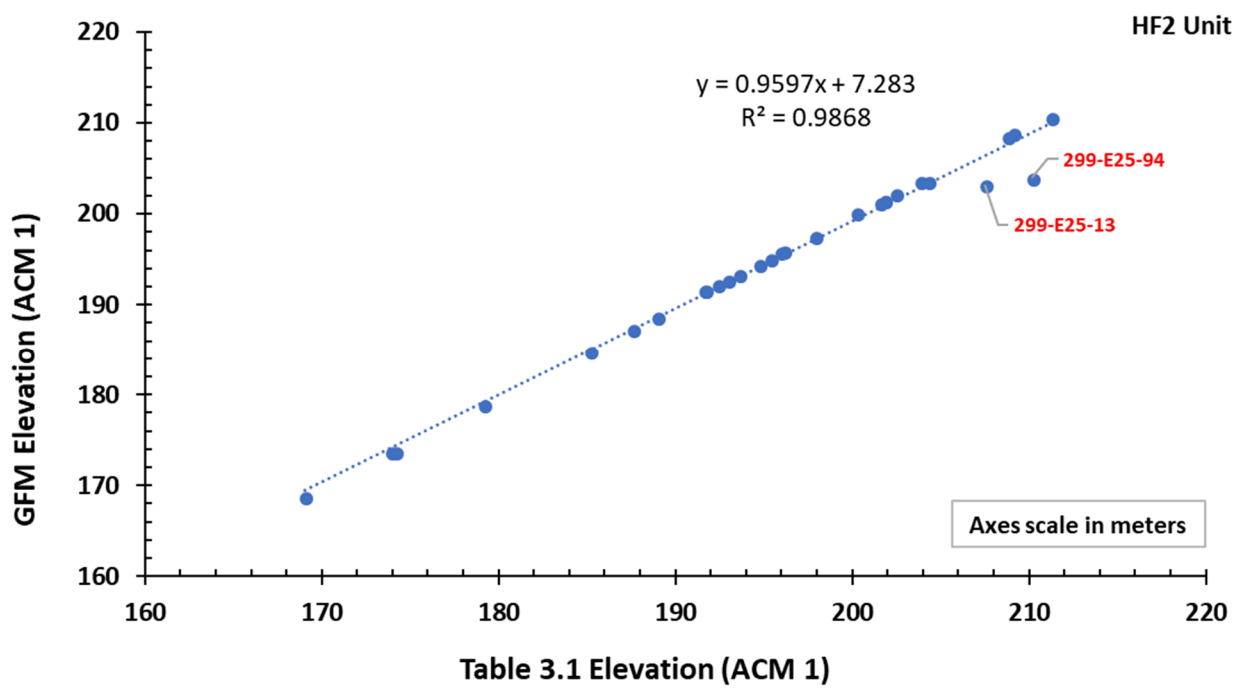
ACM1

Figure H-1. Comparison of HF1 Unit Elevation (Table 3.1 vs. GFM).



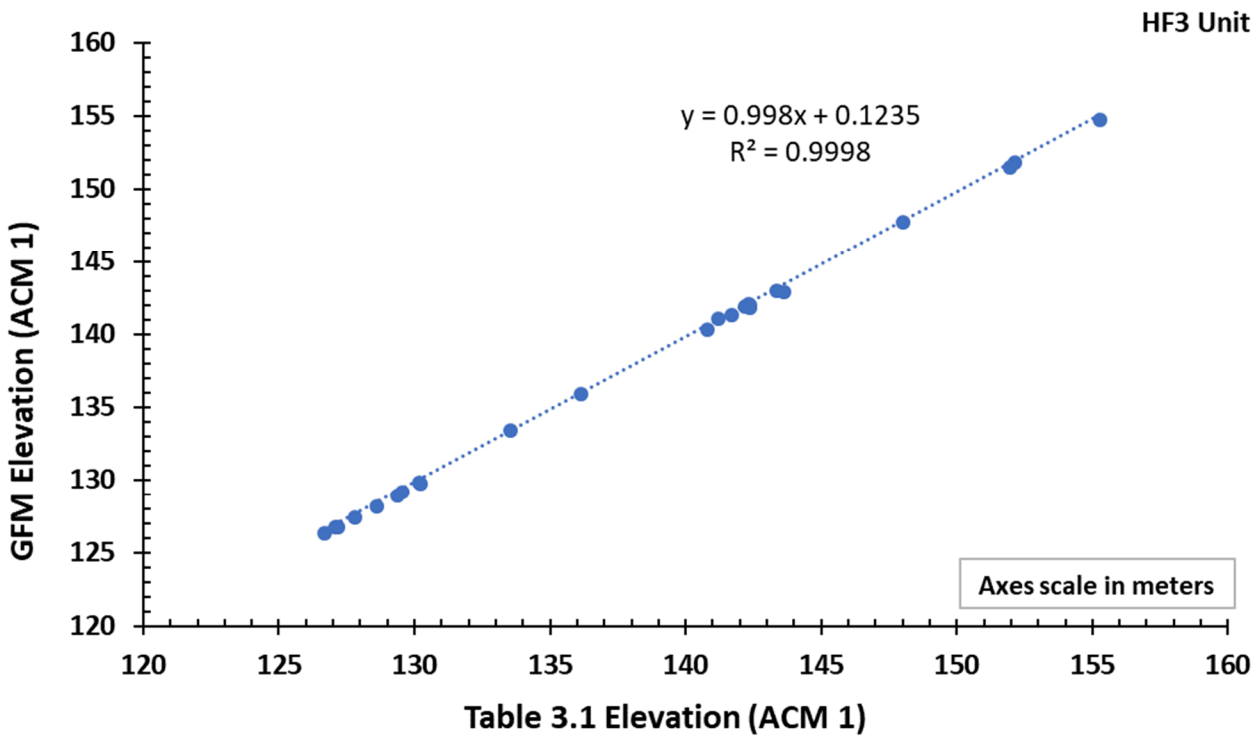
ACM = alternative conceptual model GFM = geologic framework model HF1 = Hanford formation Unit 1

Figure H-2. Comparison of HF2 Unit Elevation (Table 3.1 vs. GFM).



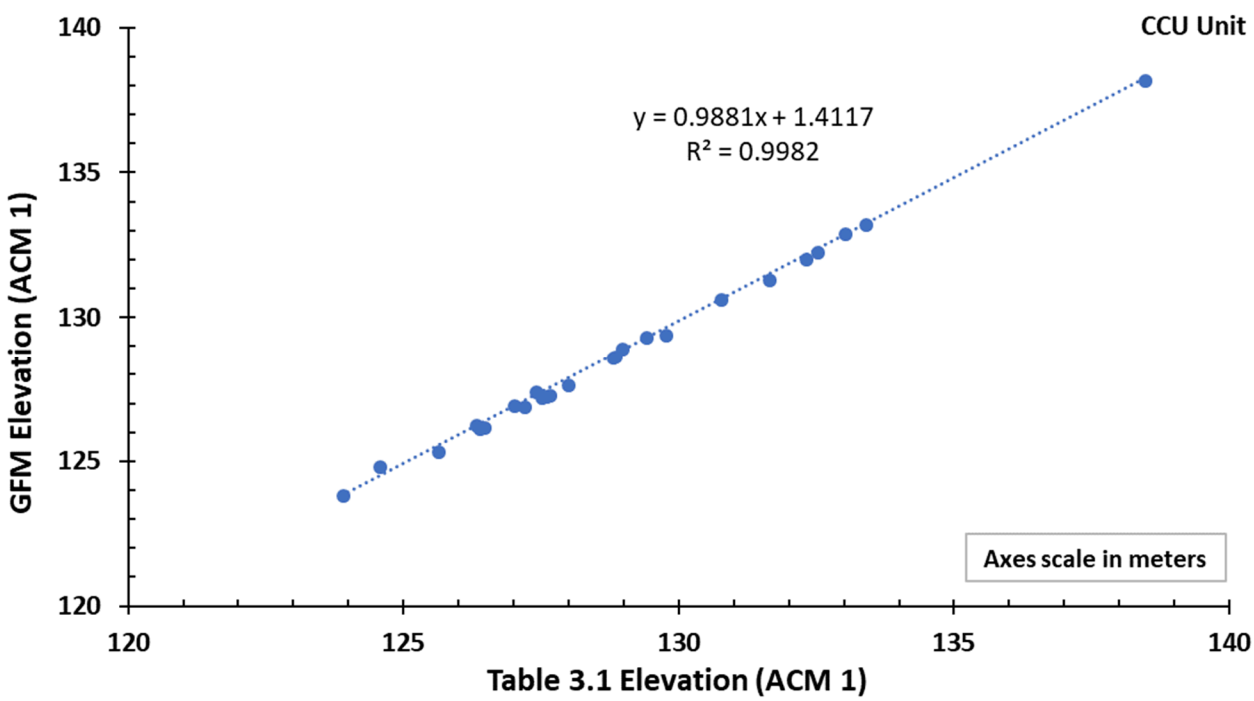
ACM = alternative conceptual model GFM = geologic framework model HF2 = Hanford formation Unit 2

Figure H-3. Comparison of HF3 Unit Elevation (Table 3.1 vs. GFM).



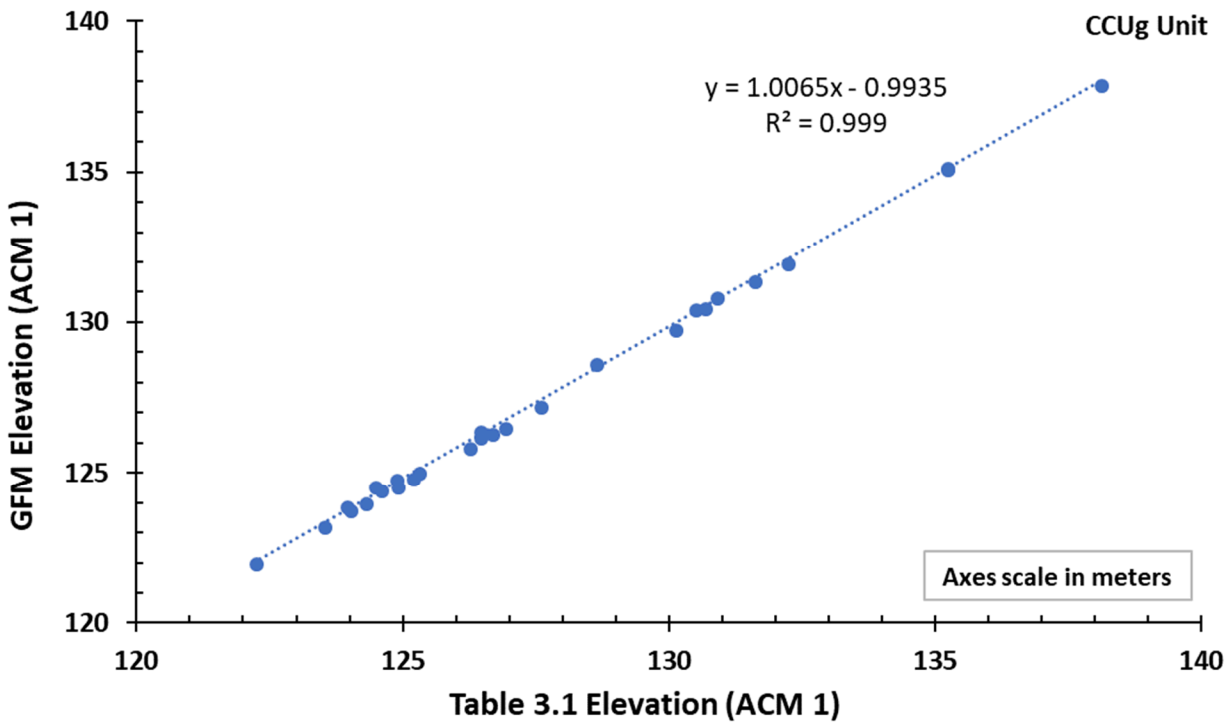
ACM = alternative conceptual model GFM = geologic framework model HF3 = Hanford formation Unit 3

Figure H-4. Comparison of CCU Unit Elevation (Table 3.1 vs. GFM).



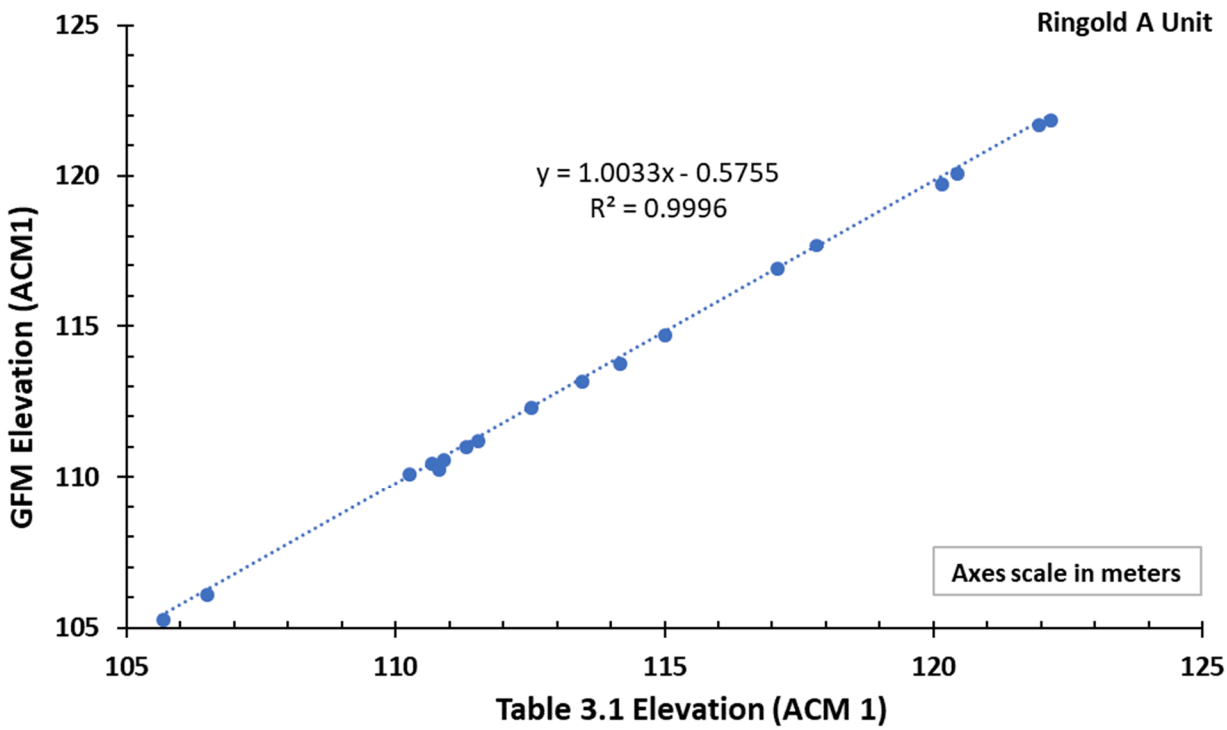
ACM = alternative conceptual model GFM = geologic framework model CCU = Cold Creek Unit

Figure H-5. Comparison of CCUg Unit Elevation (Table 3.1 vs. GFM).



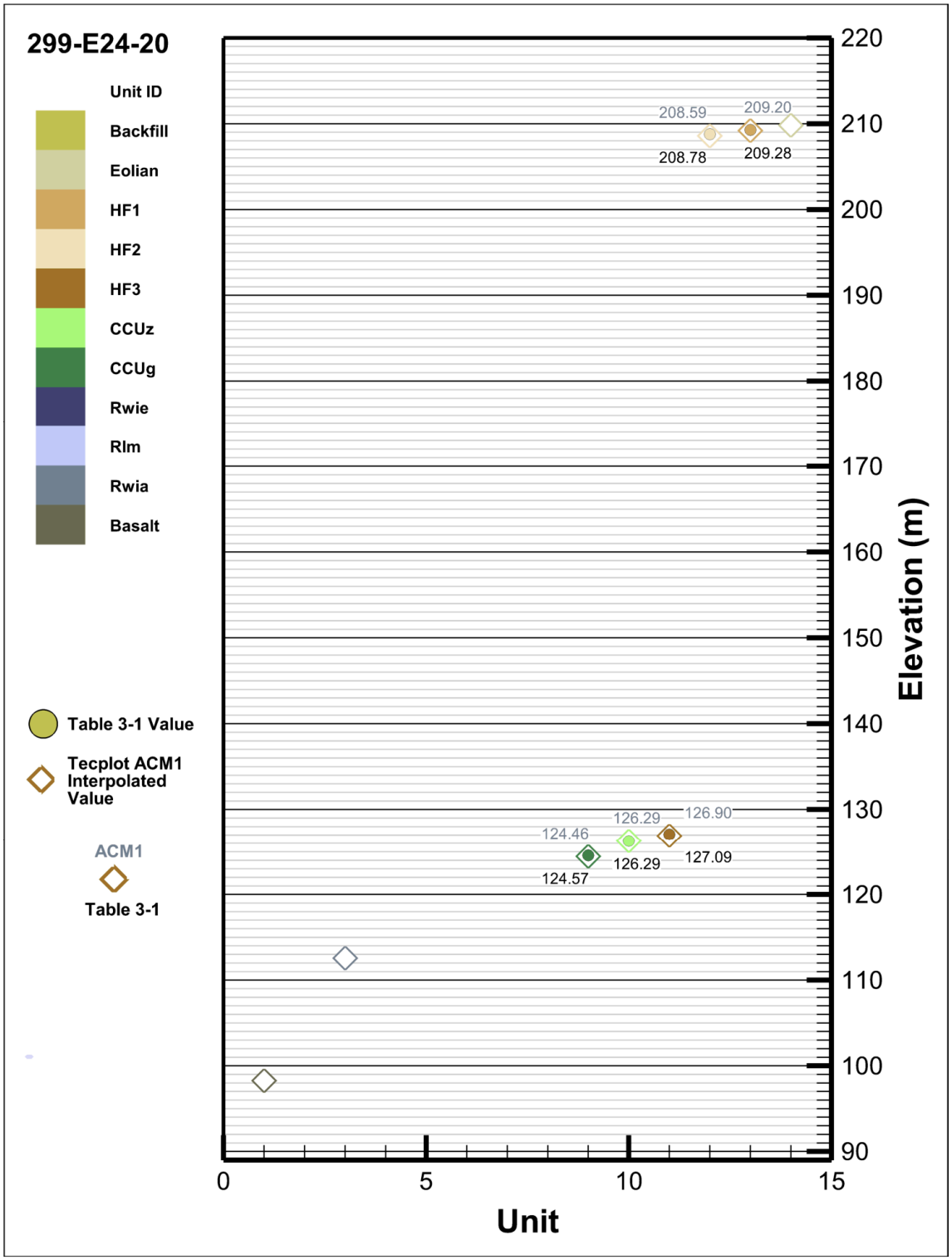
ACM = alternative conceptual model GFM = geologic framework model CCUg = Cold Creek Unit gravels

Figure H-6. Comparison of Ringold A Unit Elevation (Table 3.1 vs. GFM).



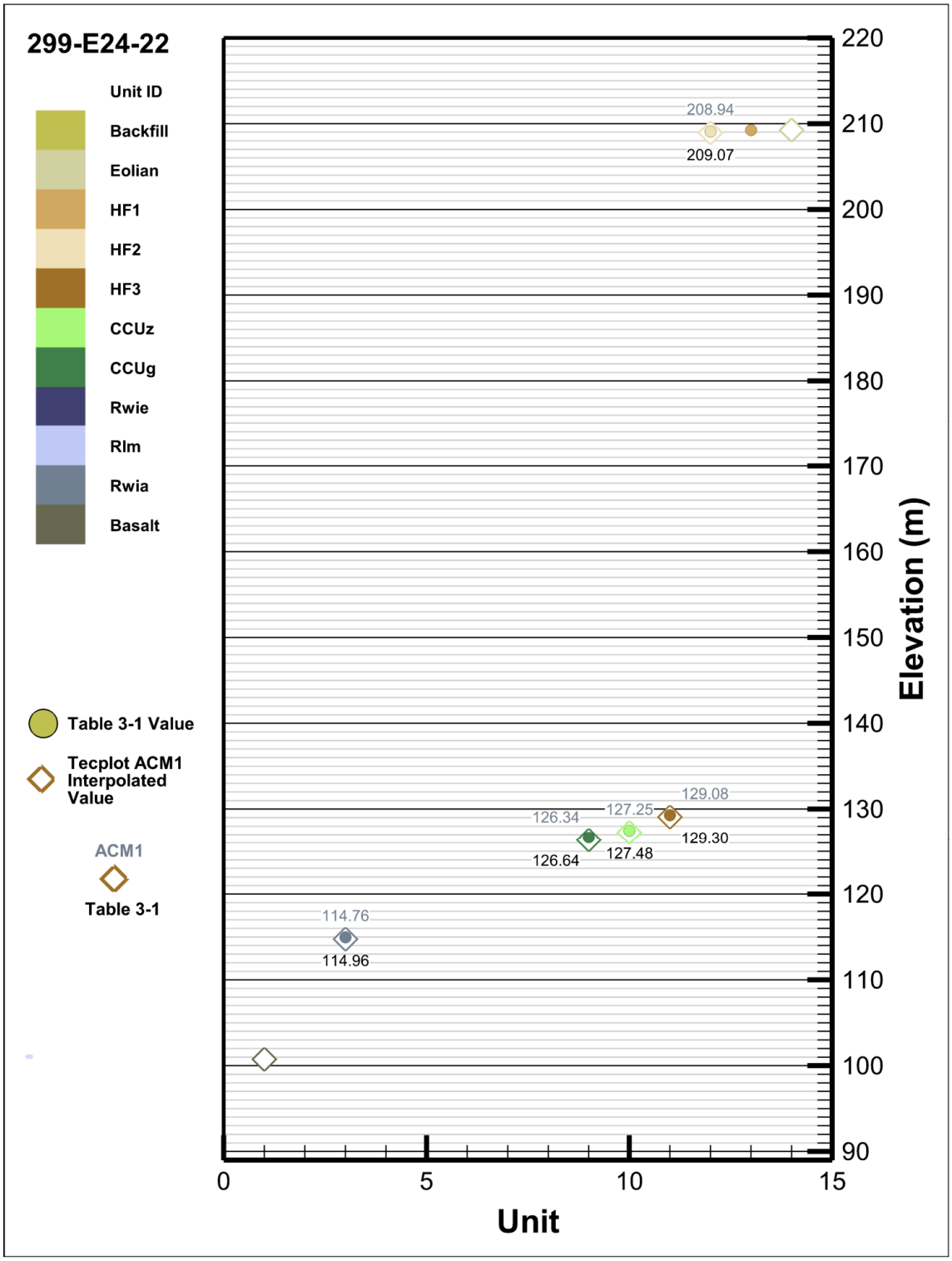
ACM = alternative conceptual model GFM = geologic framework model

Figure H-7. Well 299-E24-20 - Units Elevation Comparison (Table 3.1 vs. GFM).



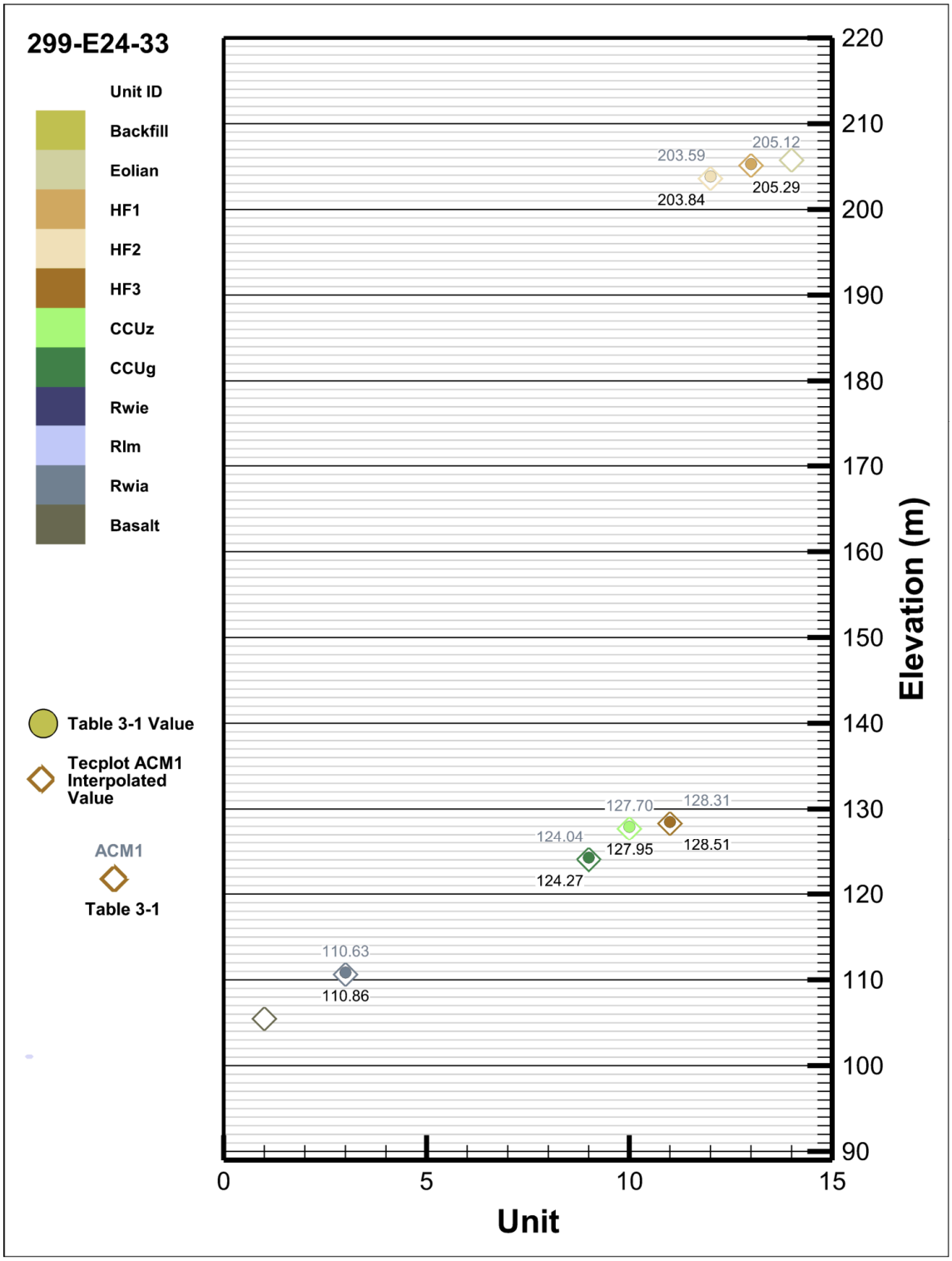
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-8. Well 299-E24-22 - Units Elevation Comparison (Table 3.1 vs. GFM).



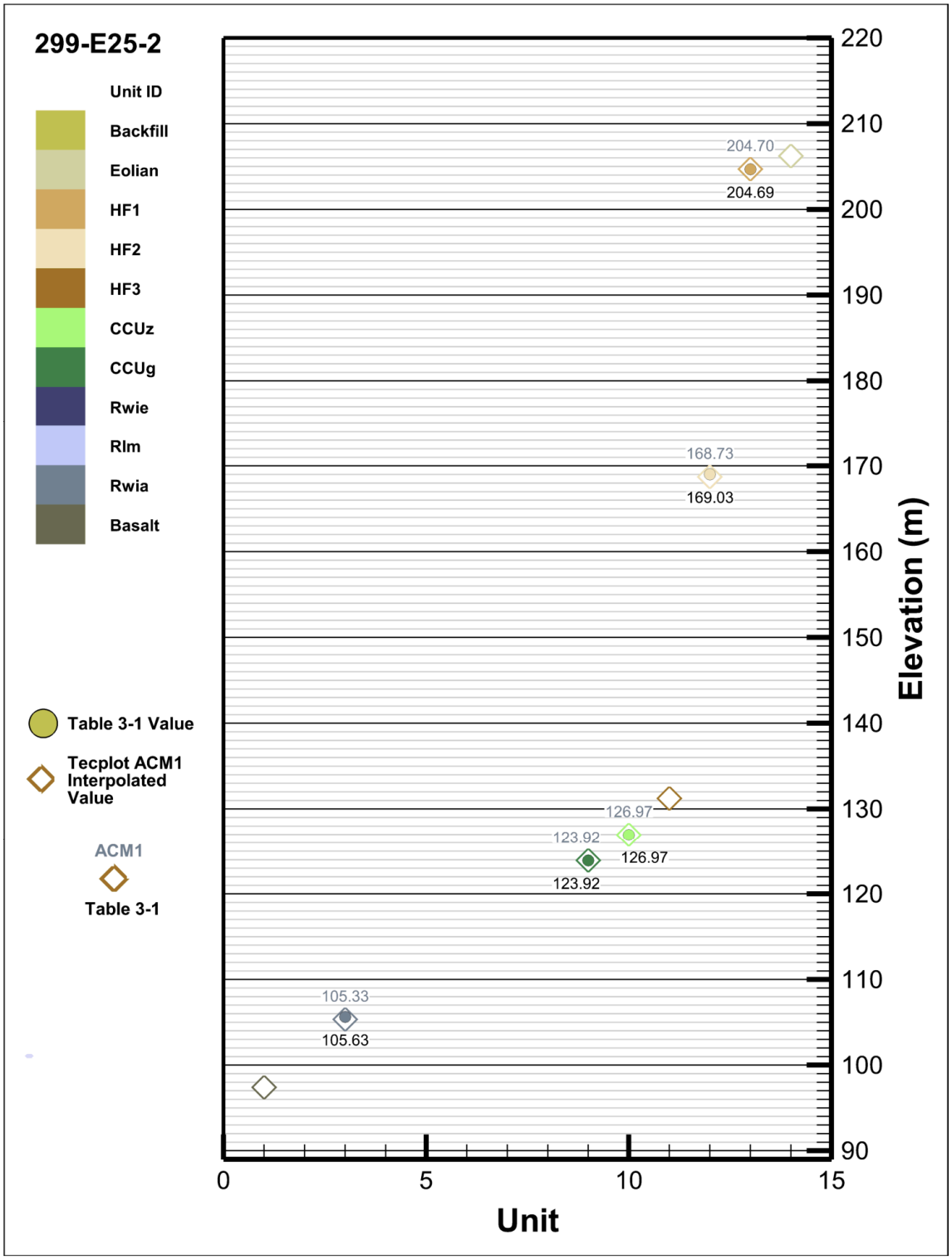
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-9. Well 299-E24-33 - Units Elevation Comparison (Table 3.1 vs. GFM).



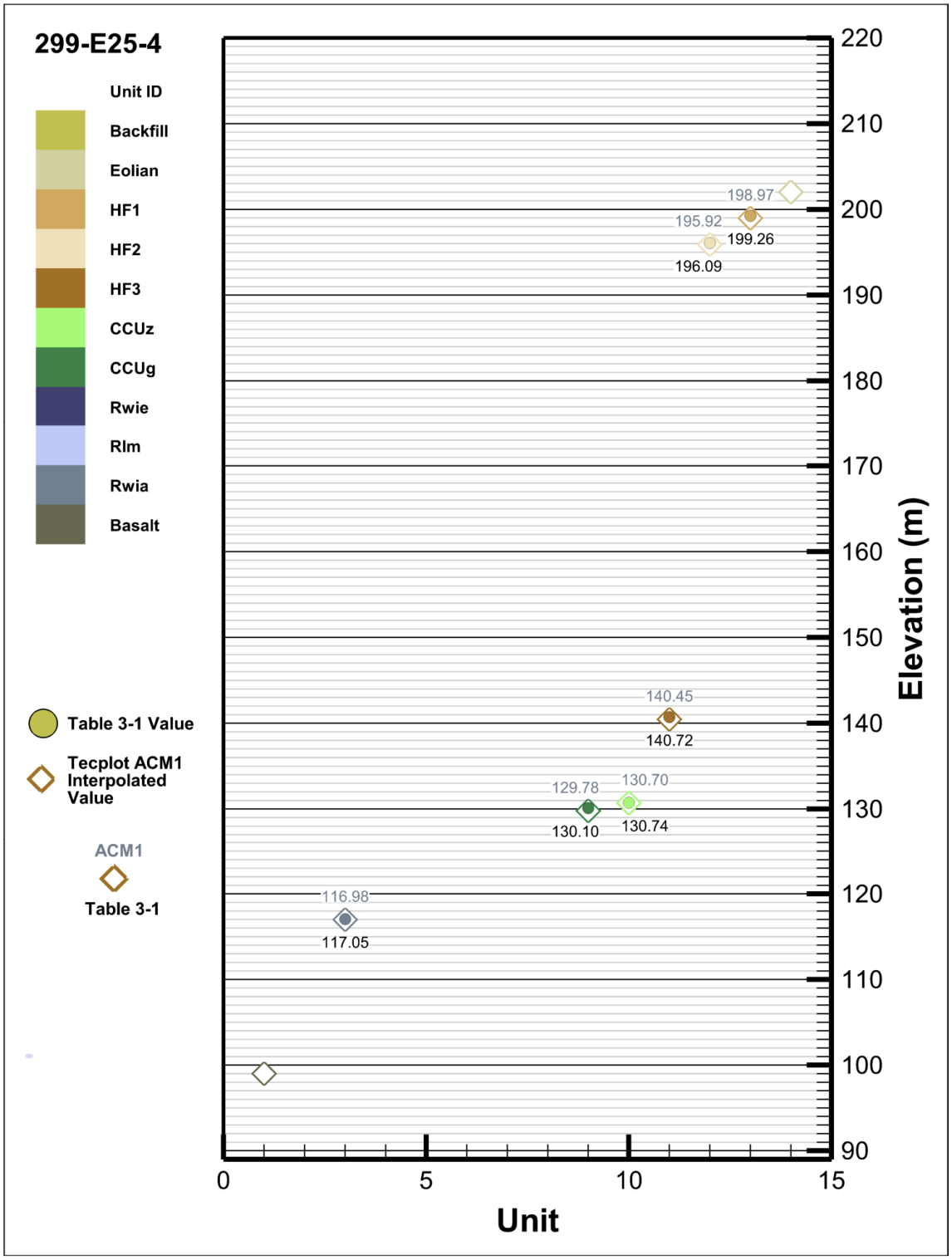
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-10. Well 299-E25-2 - Units Elevation Comparison (Table 3.1 vs. GFM).



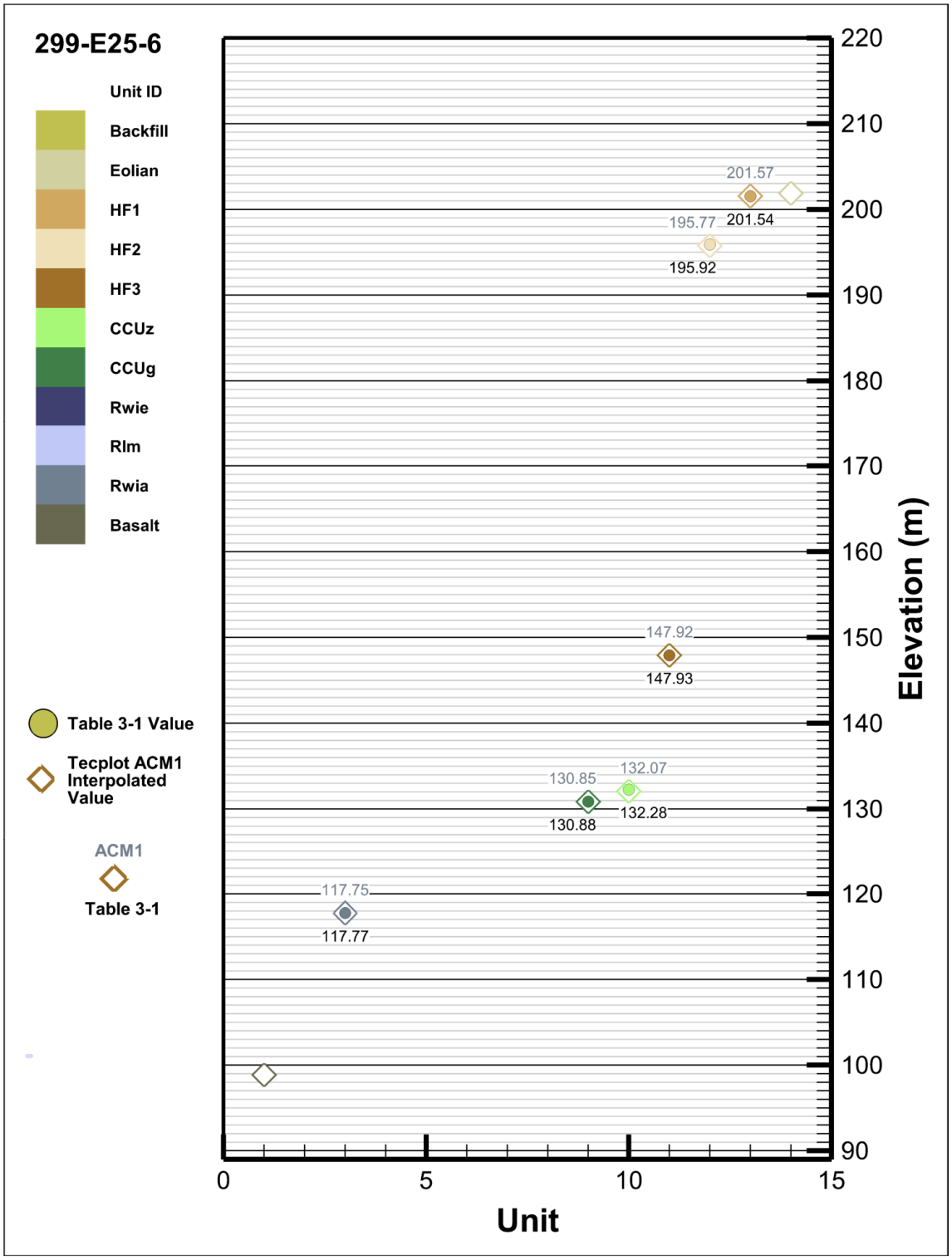
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-11. Well 299-E25-4 - Units Elevation Comparison (Table 3.1 vs. GFM).



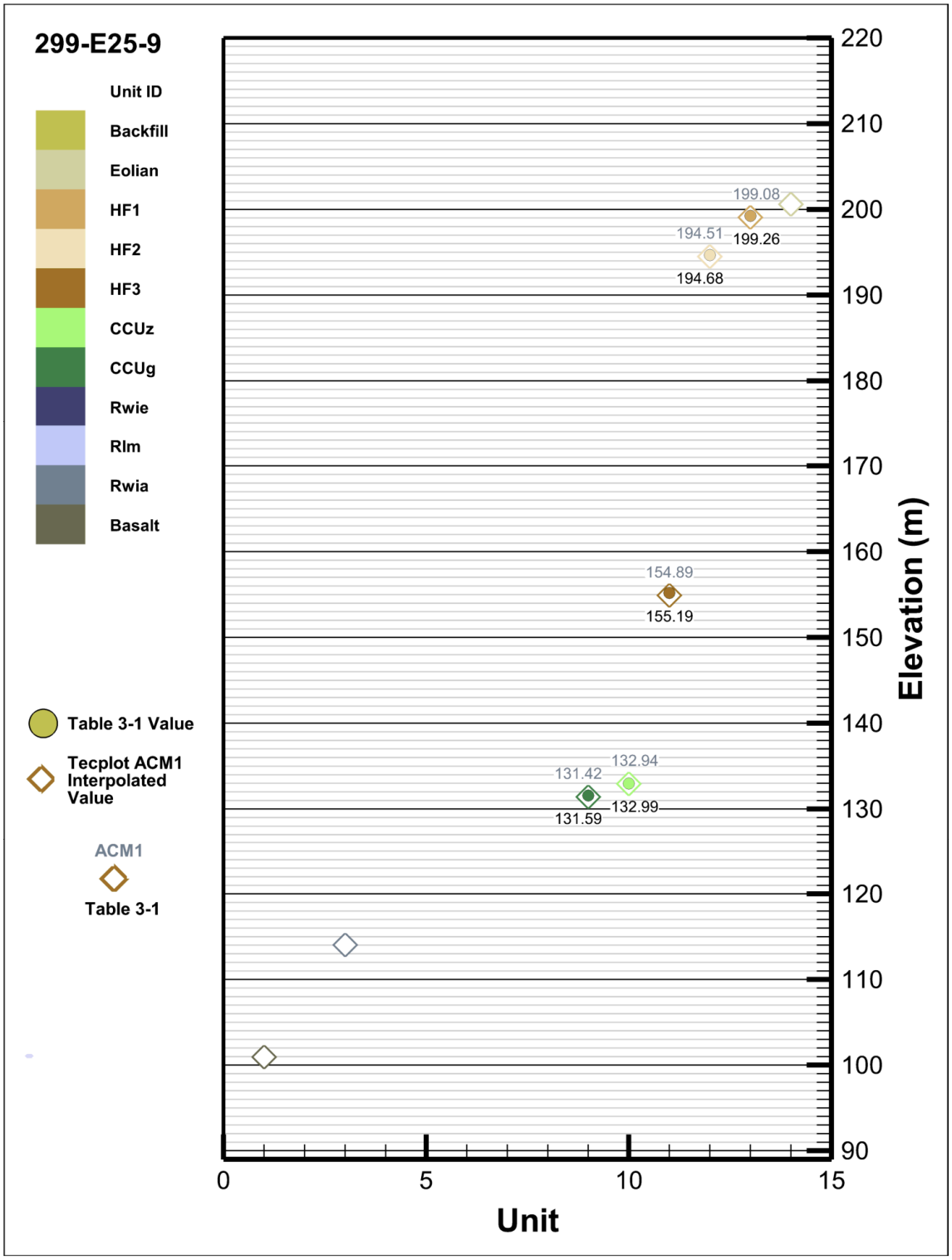
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-12. Well 299-E25-6 - Units Elevation Comparison (Table 3.1 vs. GFM).



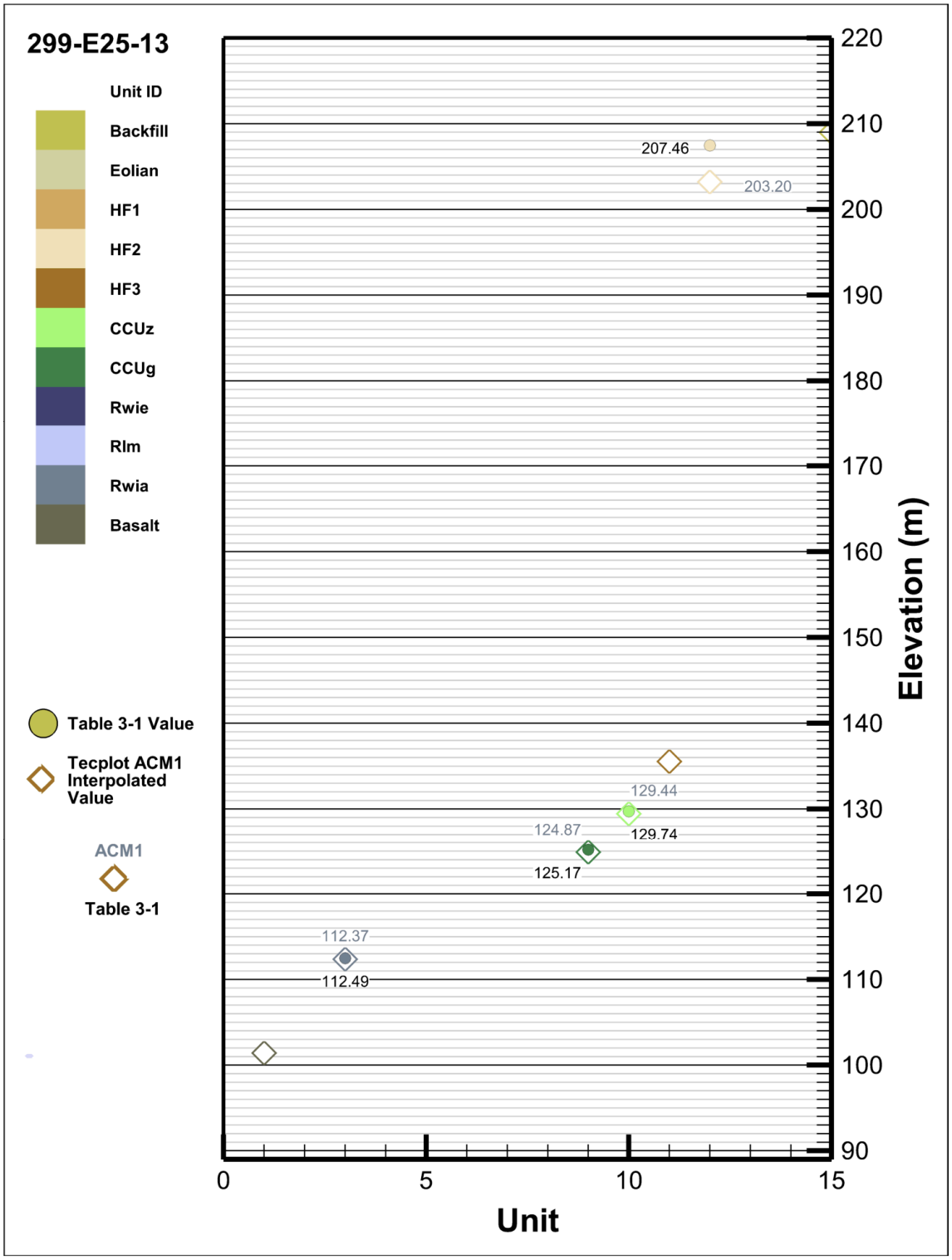
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-13. Well 299-E25-9 - Units Elevation Comparison (Table 3.1 vs. GFM).



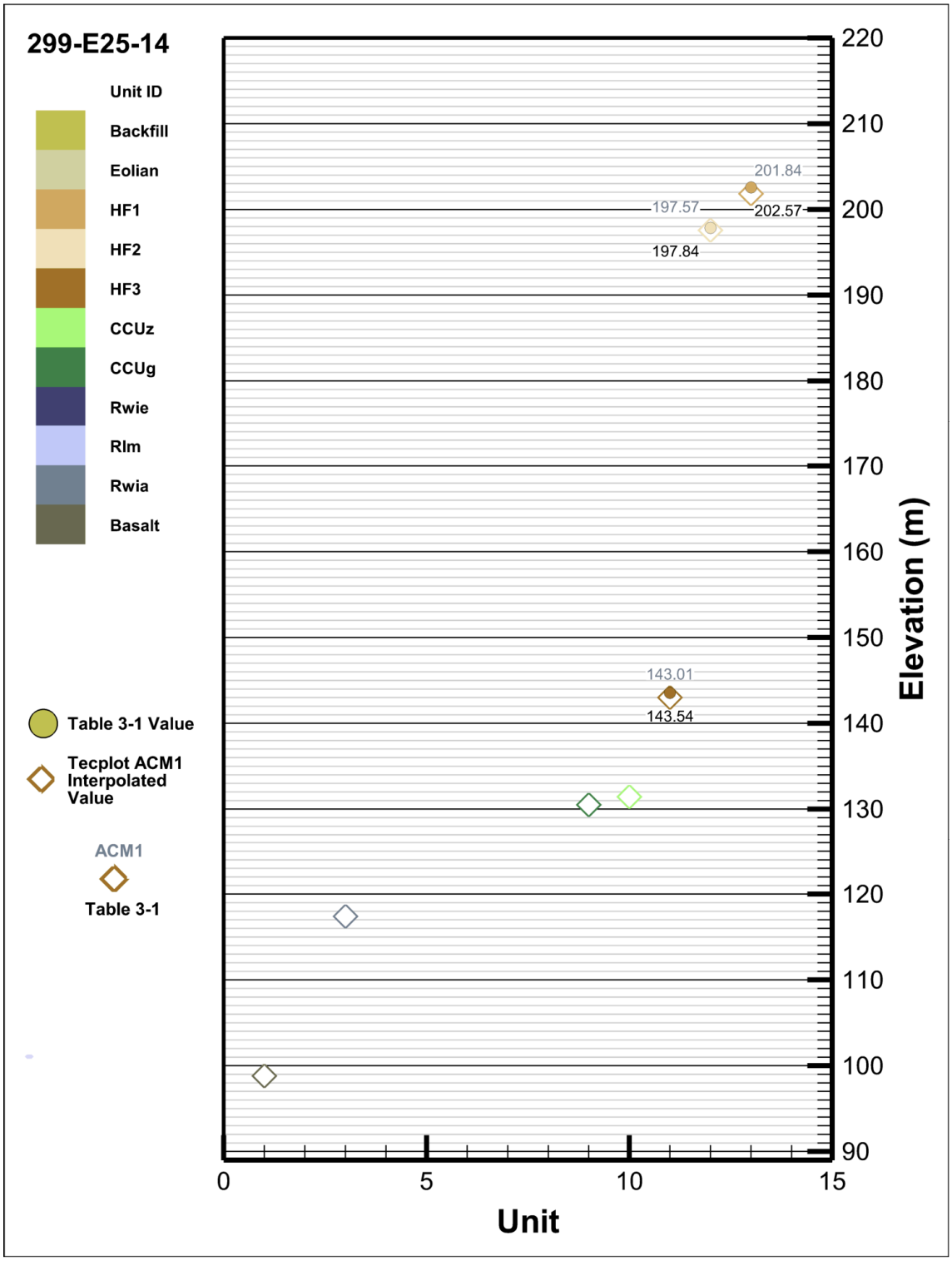
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-14. Well 299-E25-13 - Units Elevation Comparison (Table 3.1 vs. GFM).



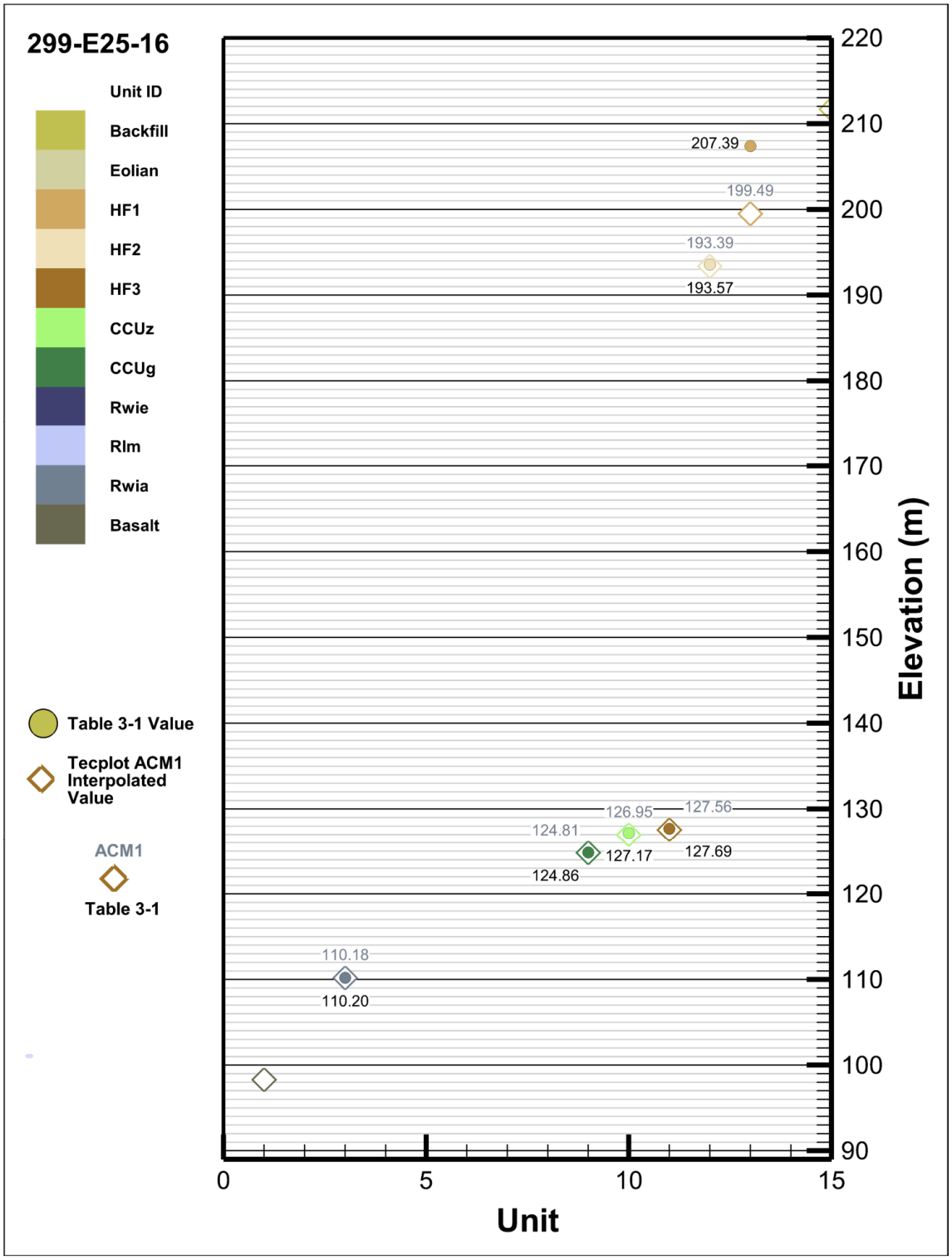
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-15. Well 299-E25-14 - Units Elevation Comparison (Table 3.1 vs. GFM).



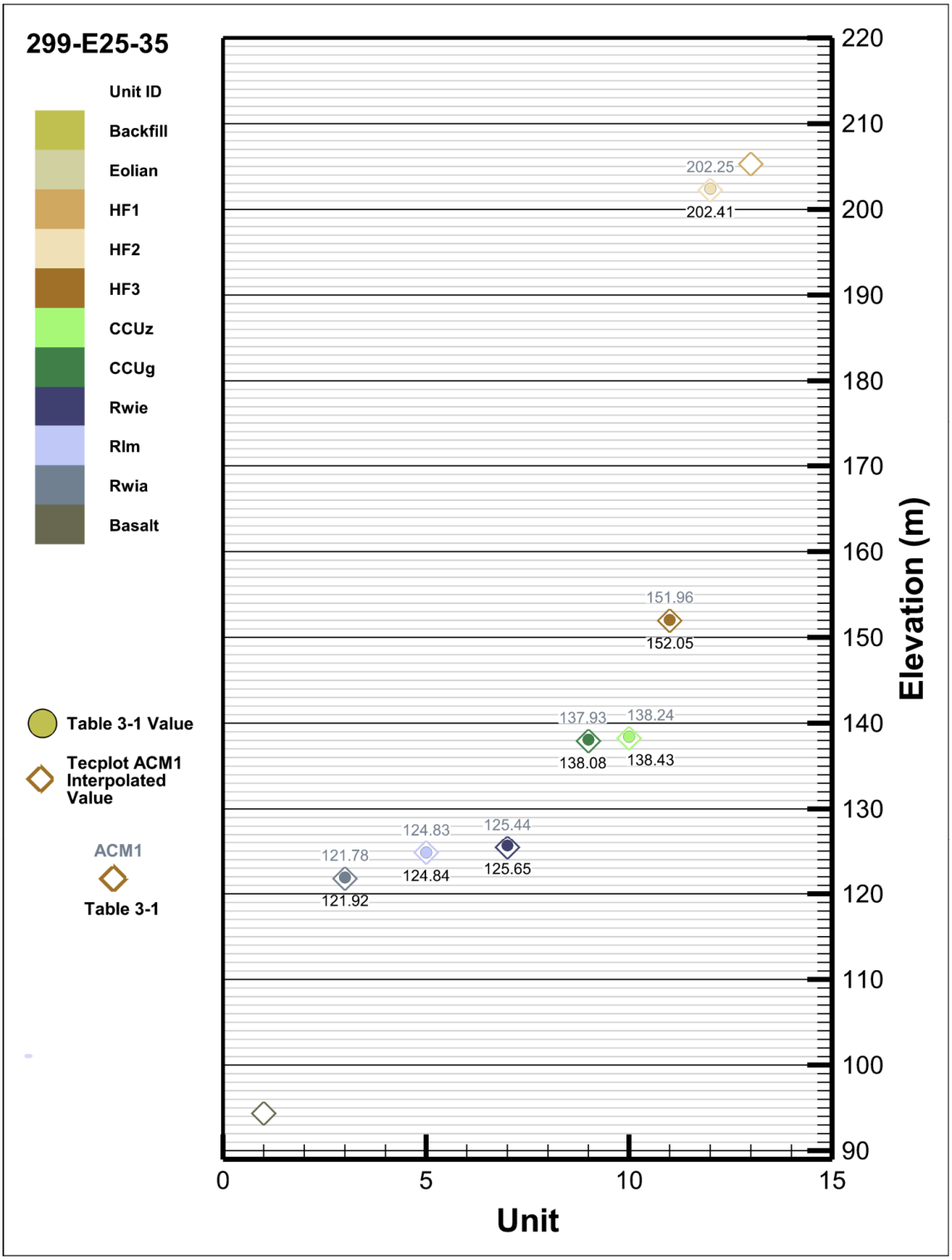
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-16. Well 299-E25-16 - Units Elevation Comparison (Table 3.1 vs. GFM).



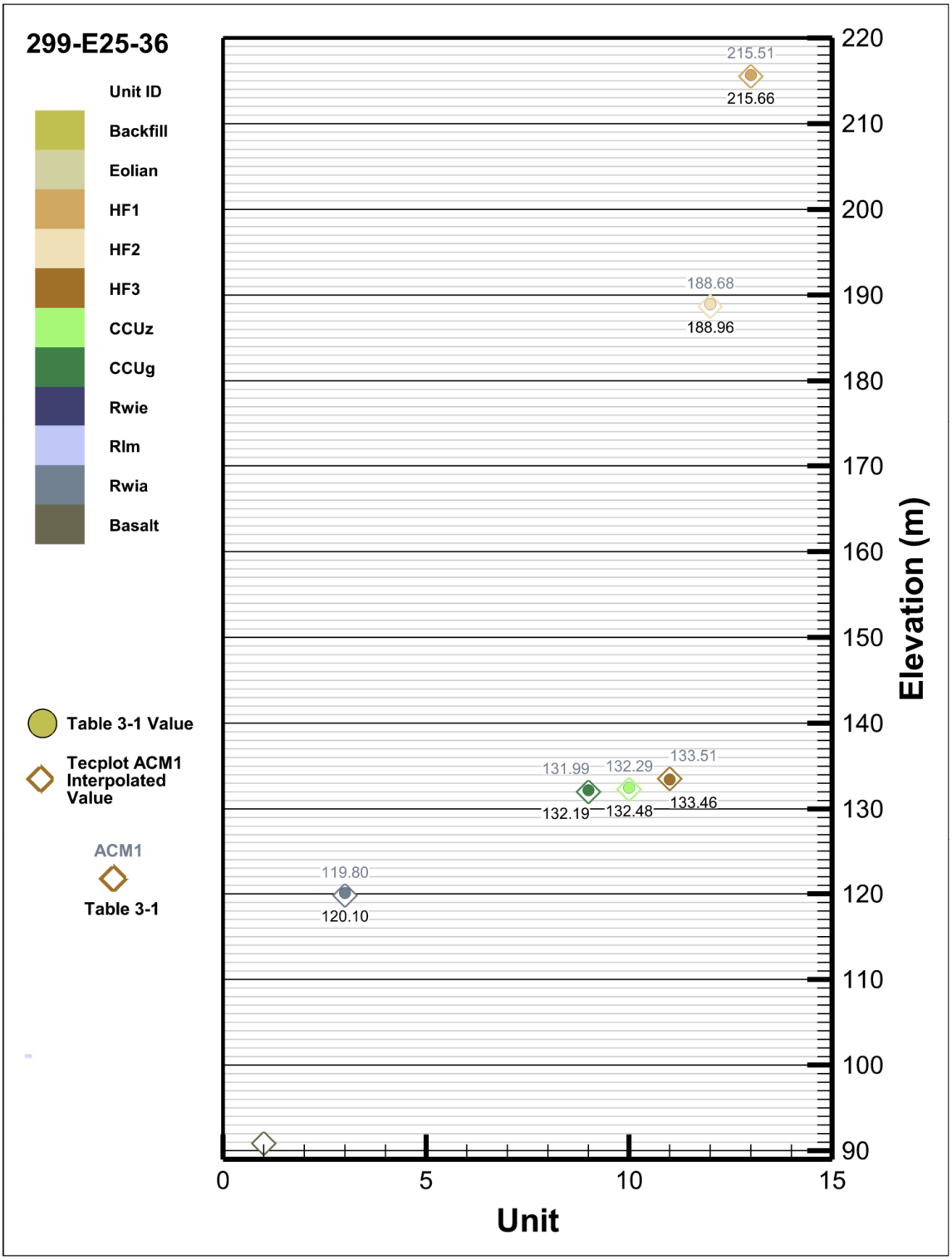
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-17. Well 299-E25-35 - Units Elevation Comparison (Table 3.1 vs. GFM).



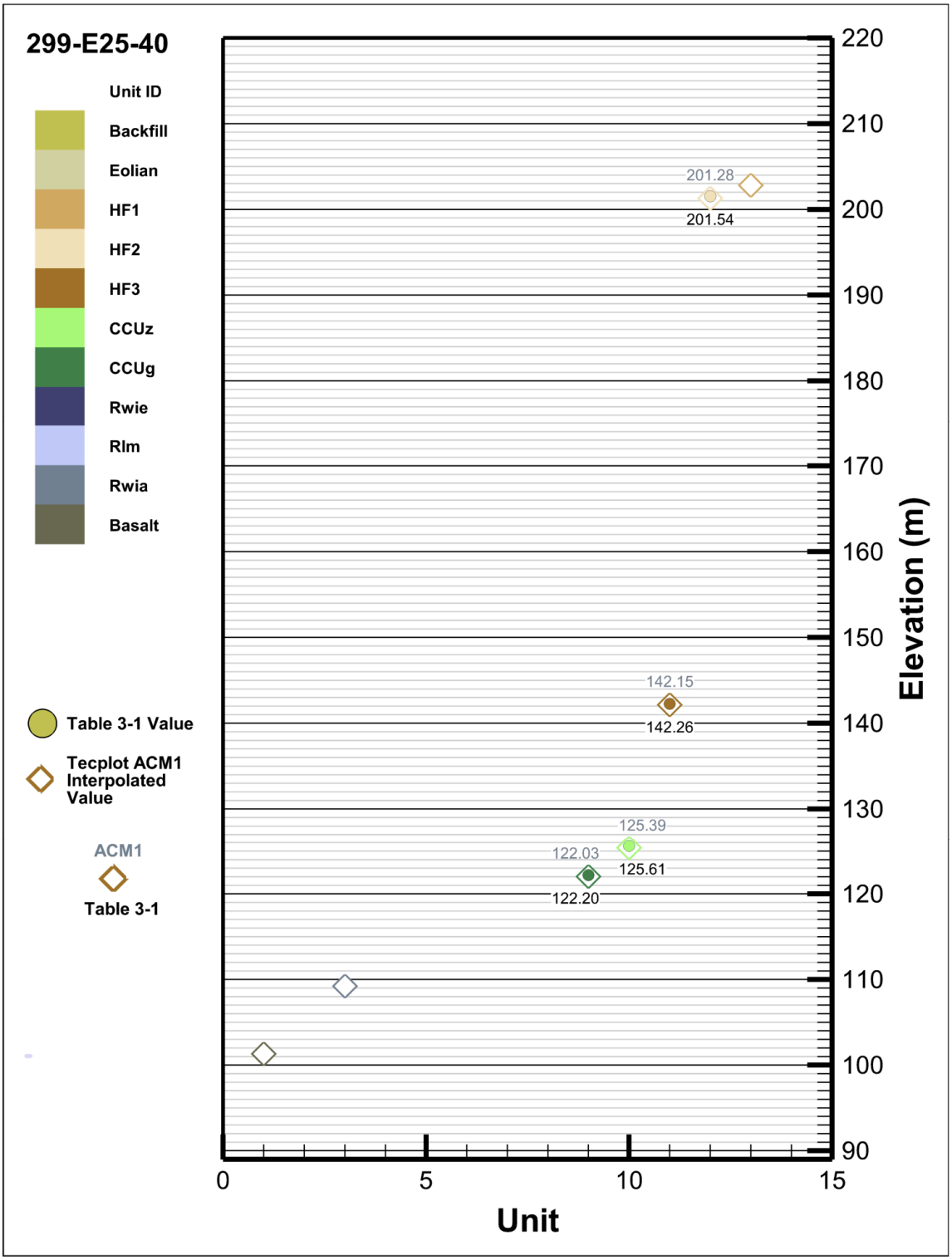
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-18. Well 299-E25-36 - Units Elevation Comparison (Table 3.1 vs. GFM).



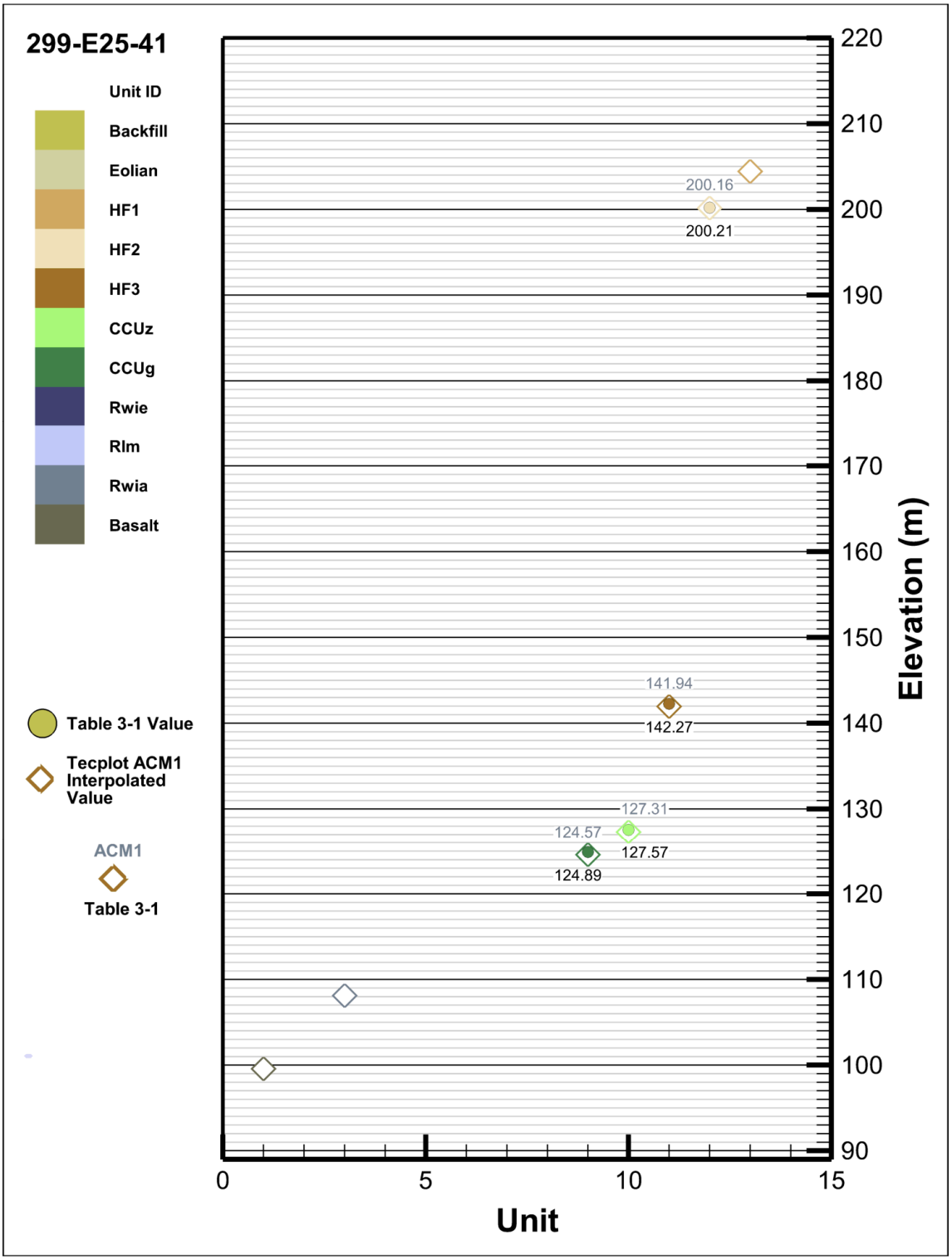
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-19. Well 299-E25-40 - Units Elevation Comparison (Table 3.1 vs. GFM).



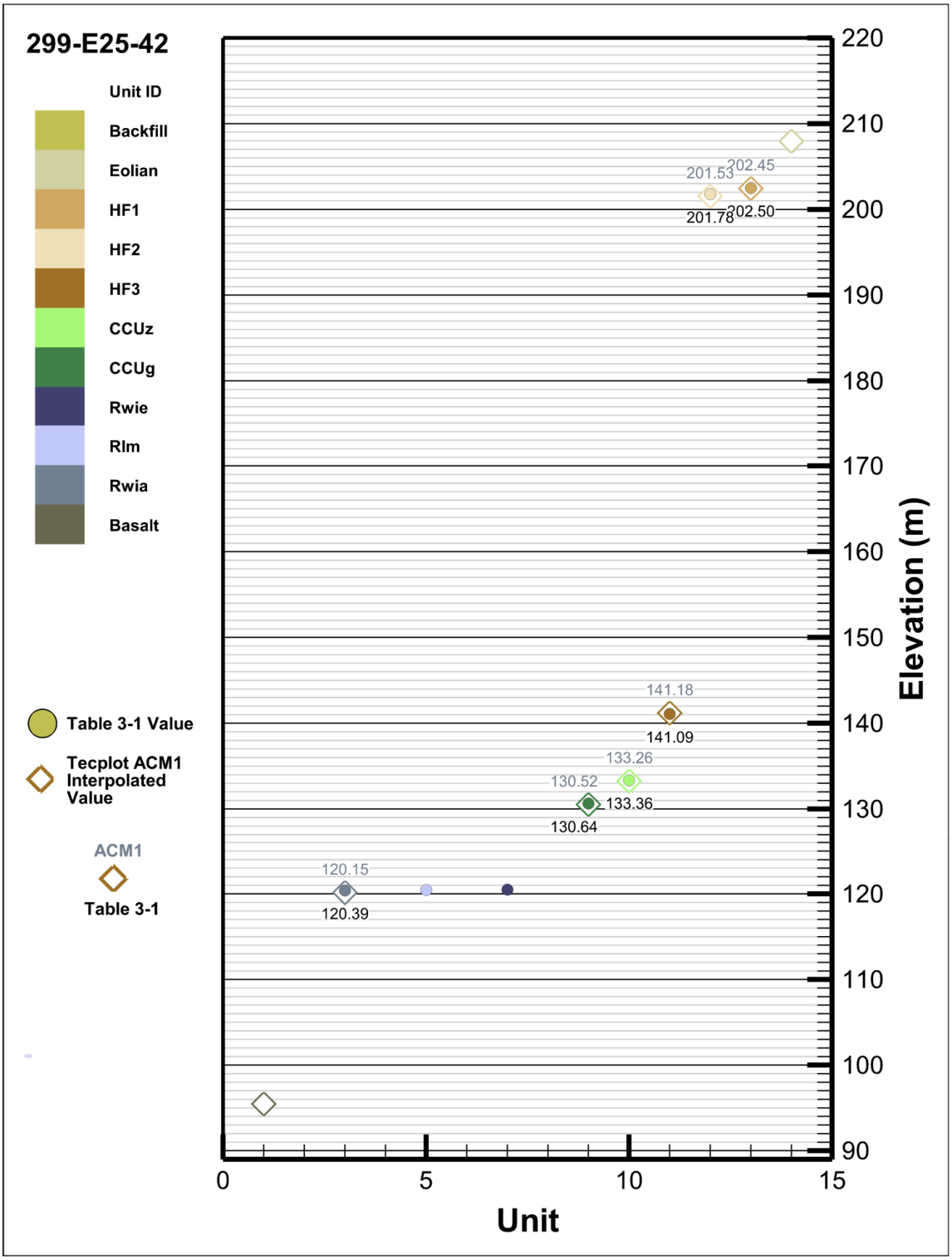
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-20. Well 299-E25-41 - Units Elevation Comparison (Table 3.1 vs GFM).



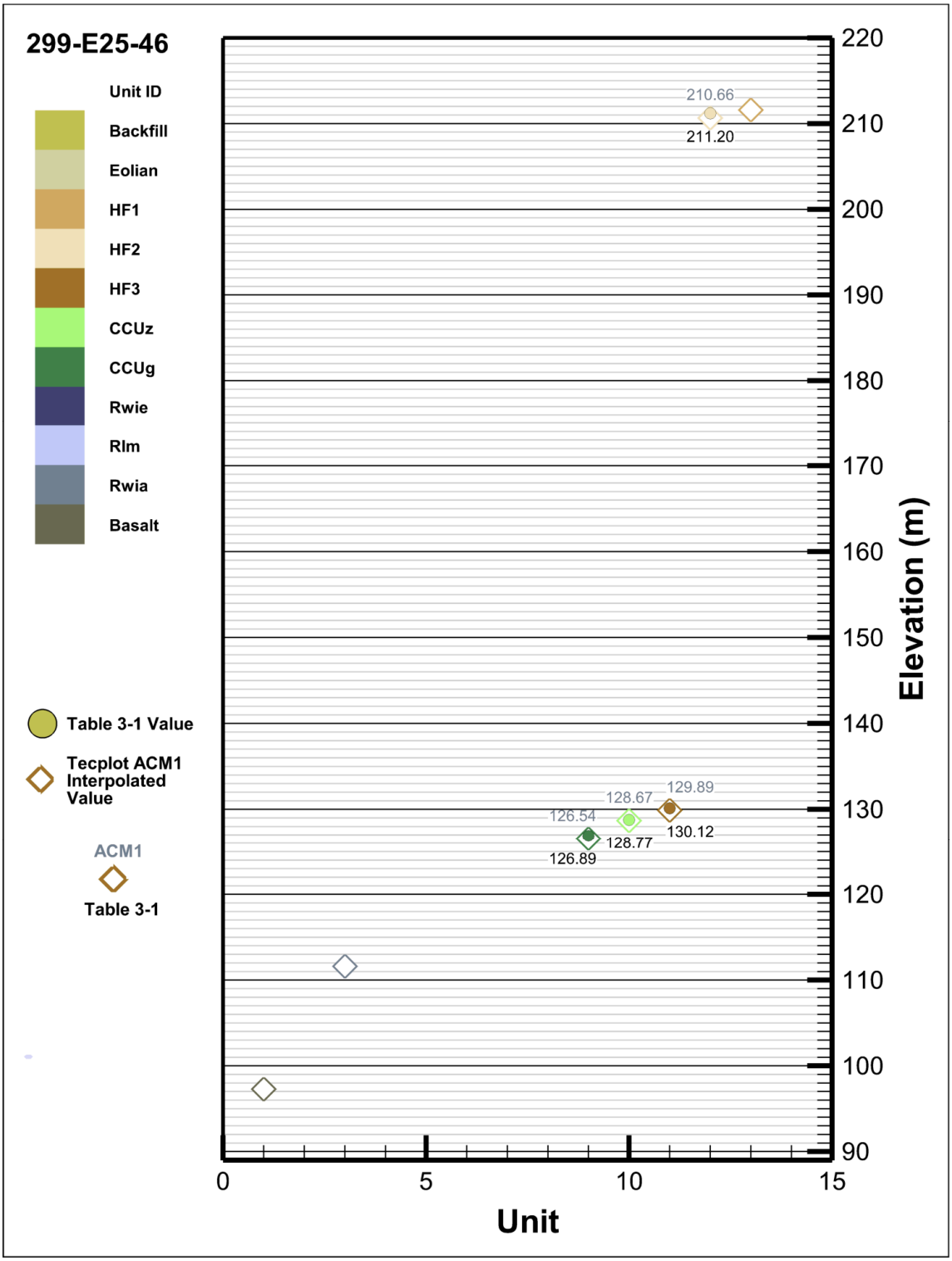
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-21. Well 299-E25-42 - Units Elevation Comparison (Table 3.1 vs GFM).



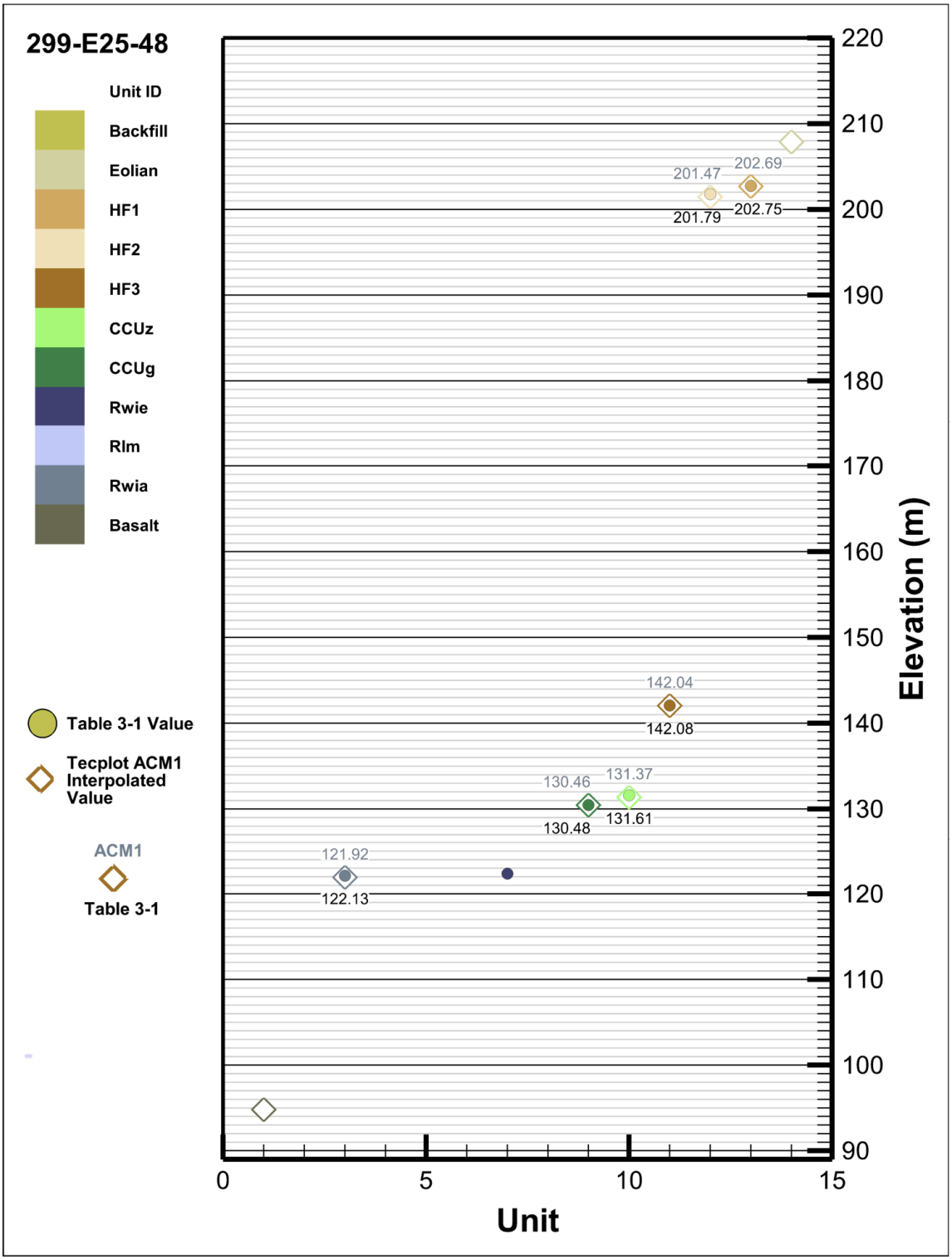
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-22. Well 299-E25-46 - Units Elevation Comparison (Table 3.1 vs GFM).



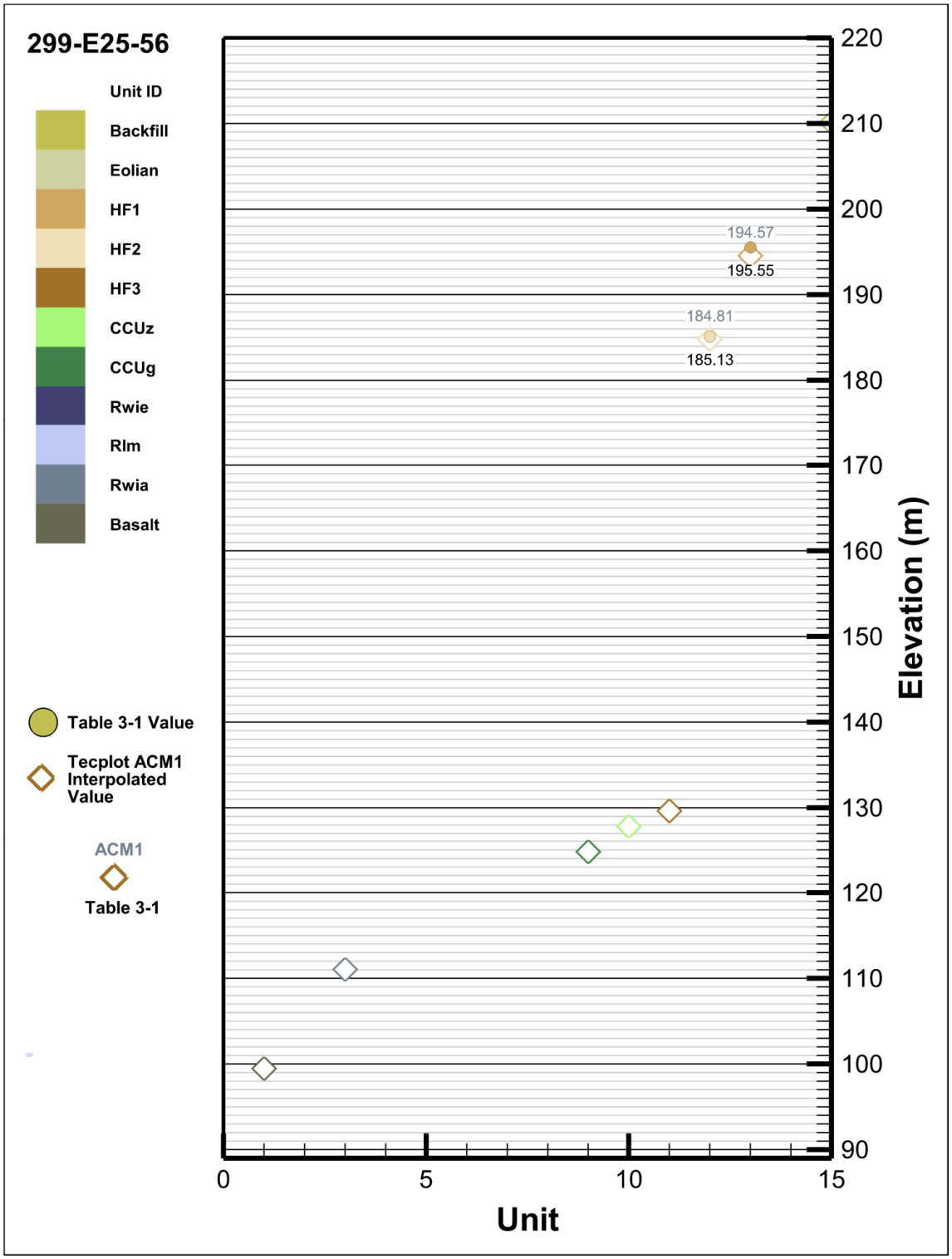
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-23. Well 299-E25-48 - Units Elevation Comparison (Table 3.1 vs GFM).



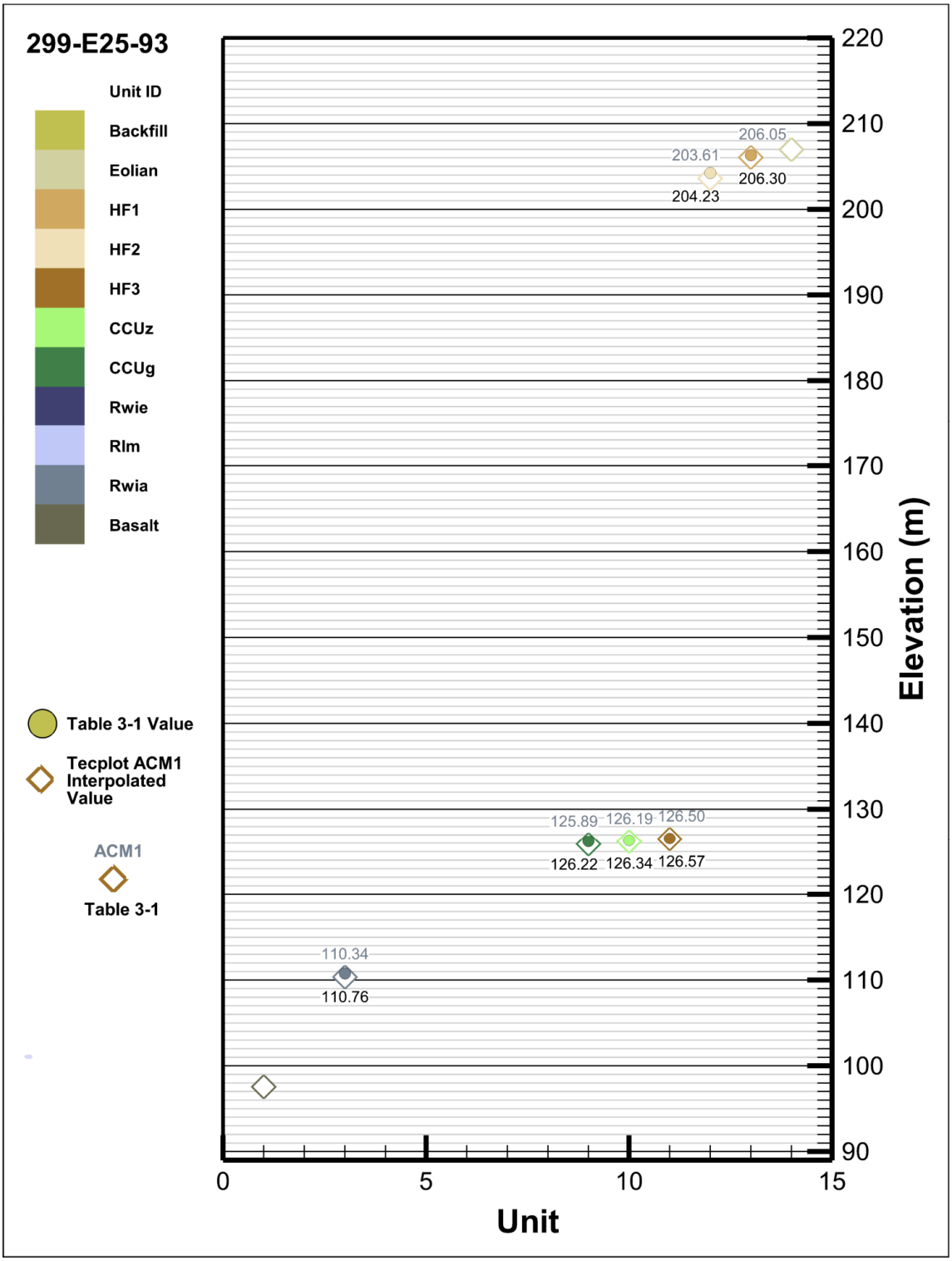
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-24. Well 299-E25-56 - Units Elevation Comparison (Table 3.1 vs GFM).



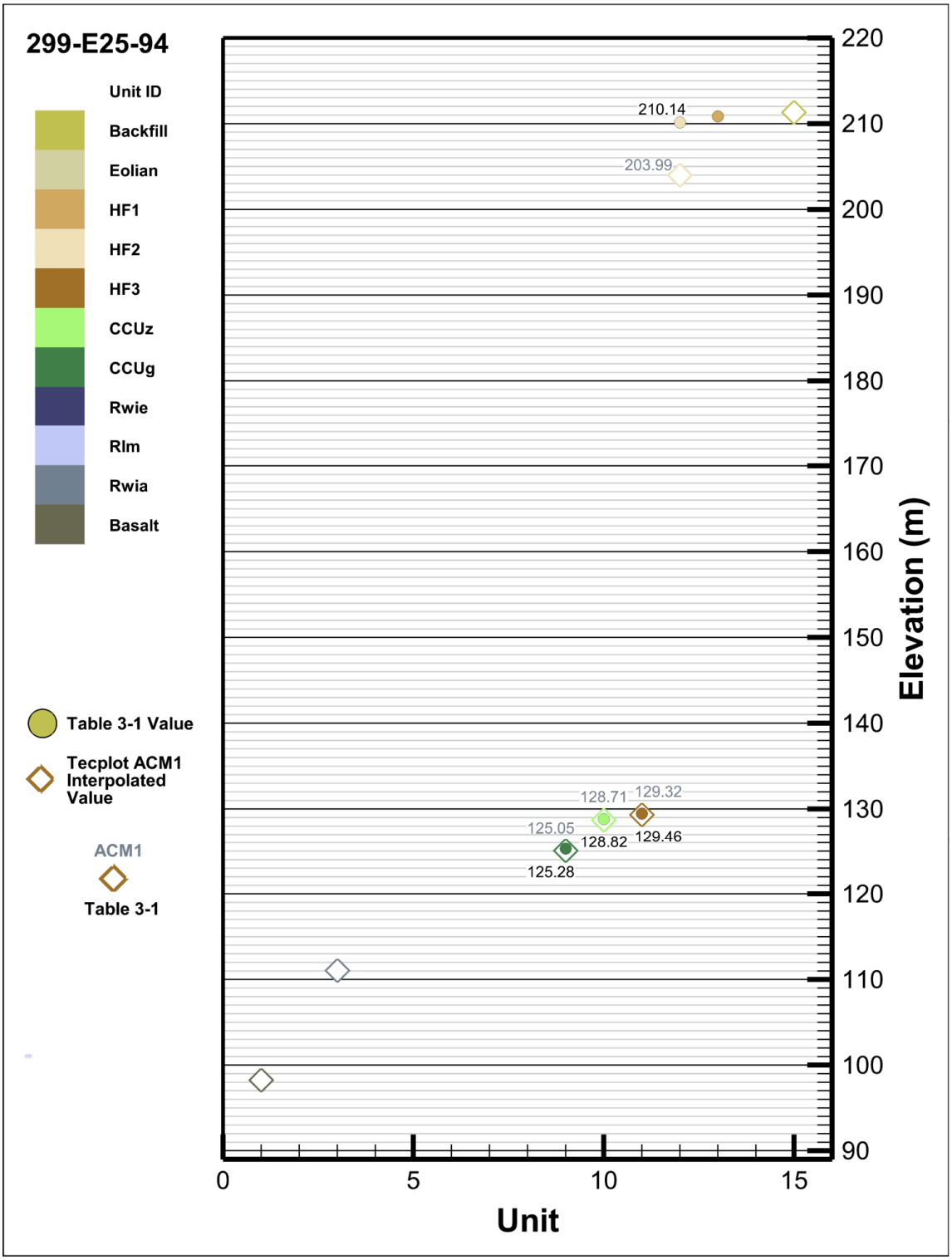
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-25. Well 299-E25-56 - Units Elevation Comparison (Table 3.1 vs GFM).



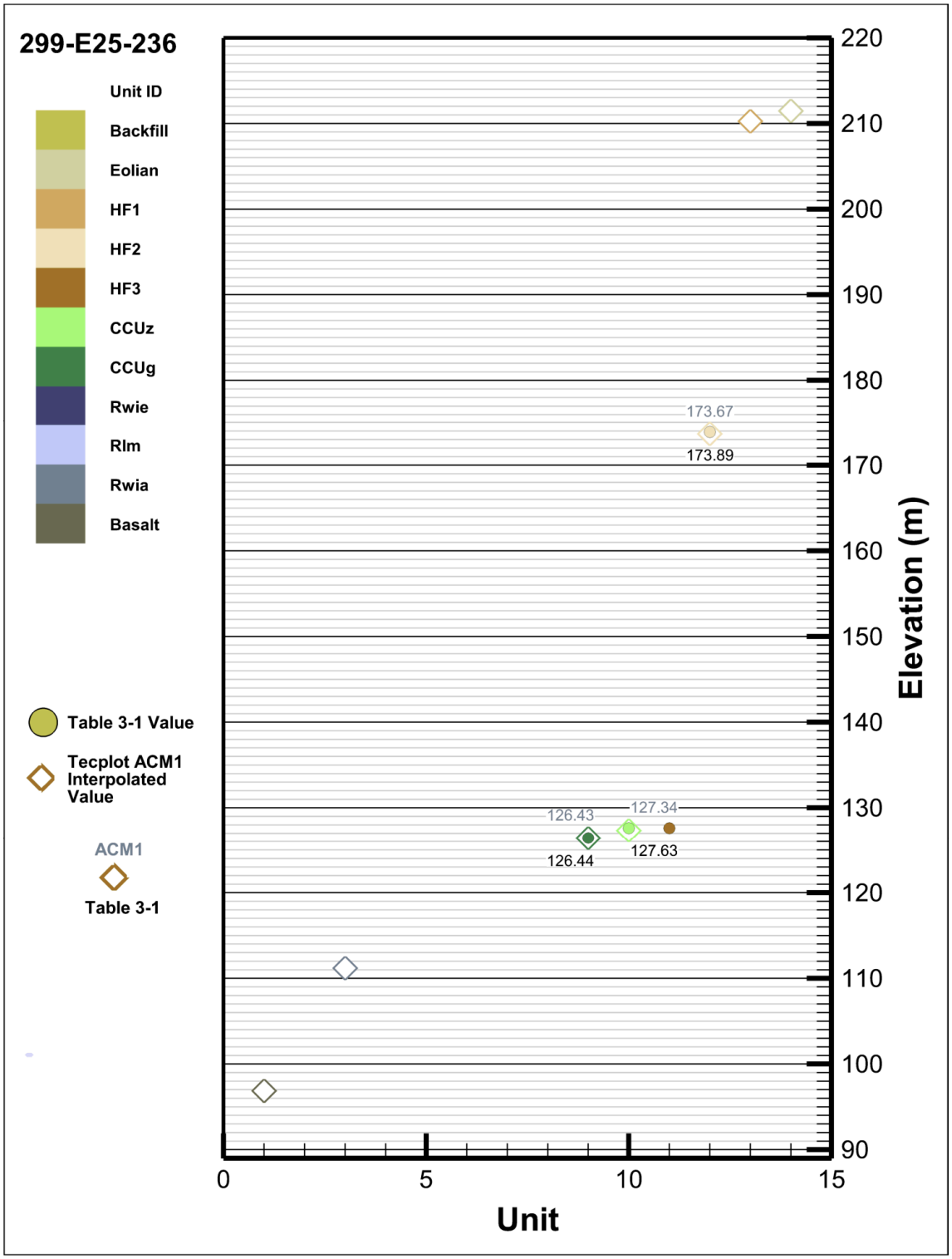
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-26. Well 299-E25-94 - Units Elevation Comparison (Table 3.1 vs GFM).



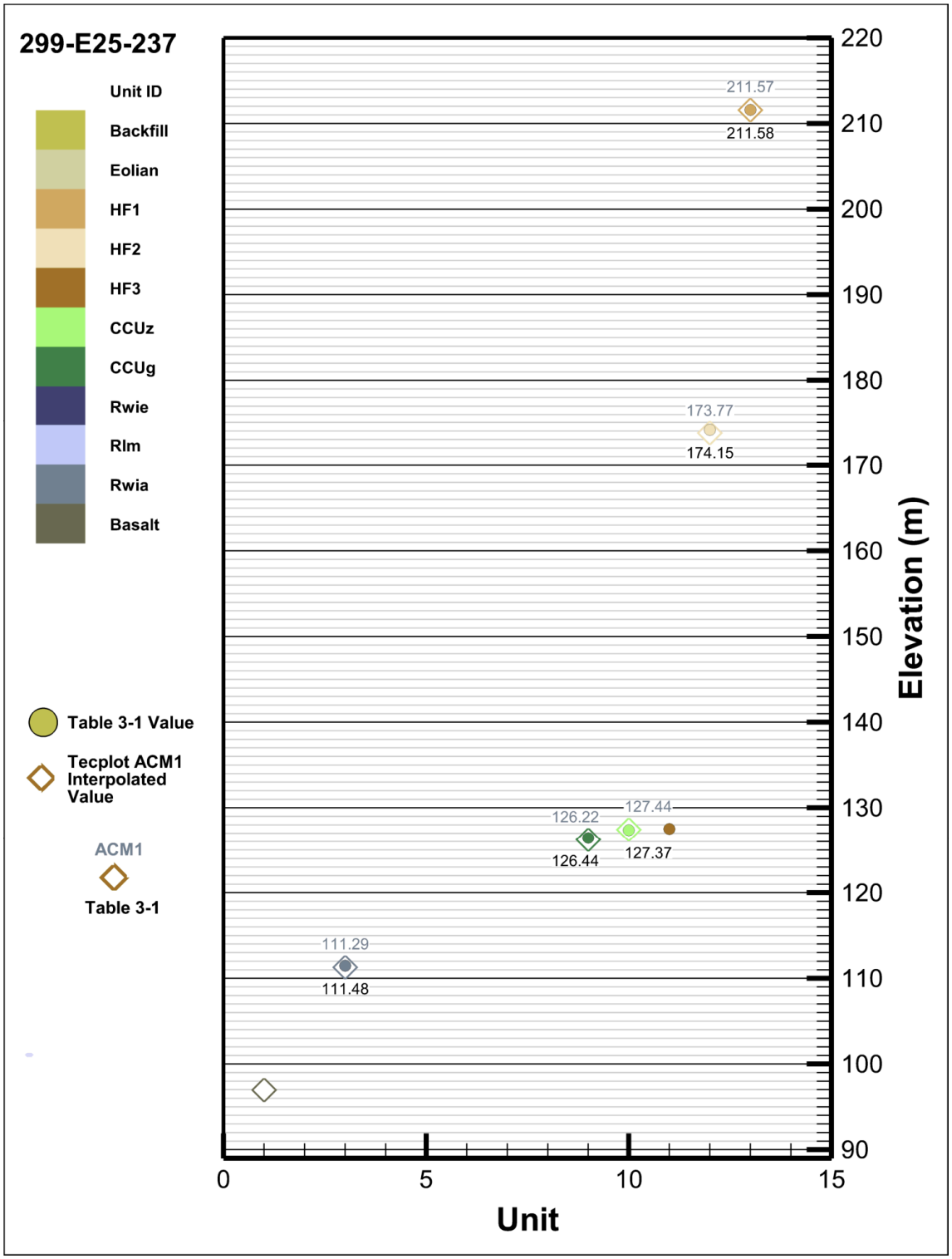
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-27. Well 299-E25-236 - Units Elevation Comparison (Table 3.1 vs GFM).



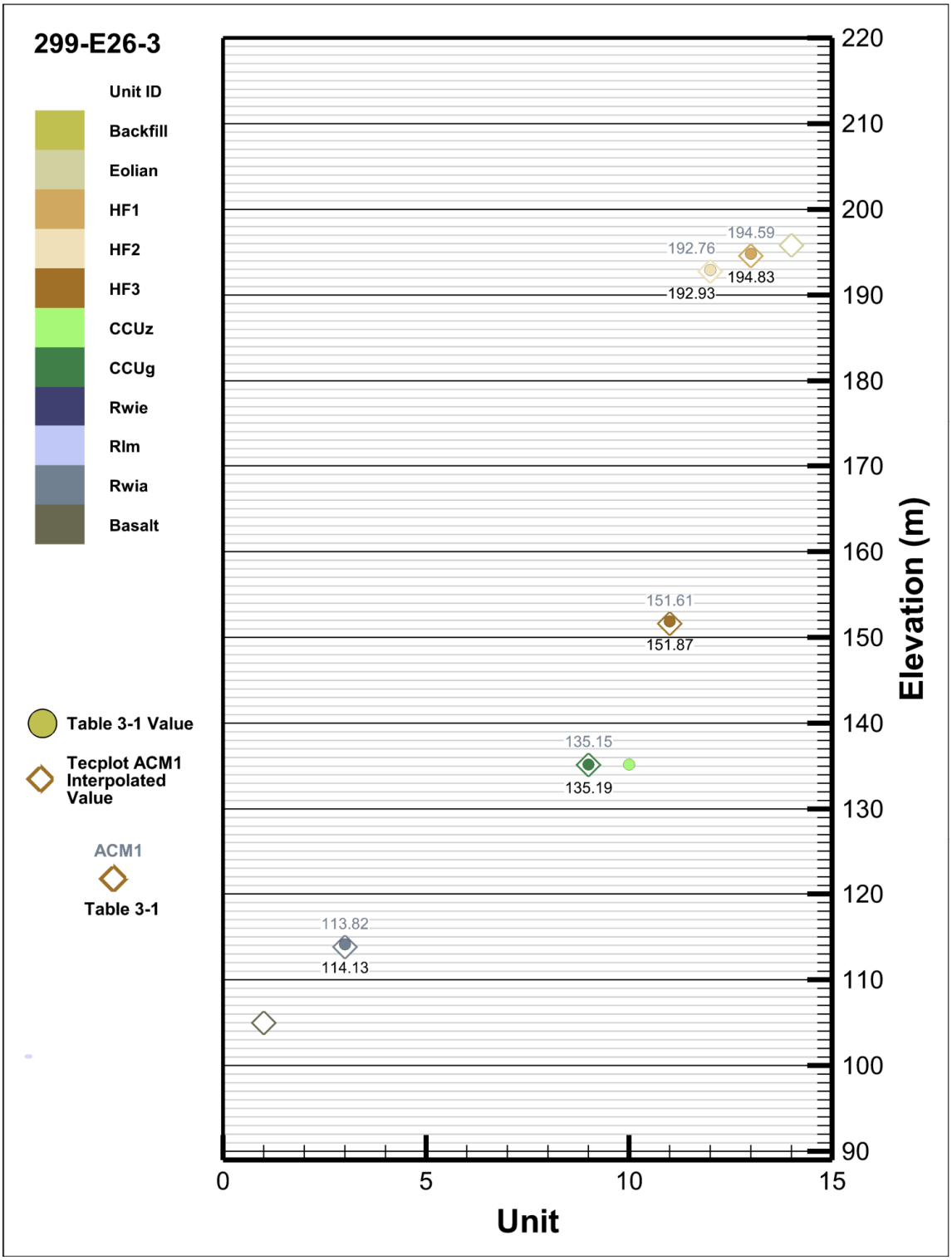
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-28. Well 299-E25-237 - Units Elevation Comparison (Table 3.1 vs GFM).



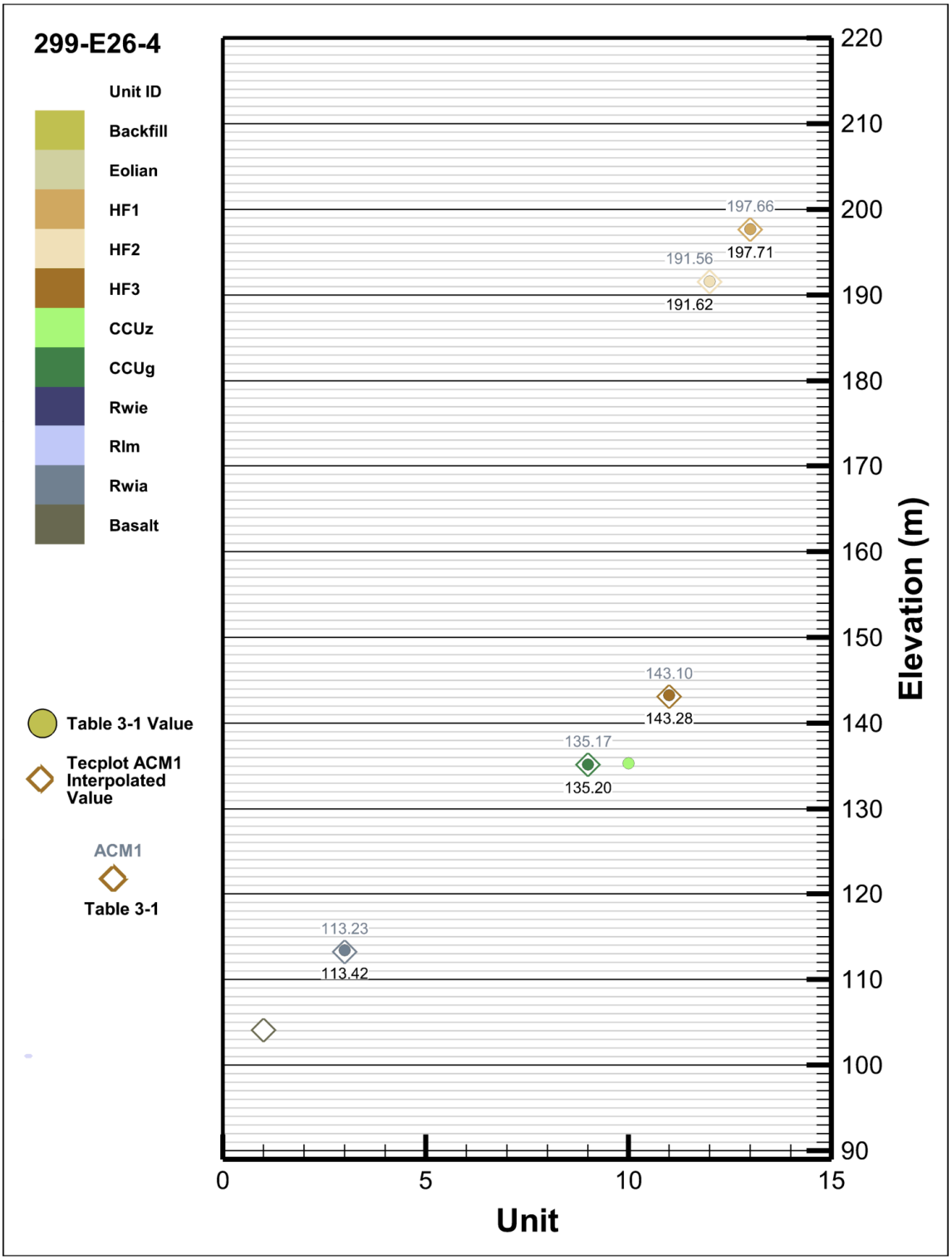
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-29. Well 299-E26-3 - Units Elevation Comparison (Table 3.1 vs GFM).



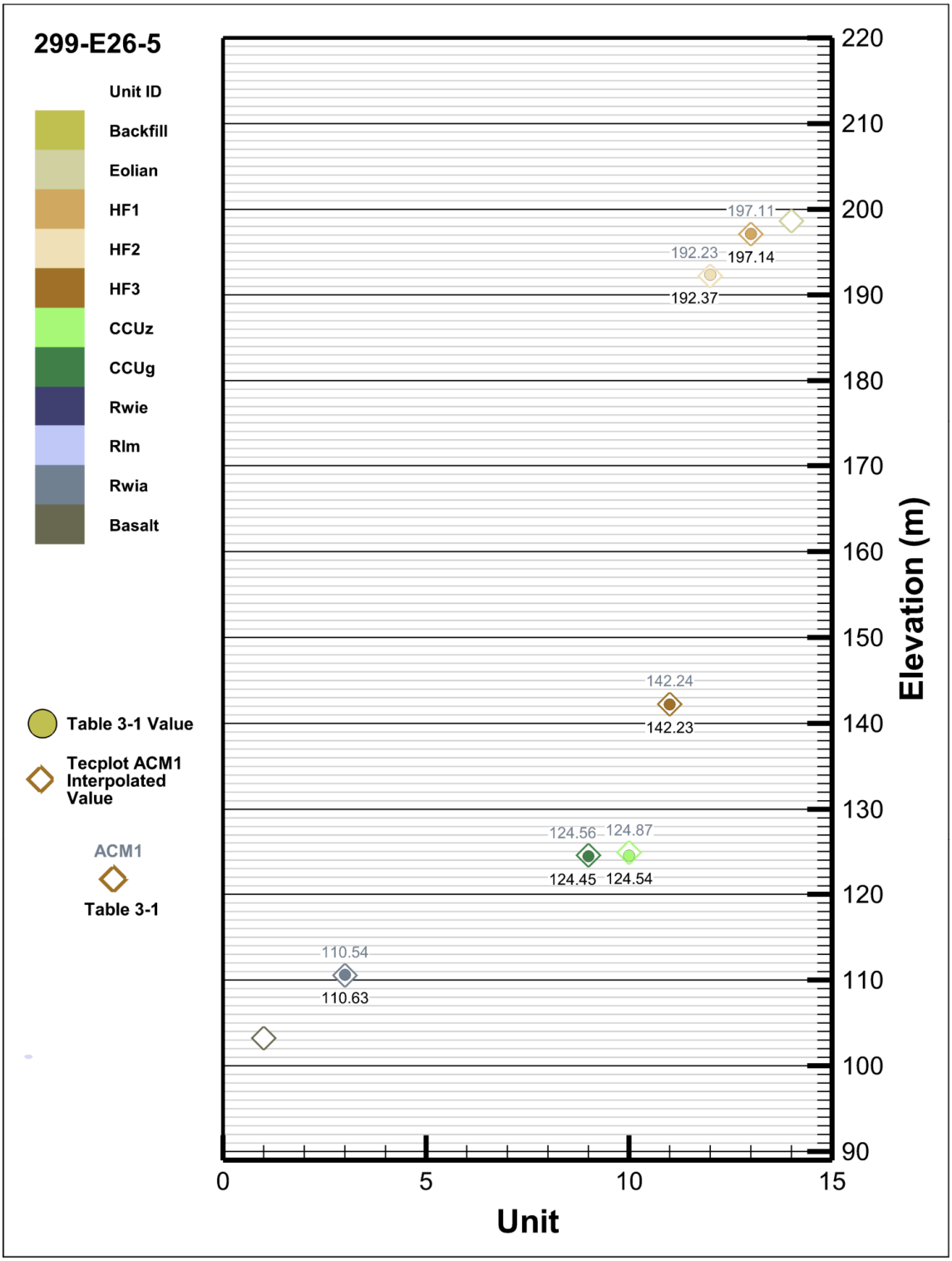
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-30. Well 299-E26-4 - Units Elevation Comparison (Table 3.1 vs GFM).



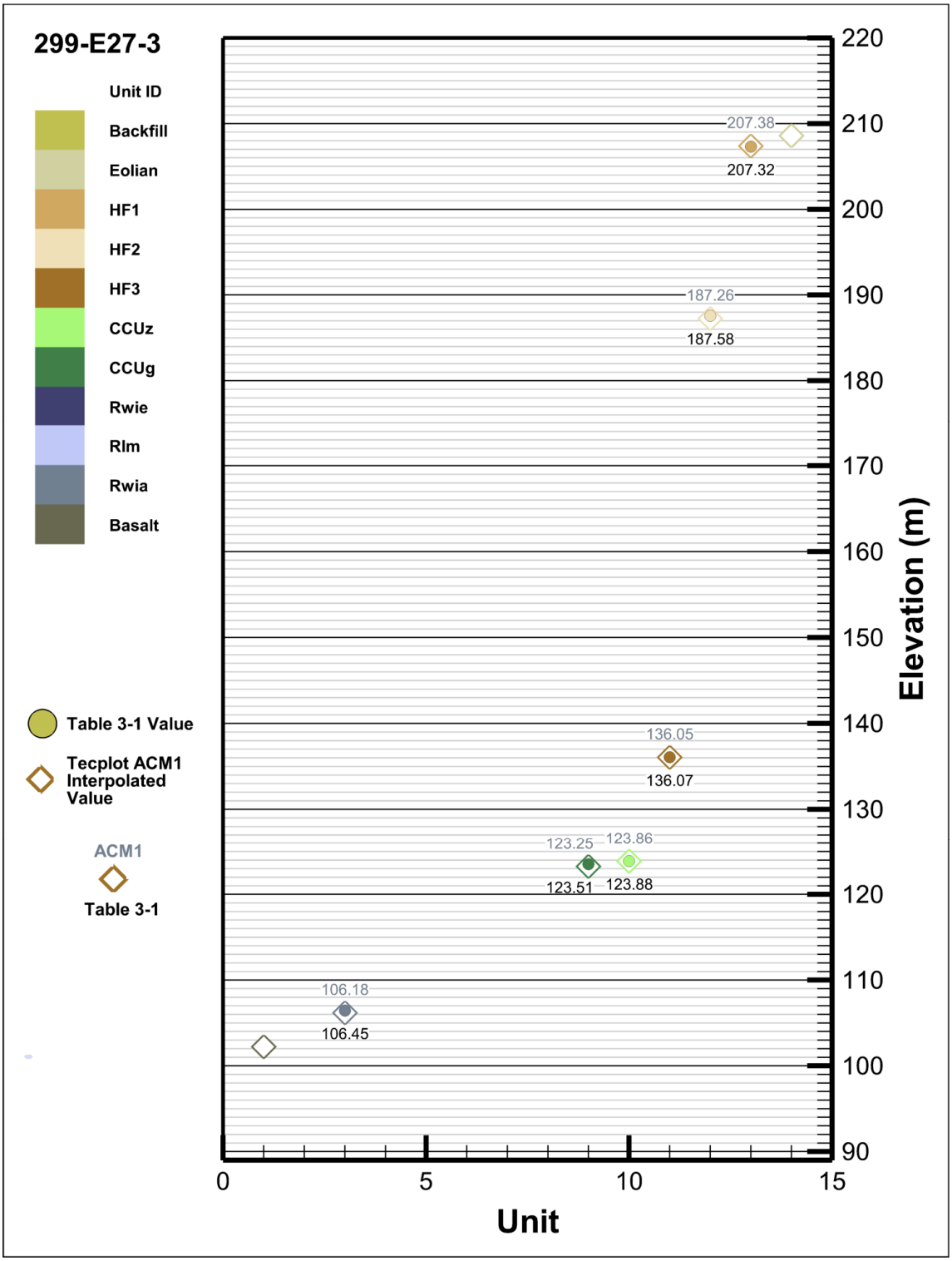
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-31. Well 299-E26-5 - Units Elevation Comparison (Table 3.1 vs GFM).



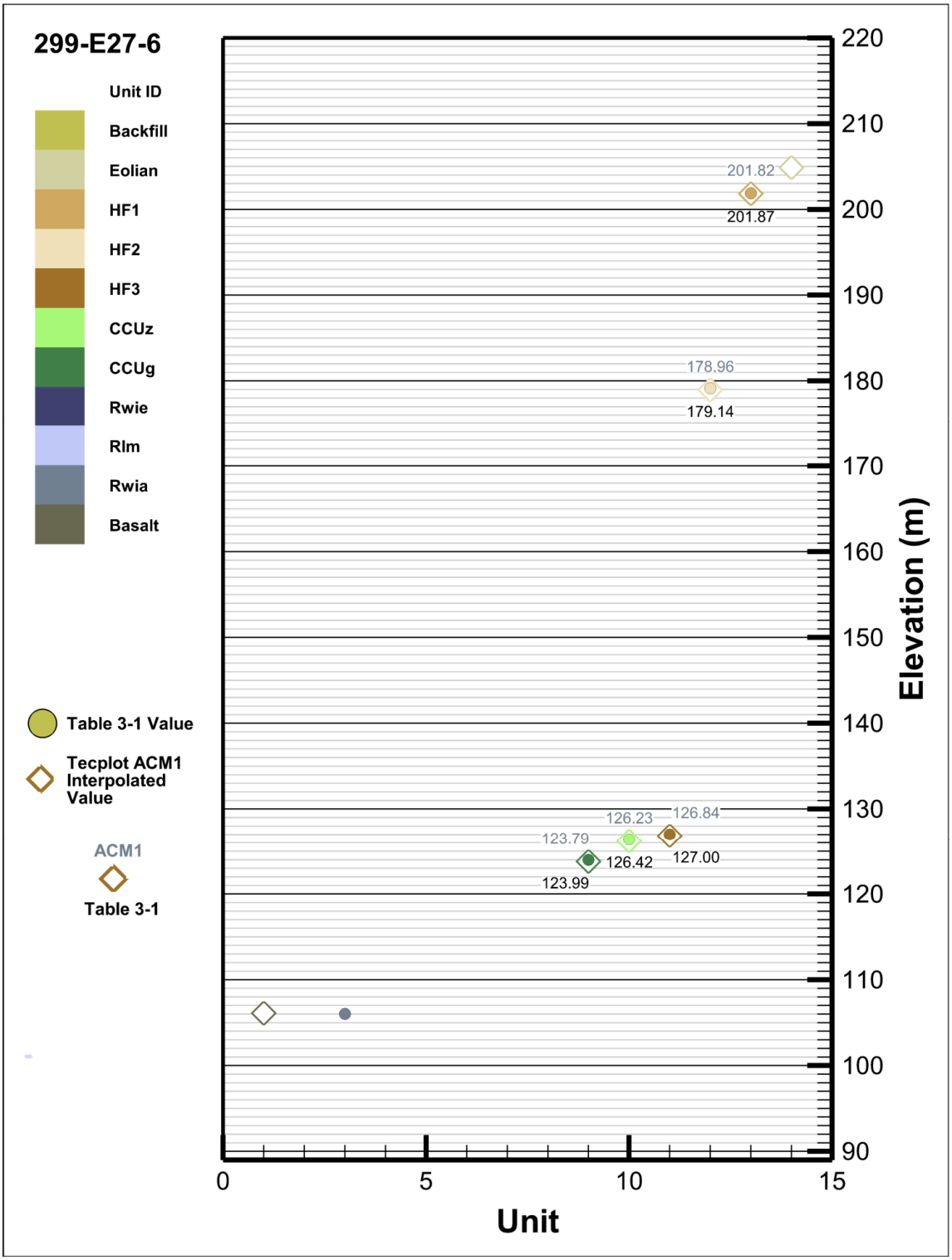
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-32. Well 299-E27-3 - Units Elevation Comparison (Table 3.1 vs GFM).



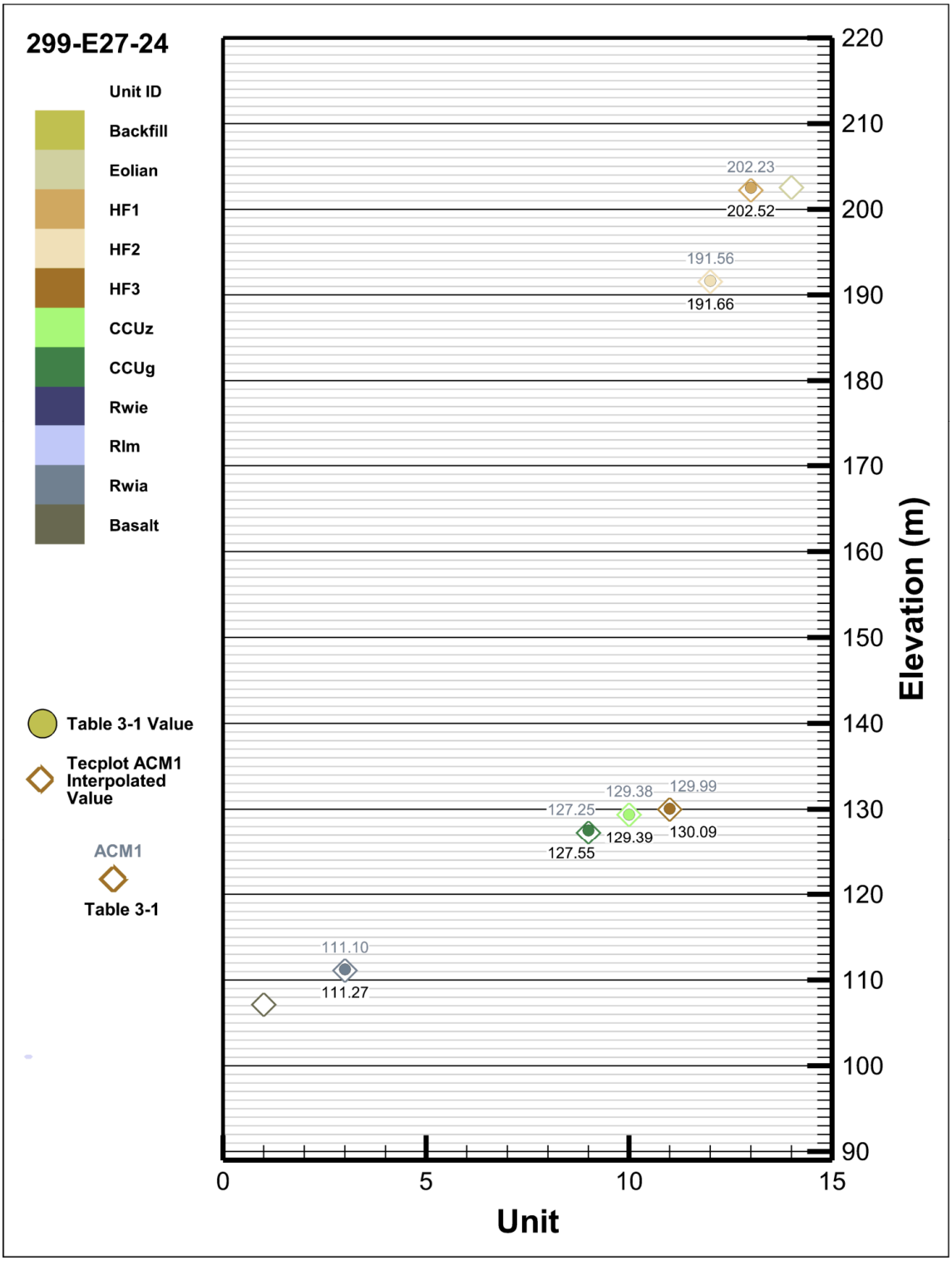
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-33. Well 299-E27-6 - Units Elevation Comparison (Table 3.1 vs GFM).



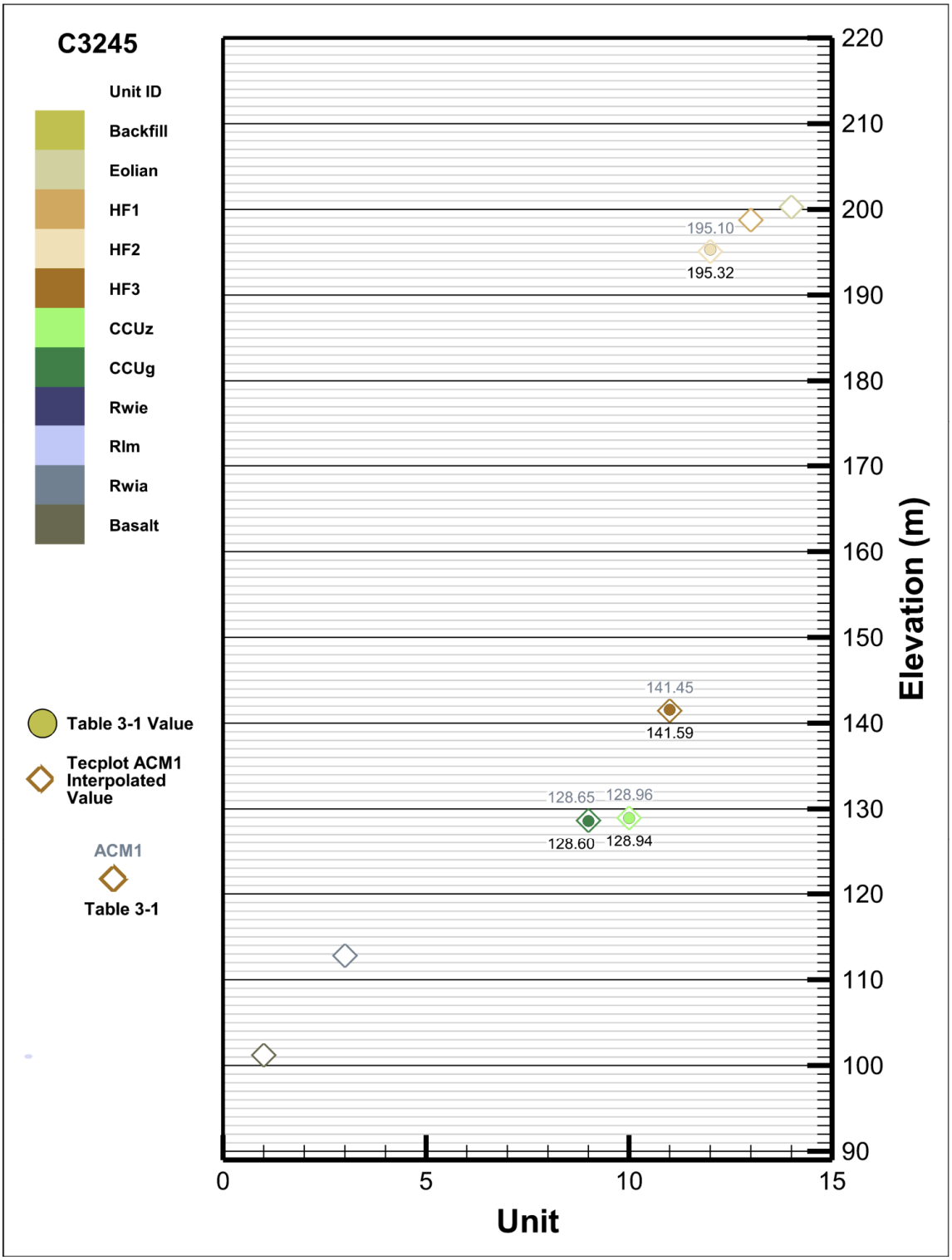
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-34. Well 299-E27-24 - Units Elevation Comparison (Table 3.1 vs GFM).



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

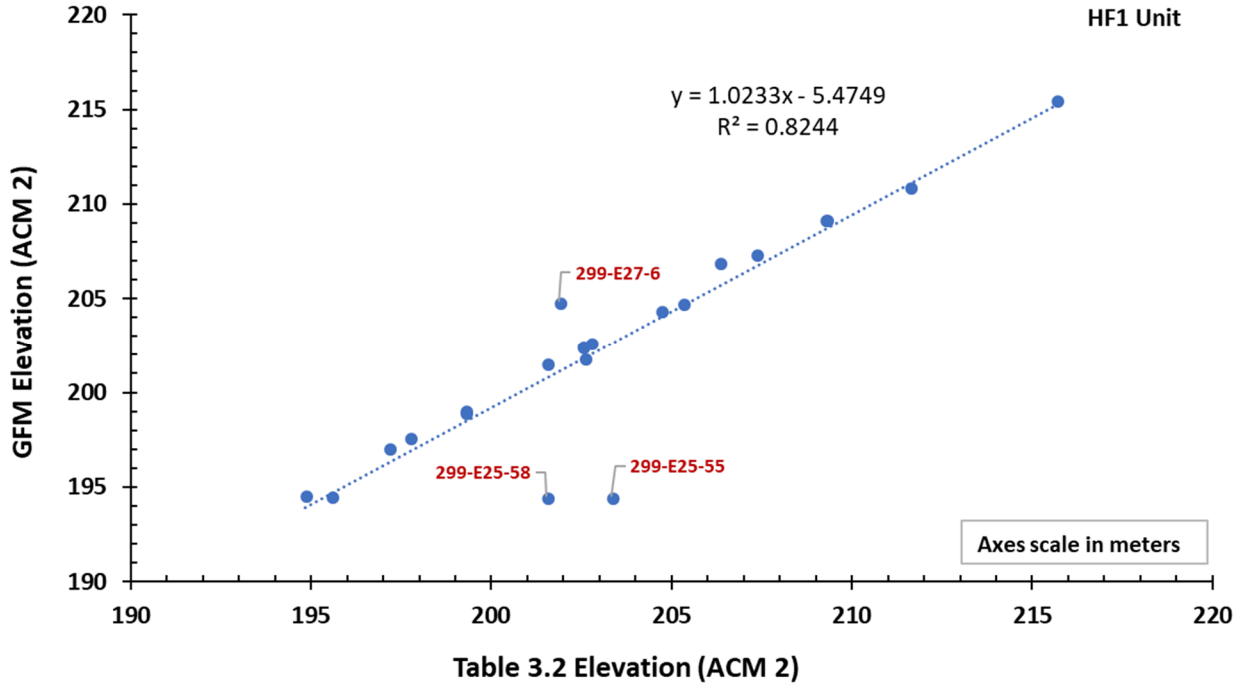
Figure H-35. Well C3245 - Units Elevation Comparison (Table 3.1 vs GFM).



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

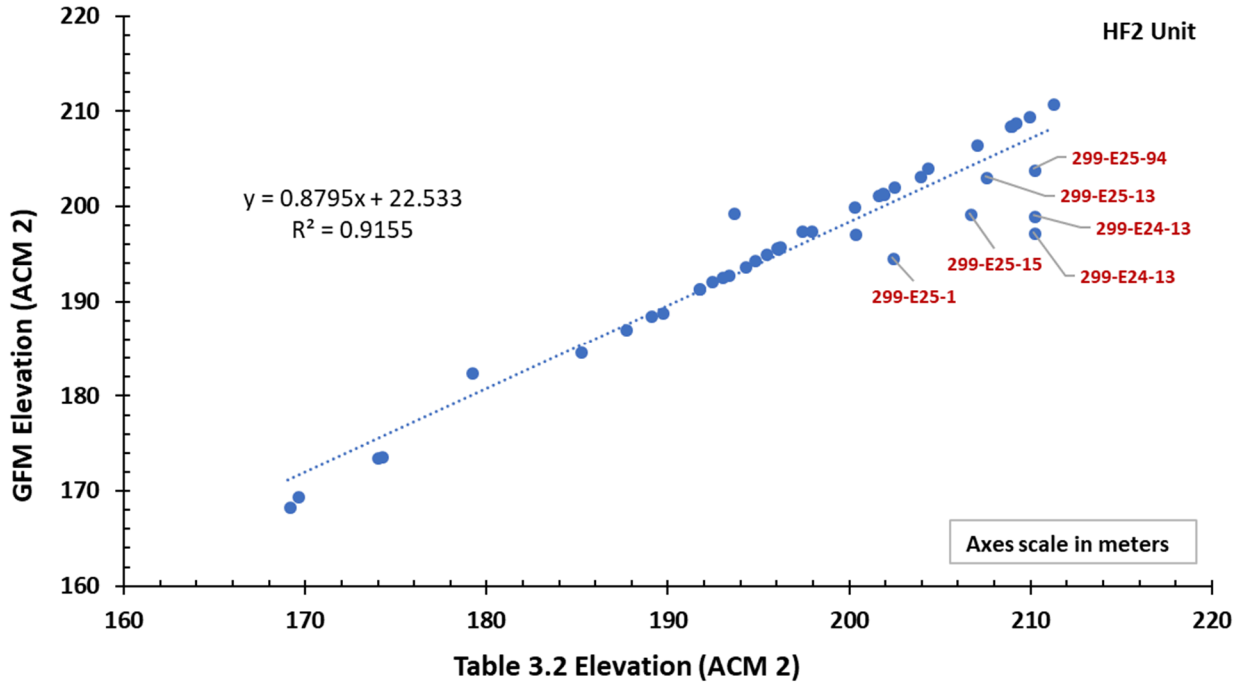
ACM2

Figure H-36. Comparison of HF1 Unit Elevation (Table 3.2 vs GFM).



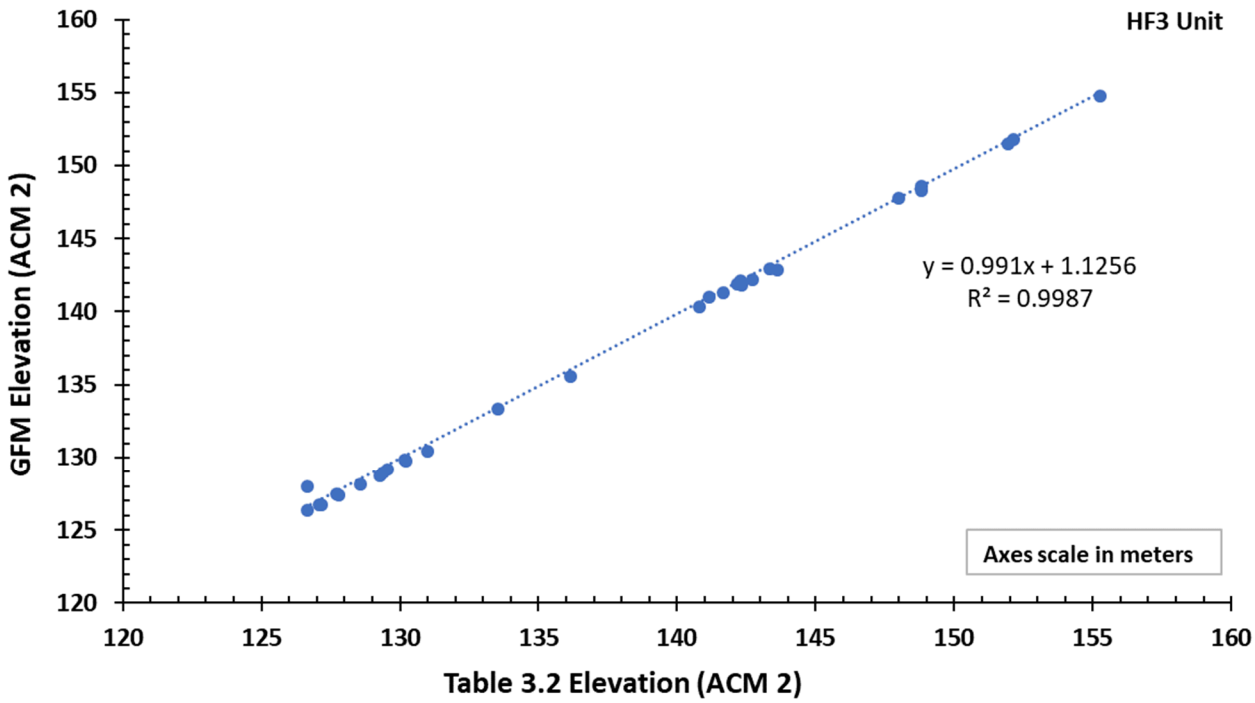
ACM = alternative conceptual model GFM = geologic framework model HF1 = Hanford formation Unit 1

Figure H-37. Comparison of HF2 Unit Elevation (Table 3.2 vs GFM).



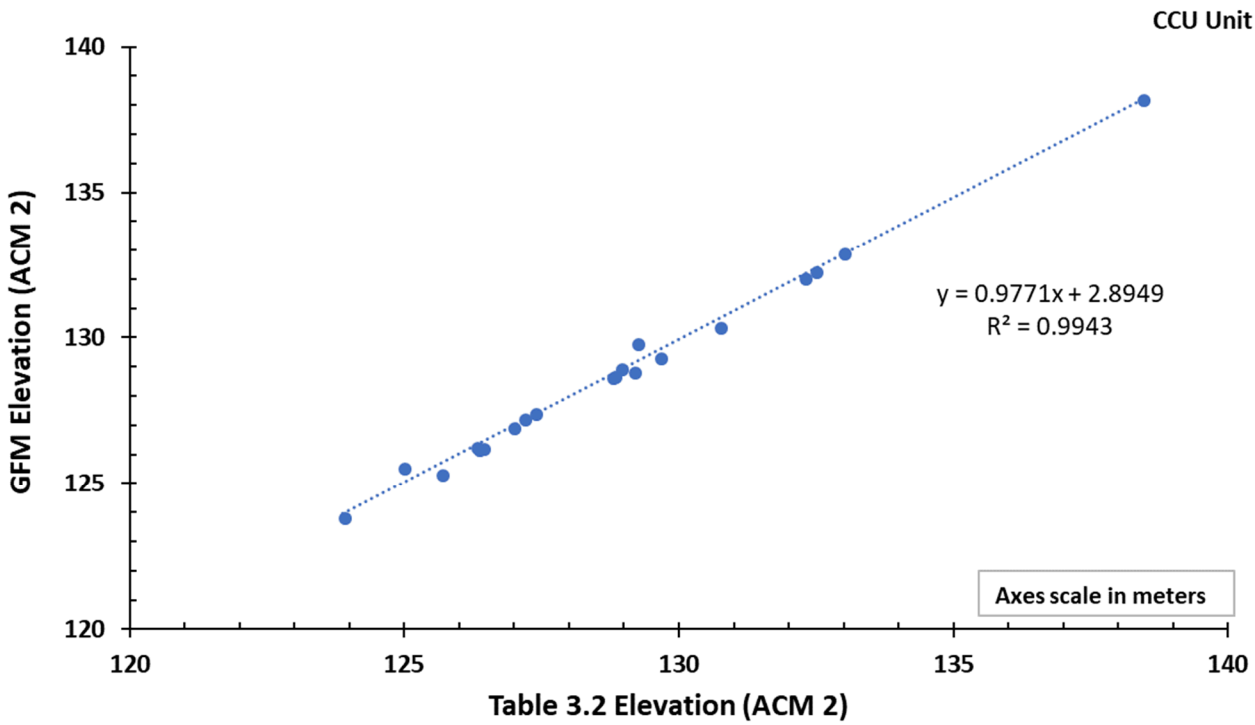
ACM = alternative conceptual model GFM = geologic framework model HF2 = Hanford formation Unit 2

Figure H-38. Comparison of HF3 Unit Elevation (Table 3.2 vs GFM).



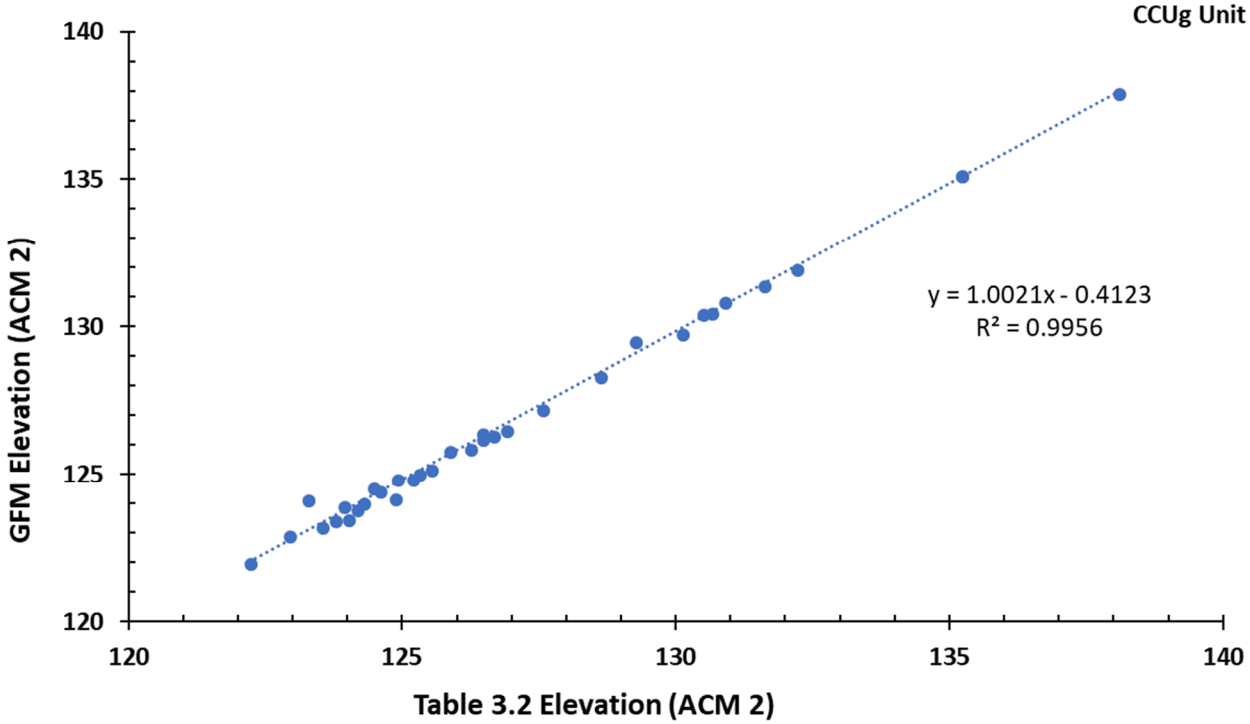
ACM = alternative conceptual model GFM = geologic framework model HF3 = Hanford formation Unit 3

Figure H-39. Comparison of CCU Unit Elevation (Table 3.2 vs GFM).



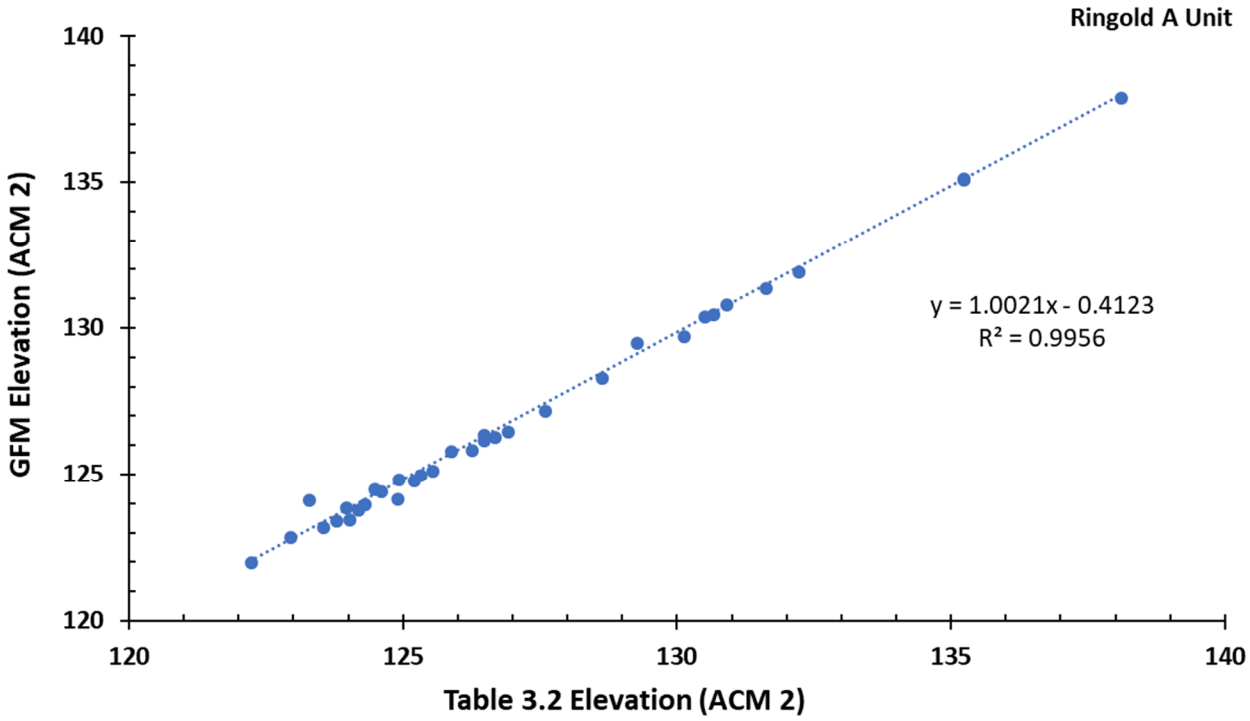
ACM = alternative conceptual model CCU = Cold Creek Unit GFM = geologic framework model

Figure H-40. Comparison of CCUg Unit Elevation (Table 3.2 vs GFM).



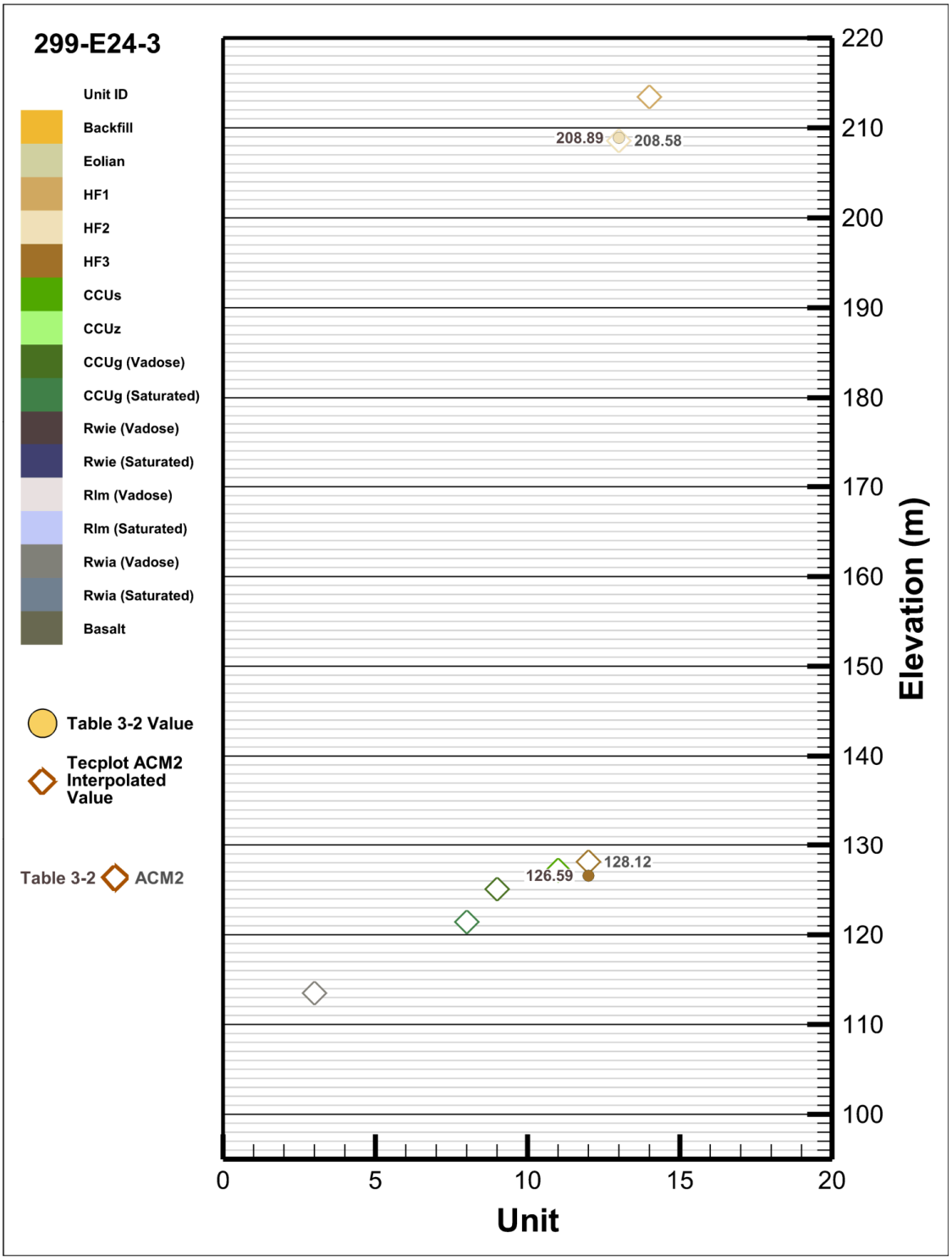
ACM = alternative conceptual model CCUg = Cold Creek Unit gravels GFM = geologic framework model

Figure H-41. Comparison of Ringold A Unit Elevation (Table 3.2 vs GFM).



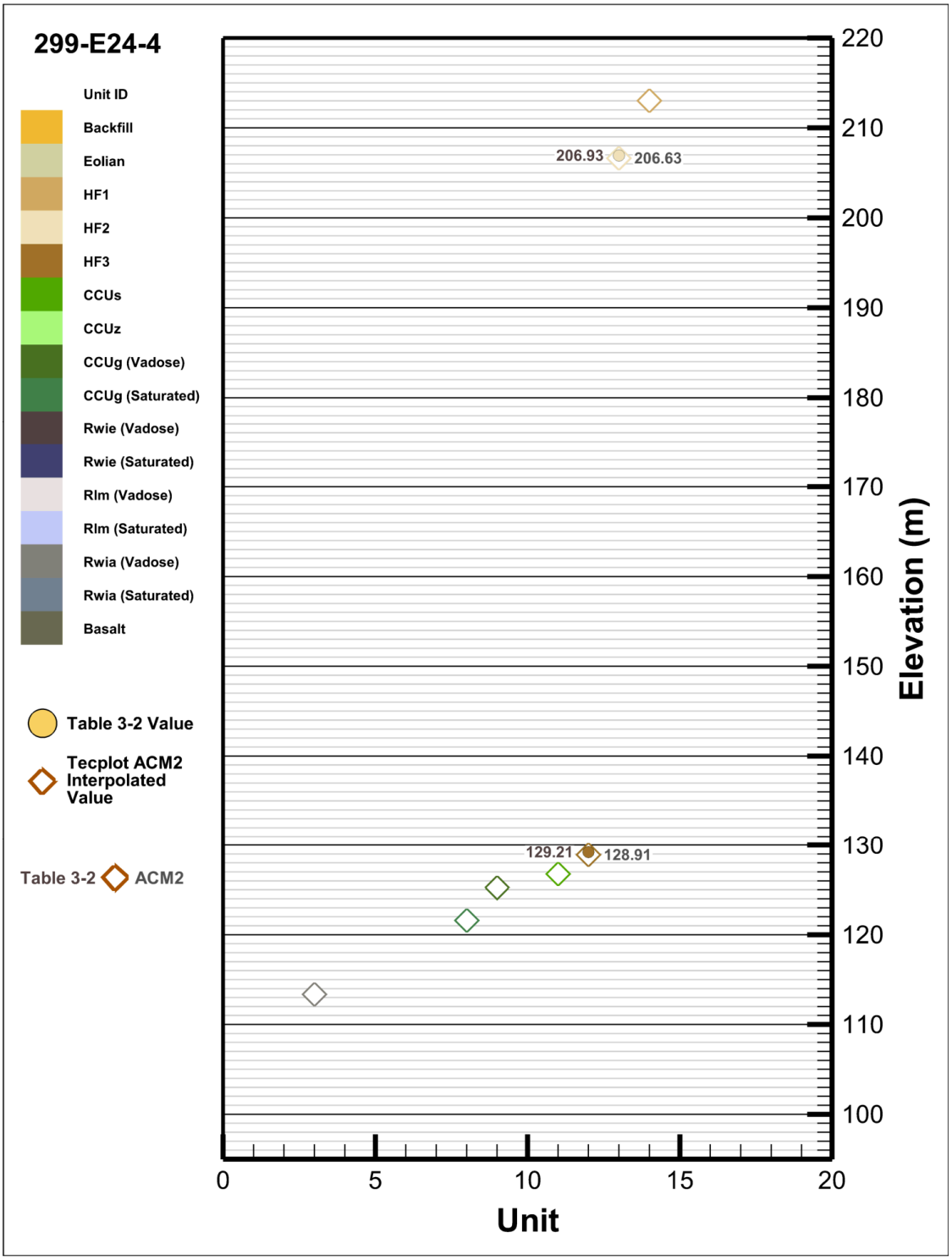
ACM = alternative conceptual model GFM = geologic framework model

Figure H-42. Well 299-E24-3 - Units Elevation Comparison (Table 3.2 vs GFM).



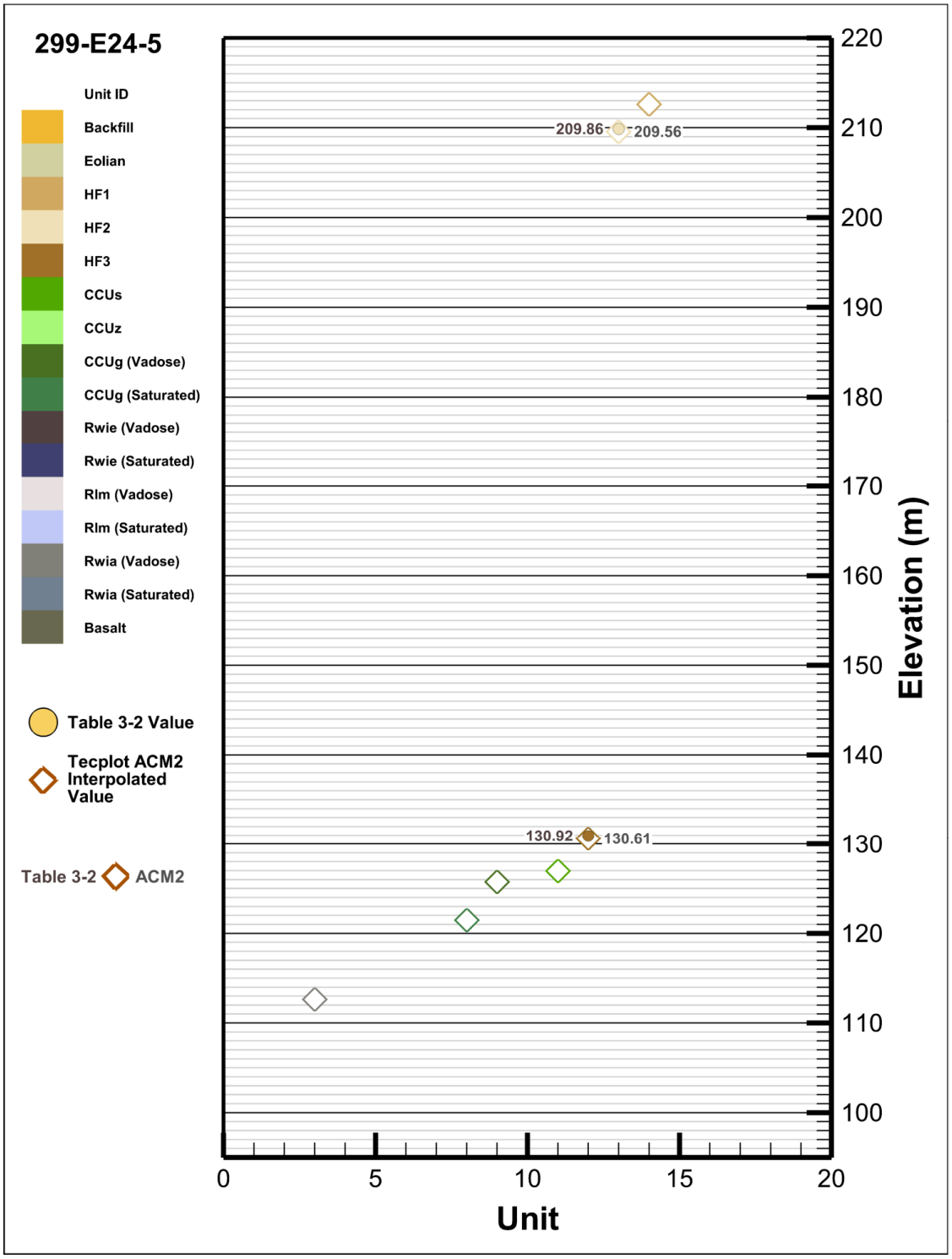
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-43. Well 299-E24-4 - Units Elevation Comparison (Table 3.2 vs GFM).



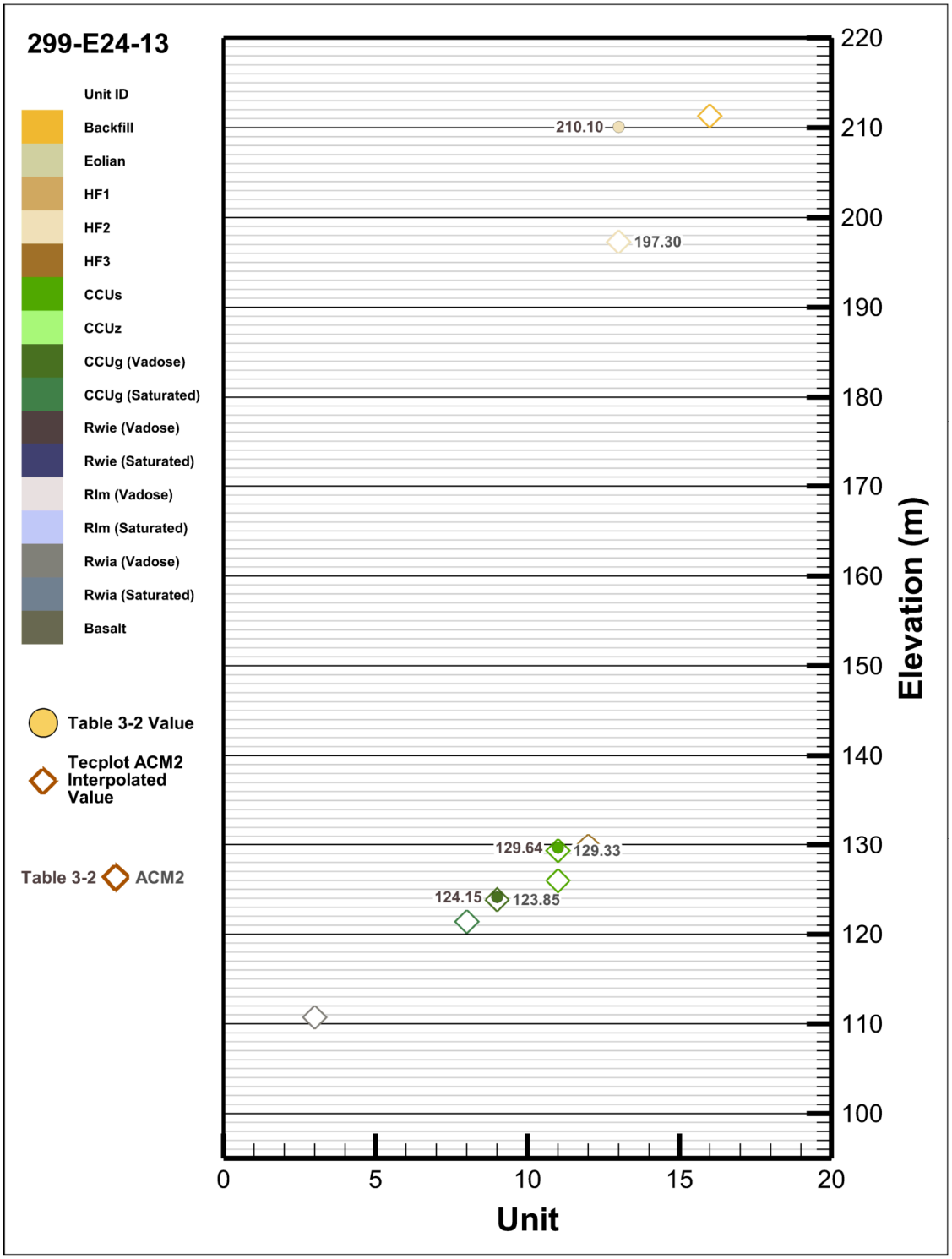
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-44. Well 299-E24-5 - Units Elevation Comparison (Table 3.2 vs GFM).



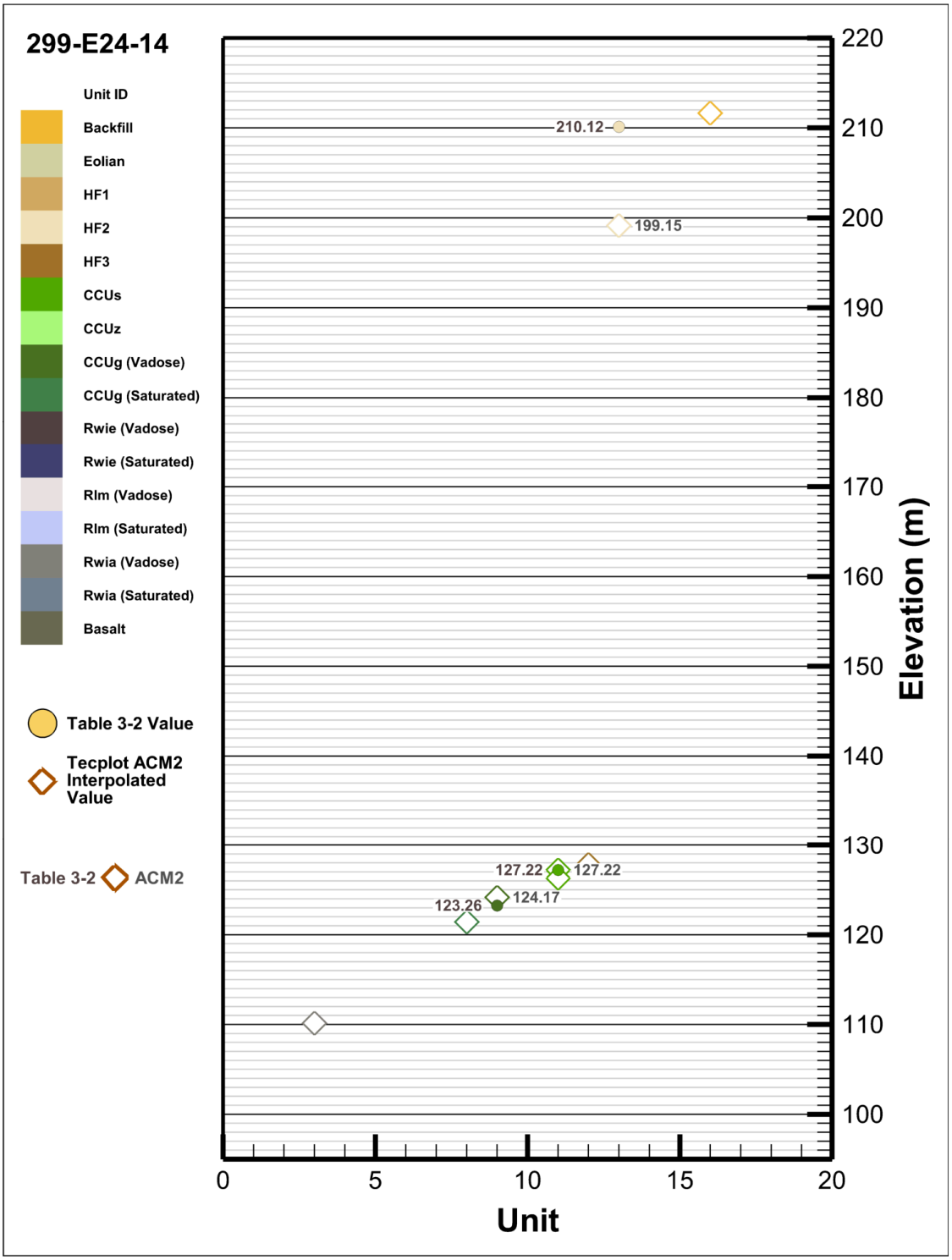
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-45. Well 299-E24-13 - Units Elevation Comparison (Table 3.2 vs GFM).



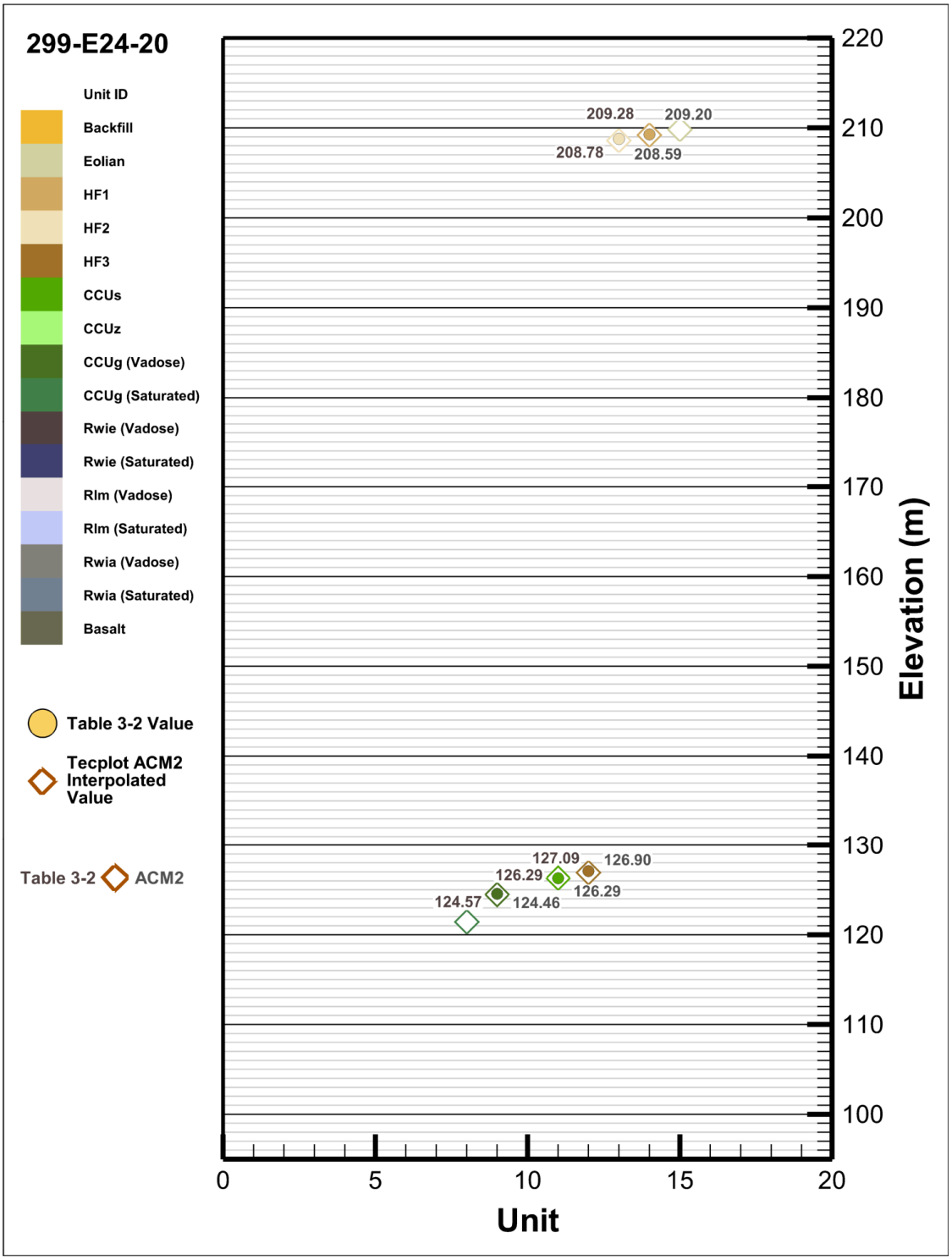
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-46. Well 299-E24-14 - Units Elevation Comparison (Table 3.2 vs GFM).



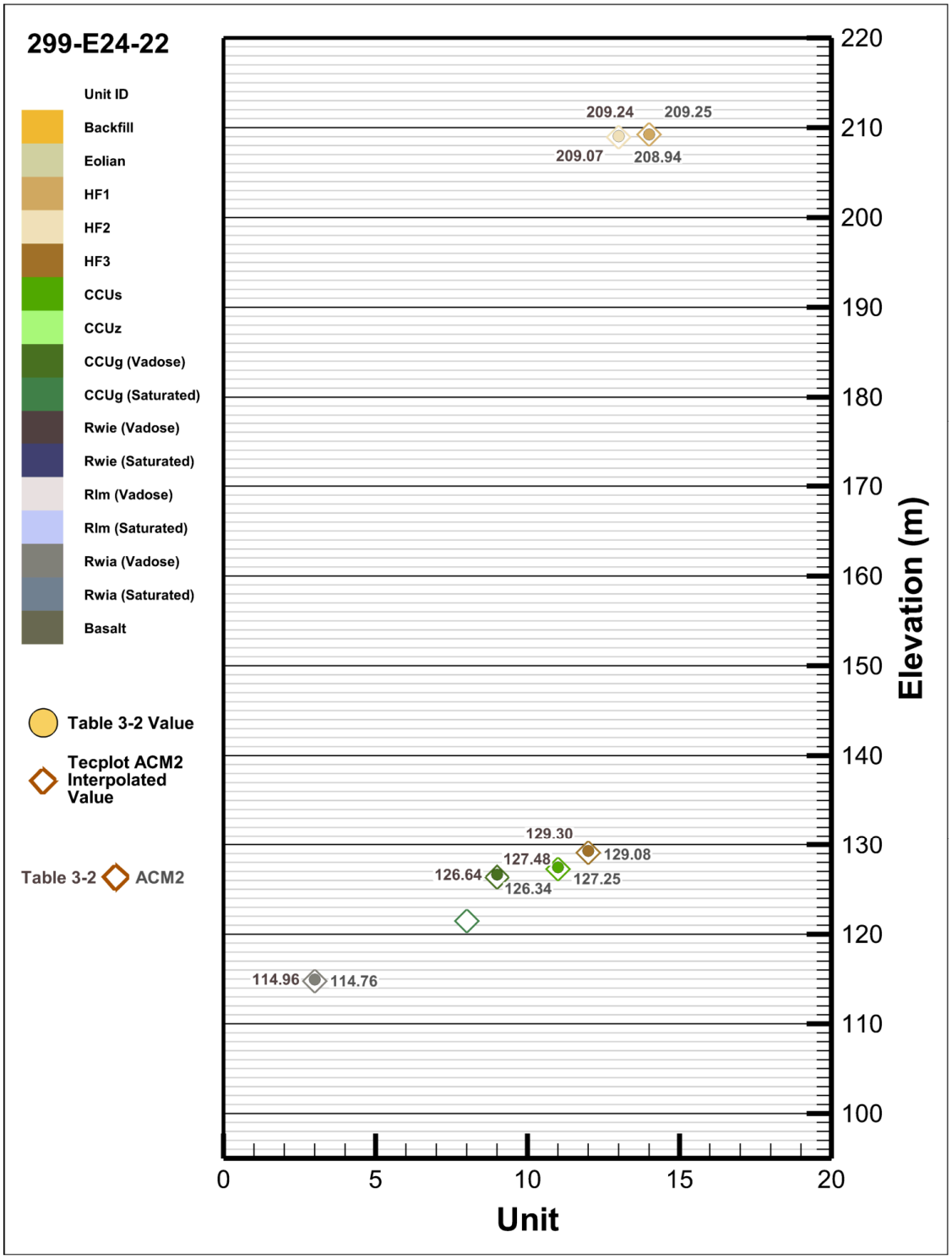
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-47. Well 299-E24-20 - Units Elevation Comparison (Table 3.2 vs GFM).



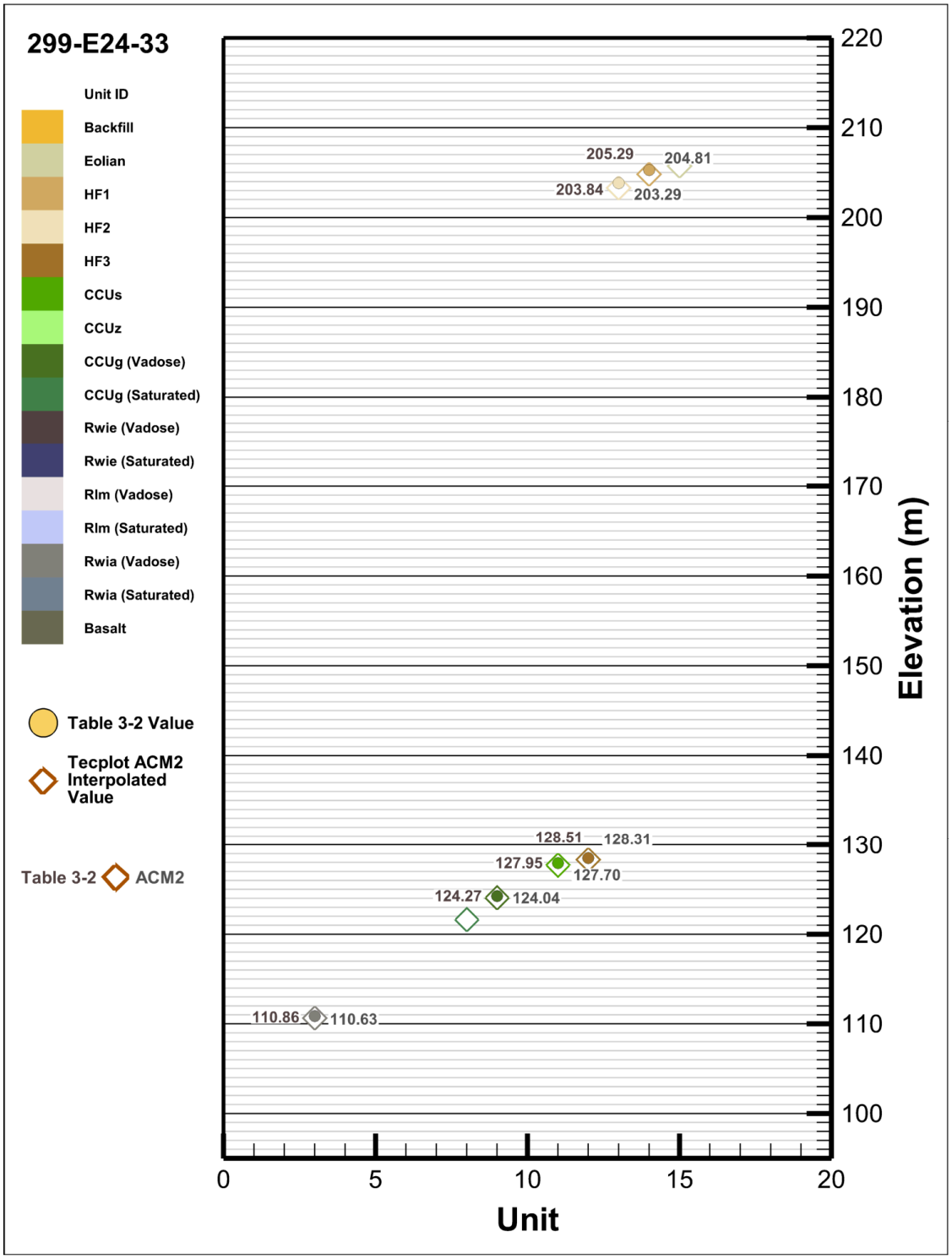
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-48. Well 299-E24-22 - Units Elevation Comparison (Table 3.2 vs GFM).



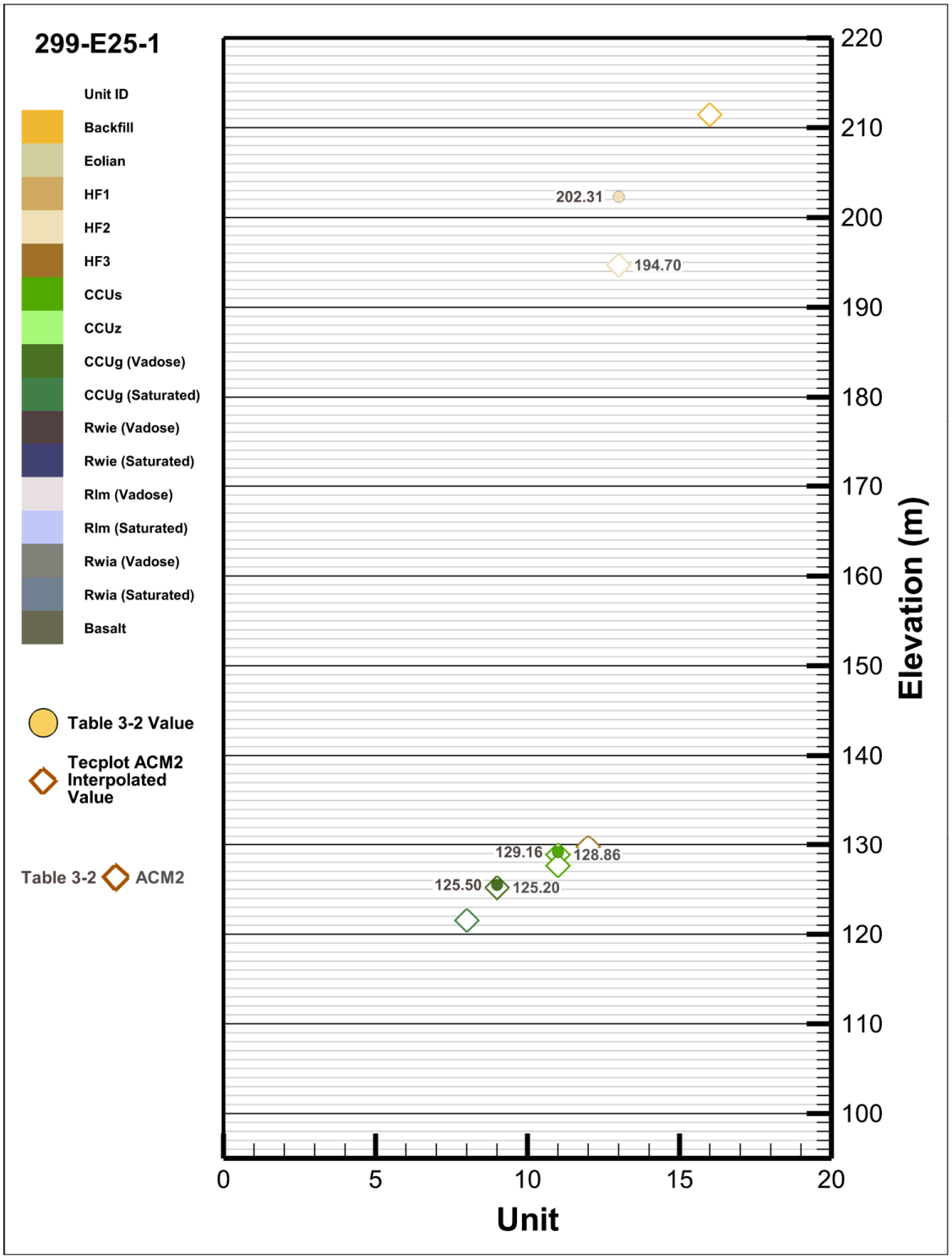
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-49. Well 299-E24-33 - Units Elevation Comparison (Table 3.2 vs GFM).



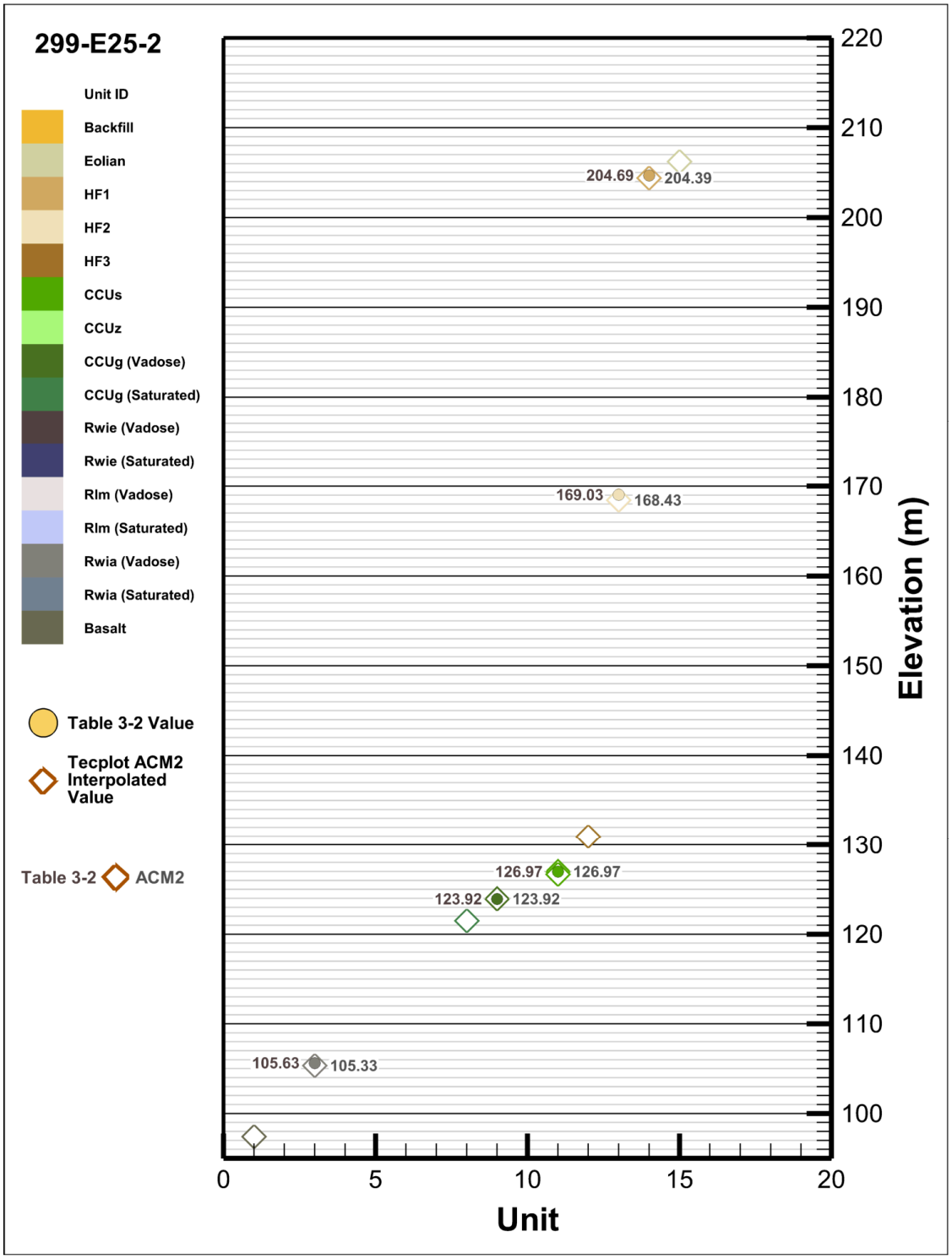
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-50. Well 299-E25-1 - Units Elevation Comparison (Table 3.2 vs GFM).



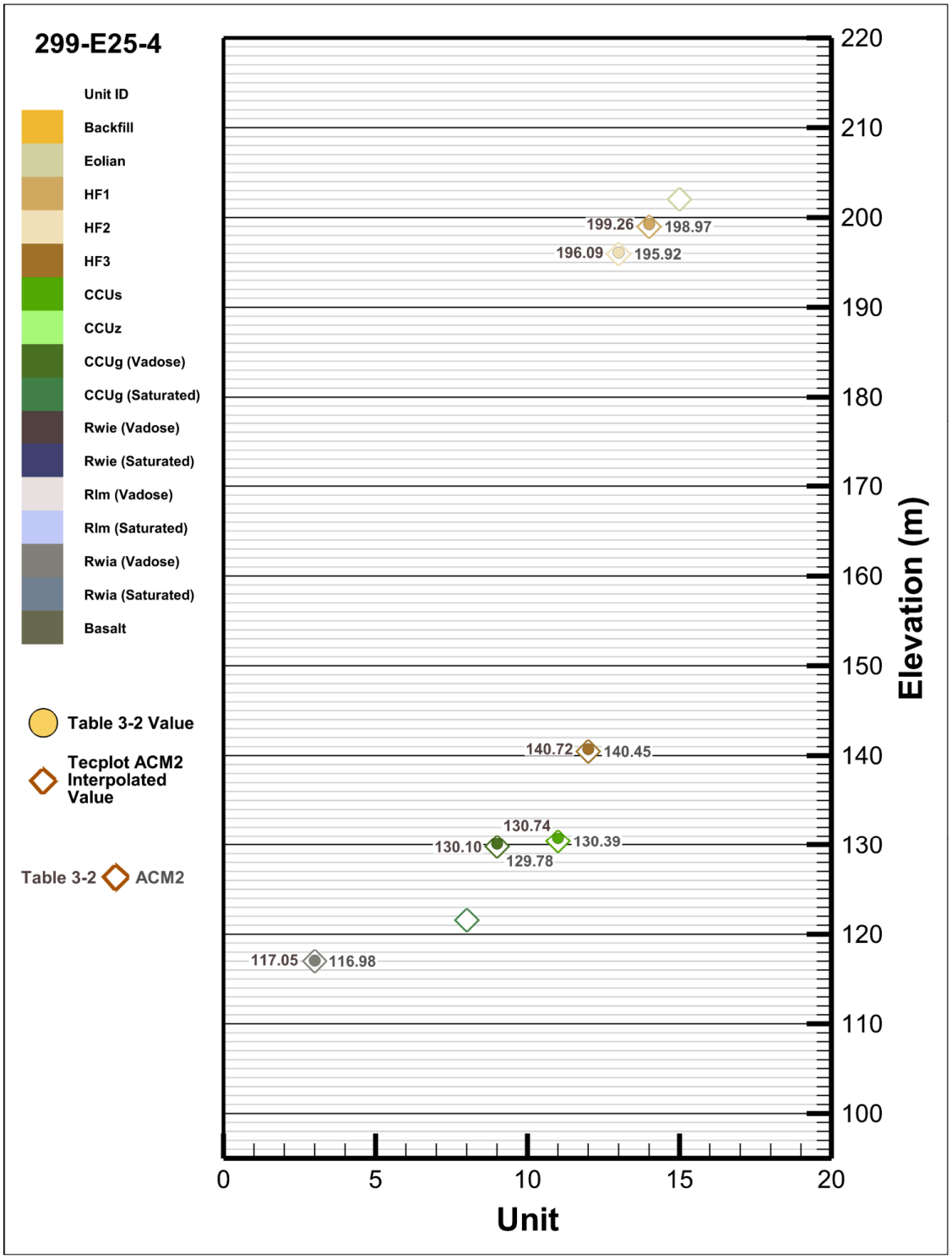
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-51. Well 299-E25-2 - Units Elevation Comparison (Table 3.2 vs GFM).



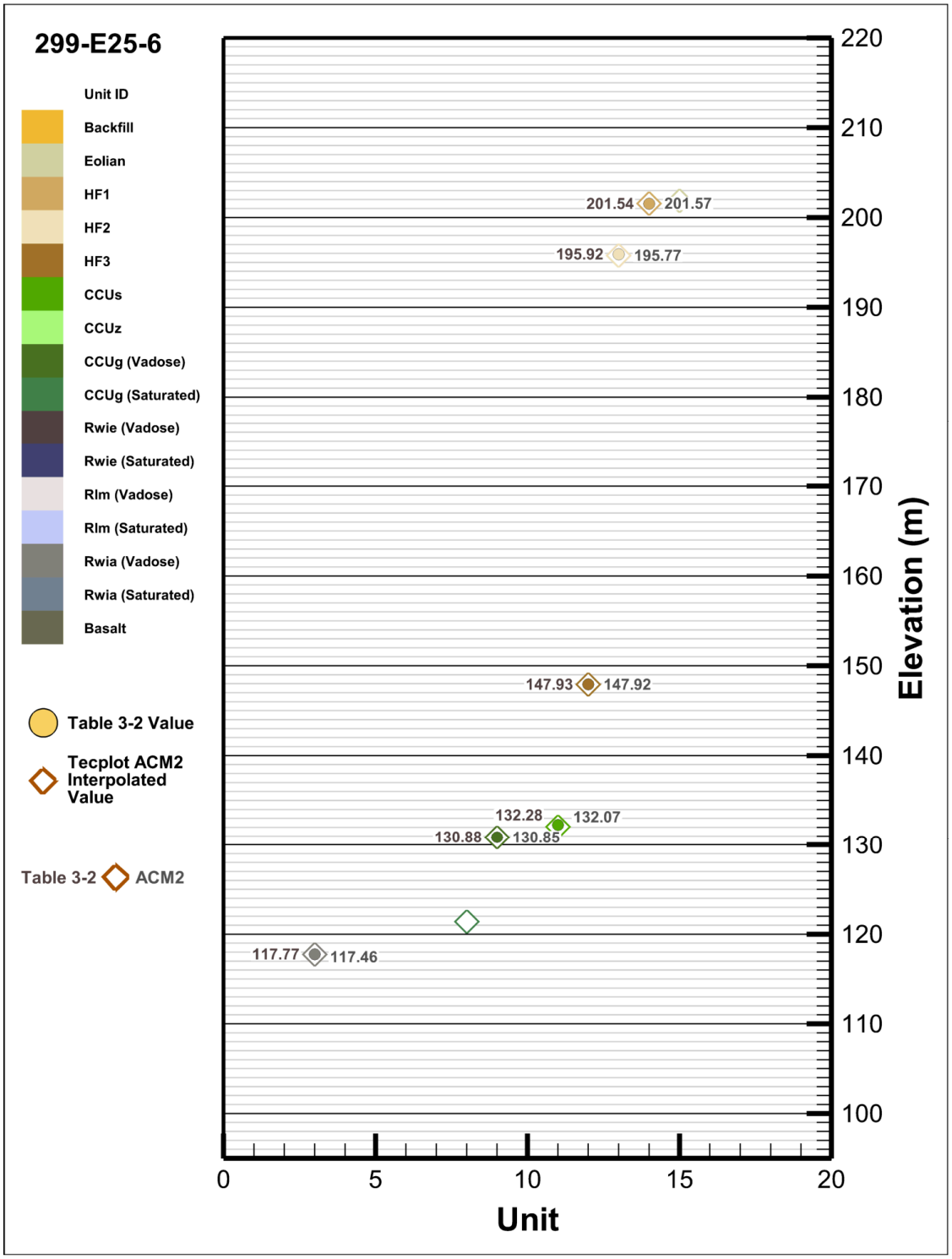
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-52. Well 299-E25-4 - Units Elevation Comparison (Table 3.2 vs GFM).



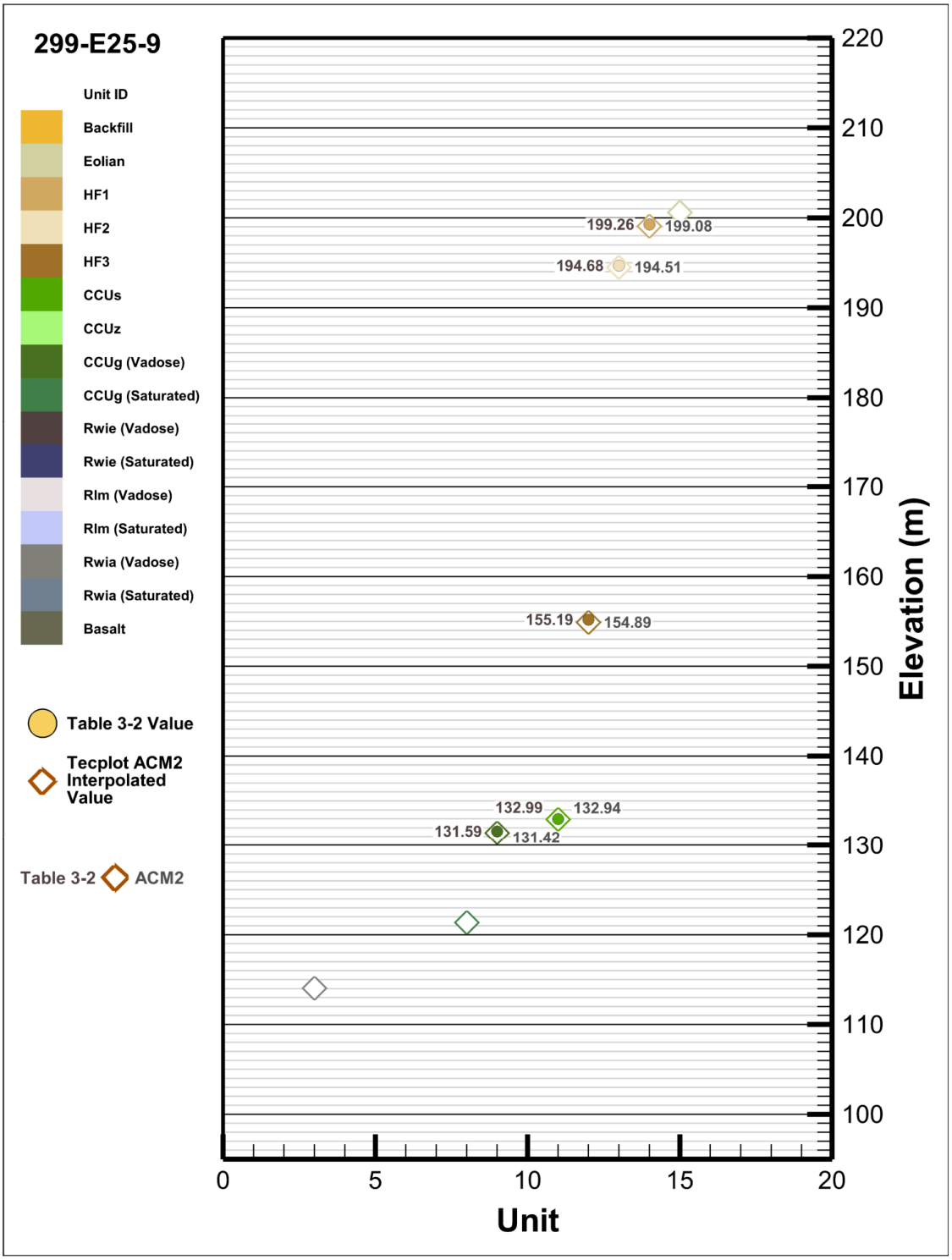
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-53. Well 299-E25-6 - Units Elevation Comparison (Table 3.2 vs GFM).



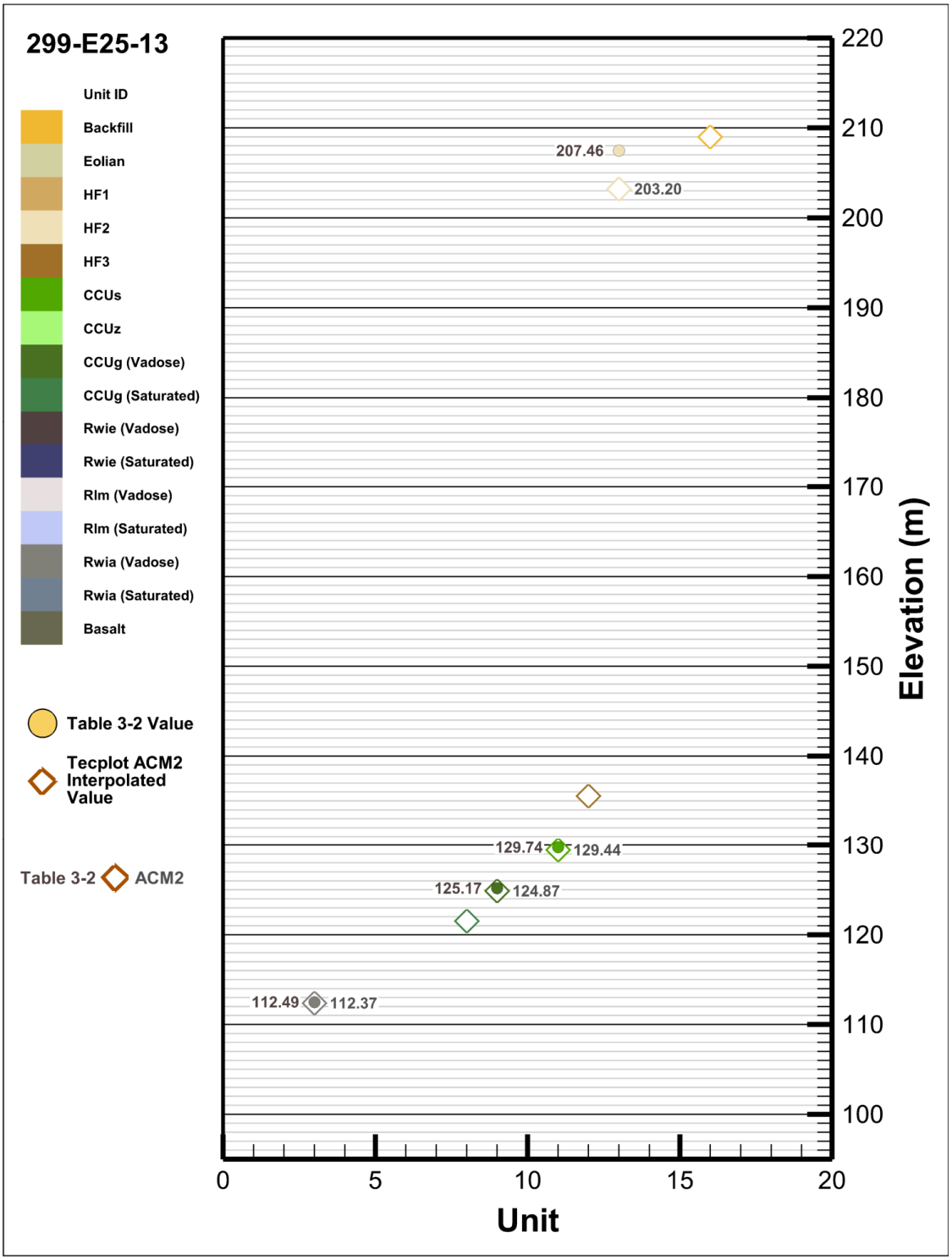
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-54. Well 299-E25-9 - Units Elevation Comparison (Table 3.2 vs GFM).



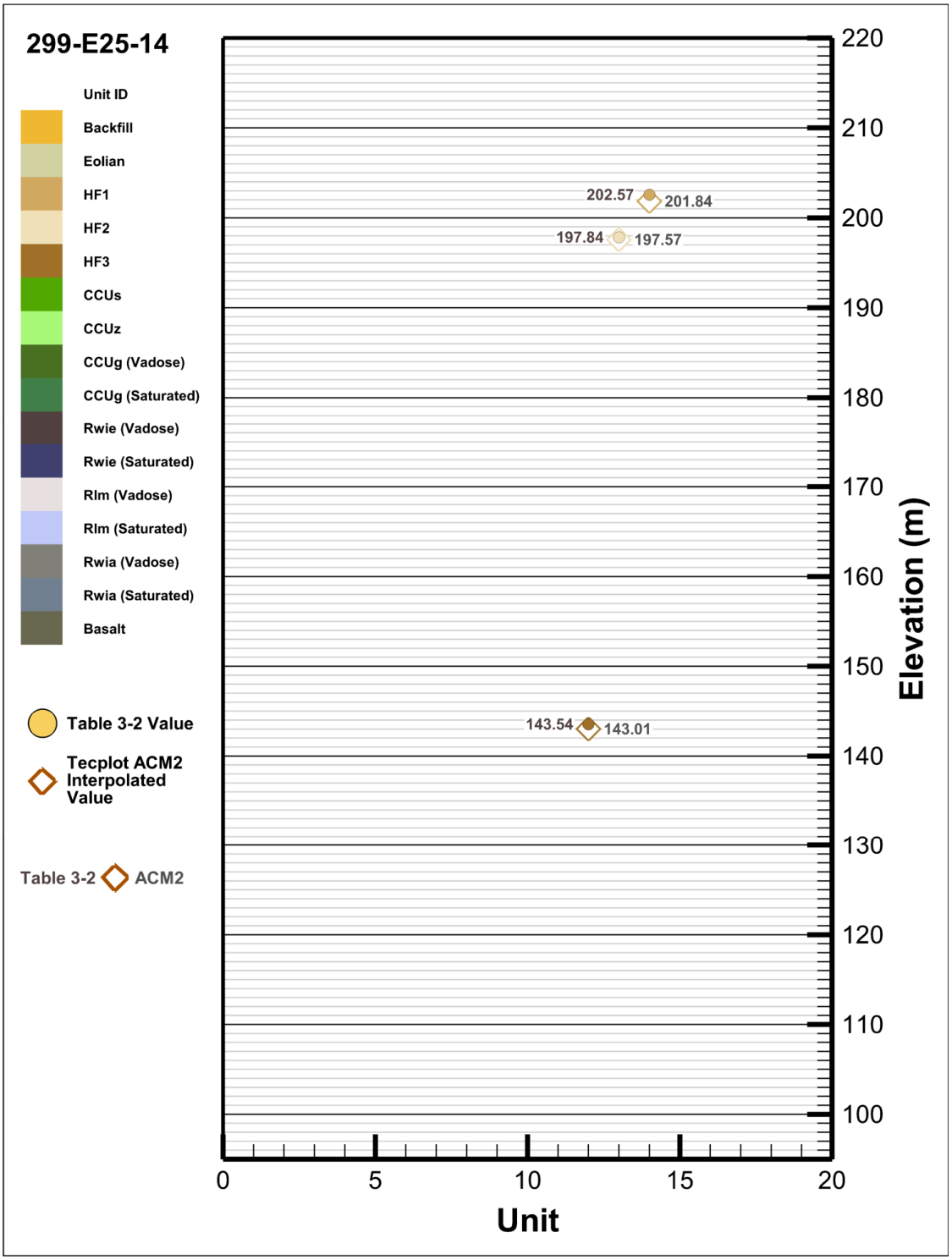
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-55. Well 299-E25-13 - Units Elevation Comparison (Table 3.2 vs GFM).



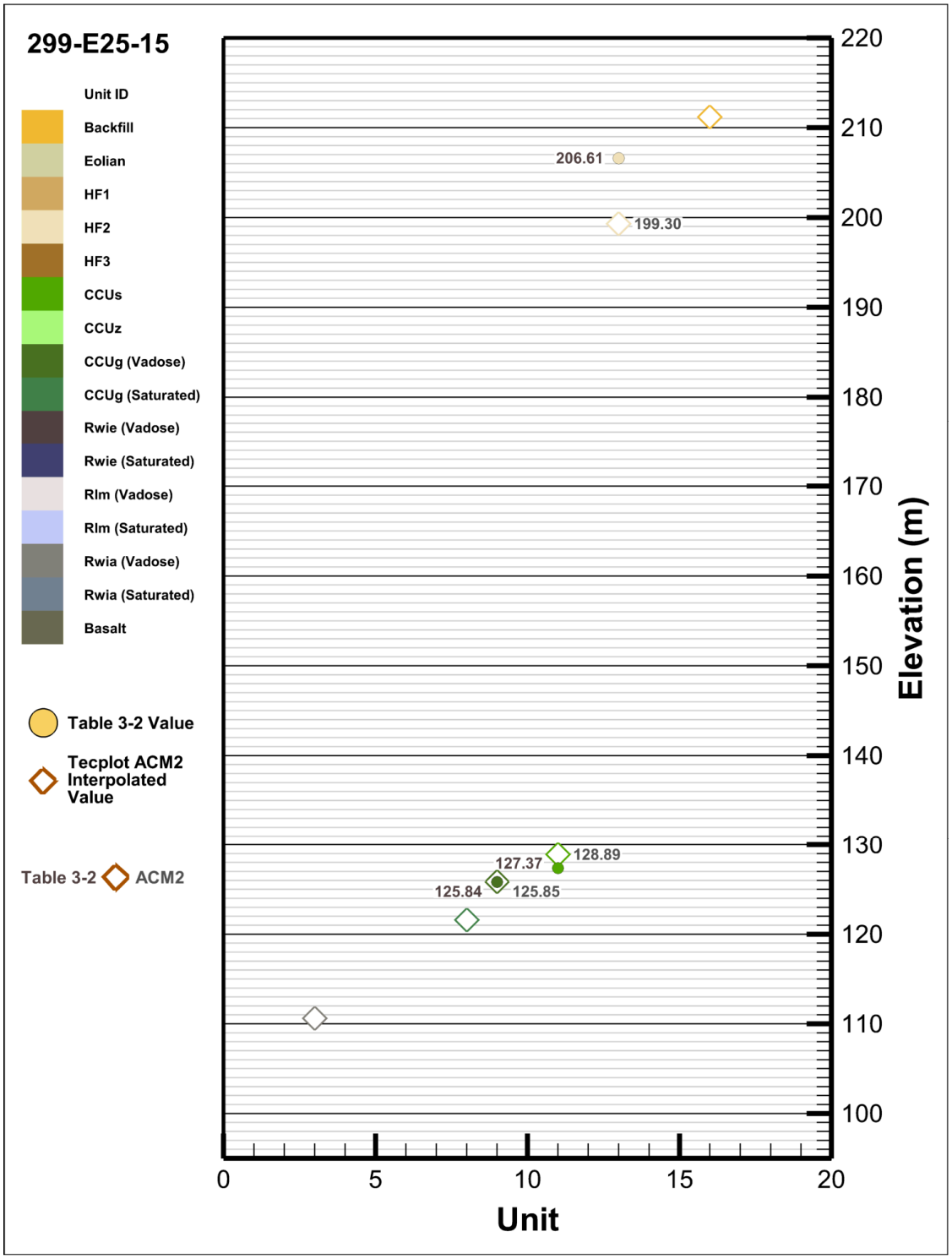
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-56. Well 299-E25-14 - Units Elevation Comparison (Table 3.2 vs GFM).



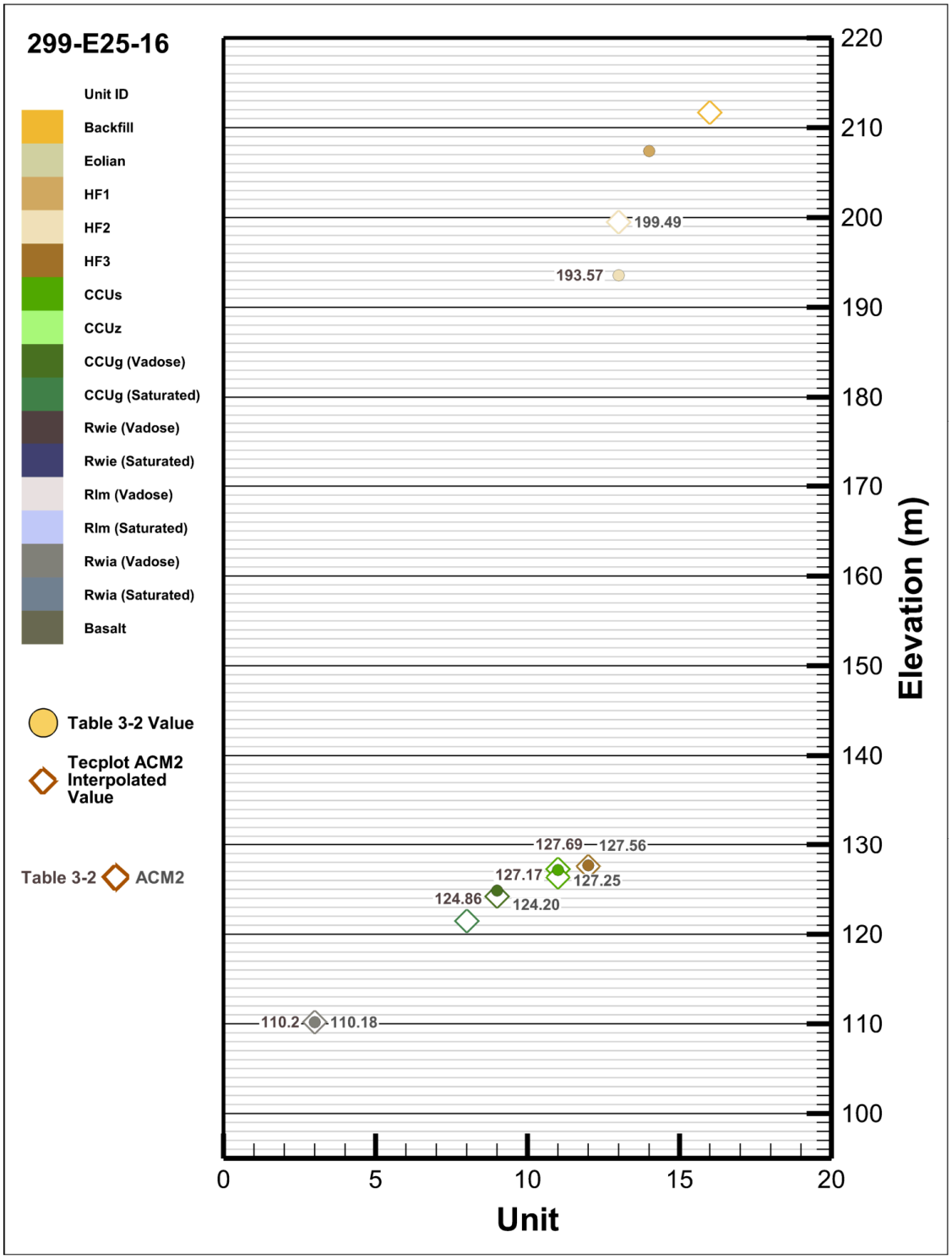
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-57. Well 299-E25-15 - Units Elevation Comparison (Table 3.2 vs GFM).



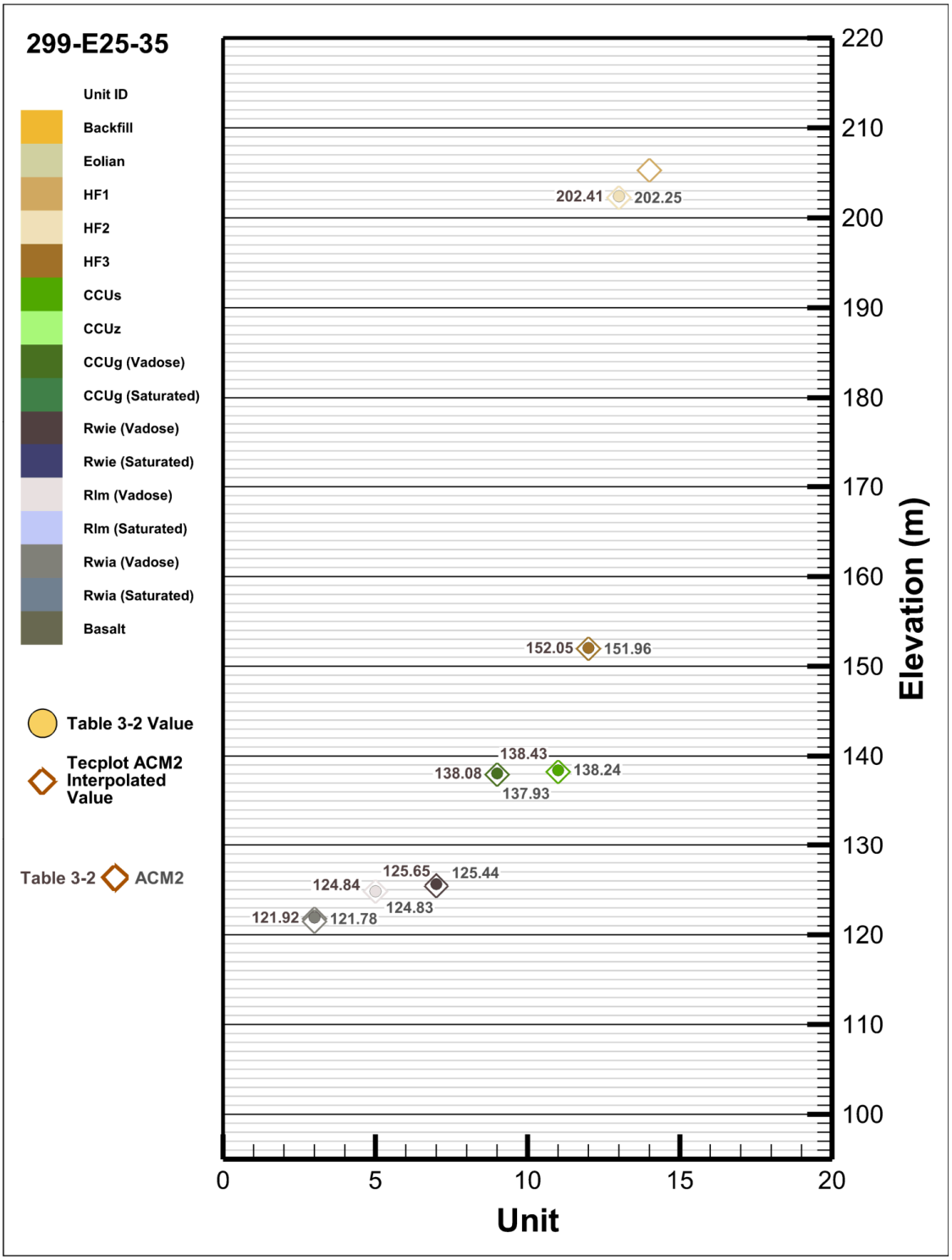
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-58. Well 299-E25-16 - Units Elevation Comparison (Table 3.2 vs GFM).



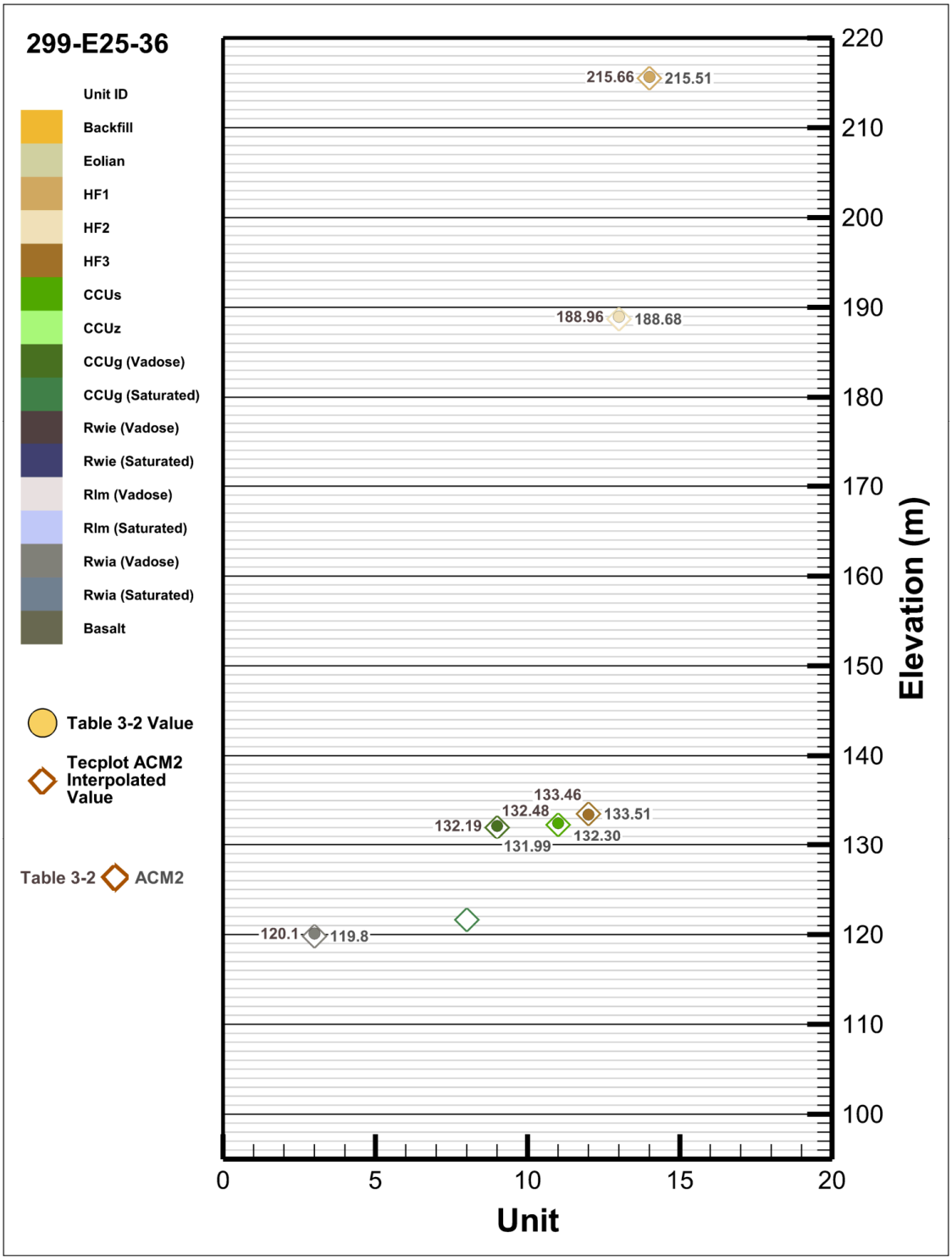
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-59. Well 299-E25-35 - Units Elevation Comparison (Table 3.2 vs GFM).



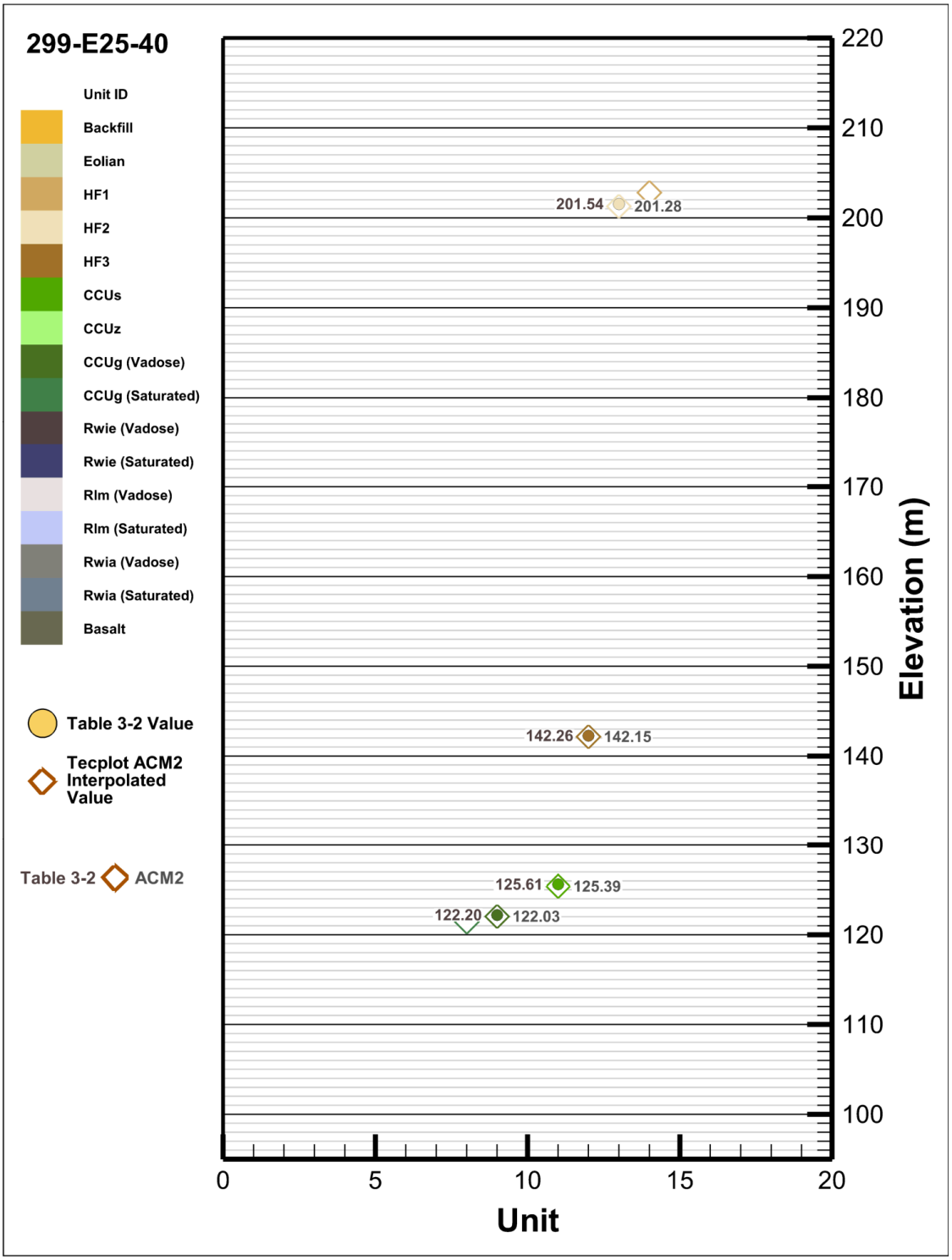
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-60. Well 299-E25-36 - Units Elevation Comparison (Table 3.2 vs GFM).



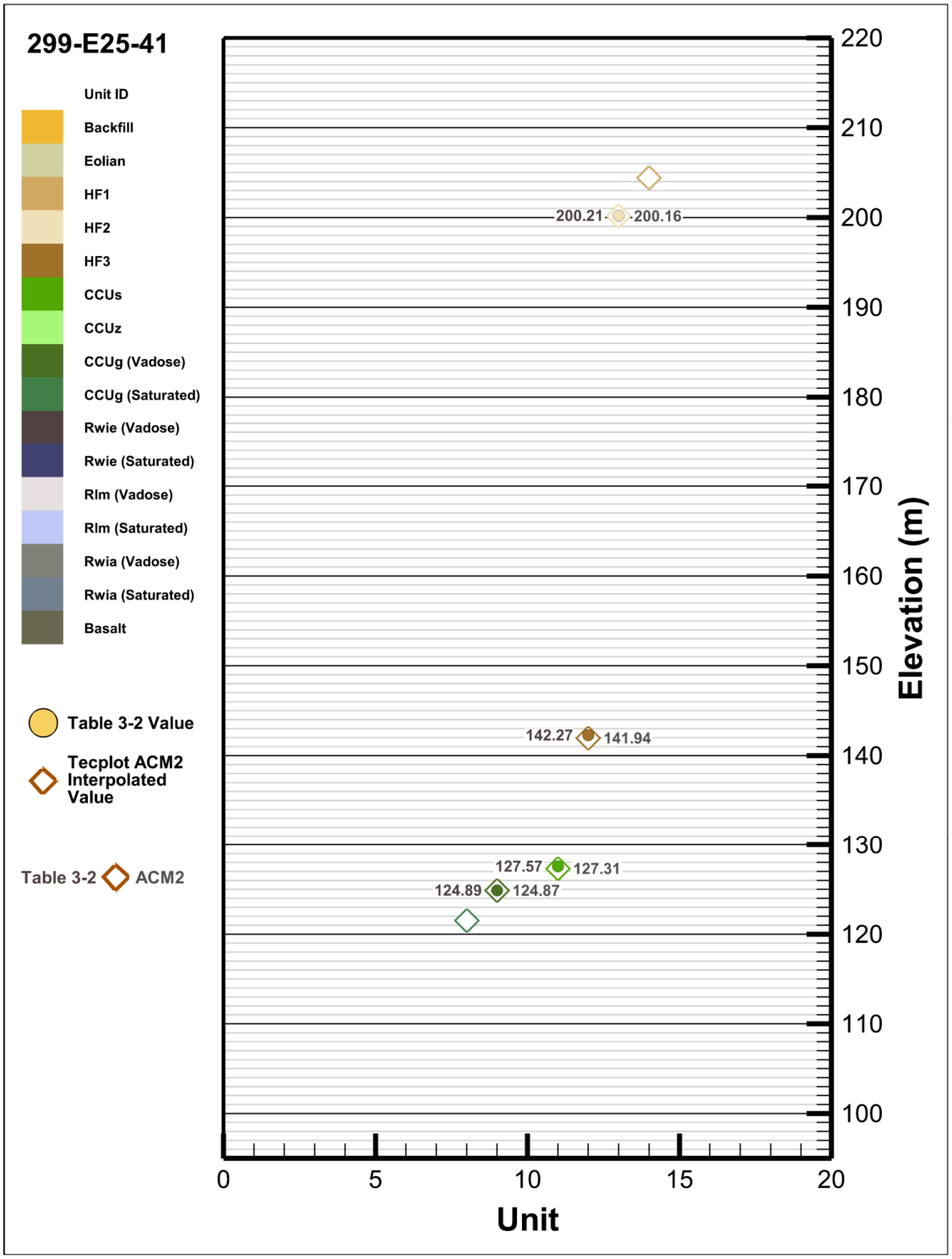
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-61. Well 299-E25-40 - Units Elevation Comparison (Table 3.2 vs GFM).



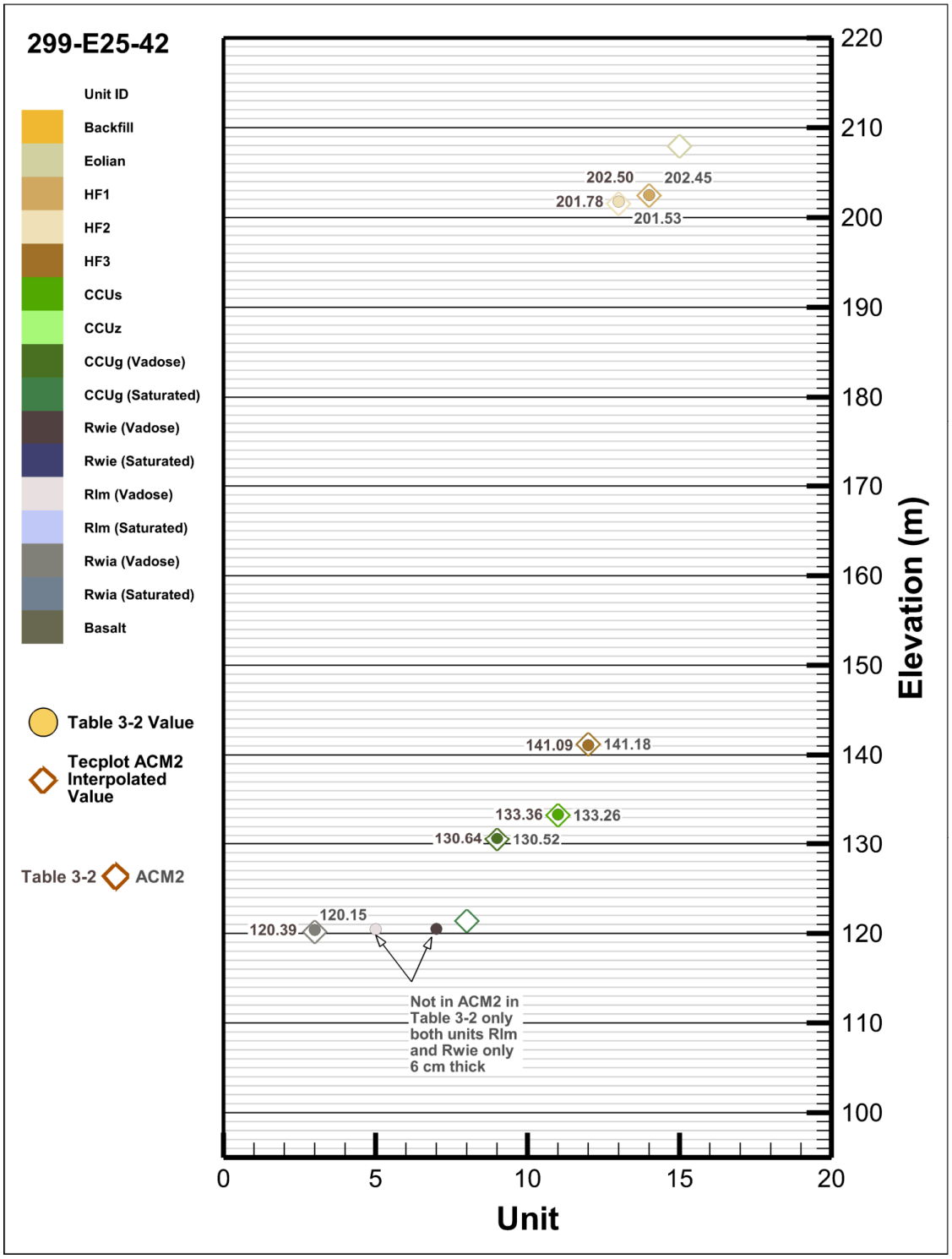
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-62. Well 299-E25-41 - Units Elevation Comparison (Table 3.2 vs GFM).



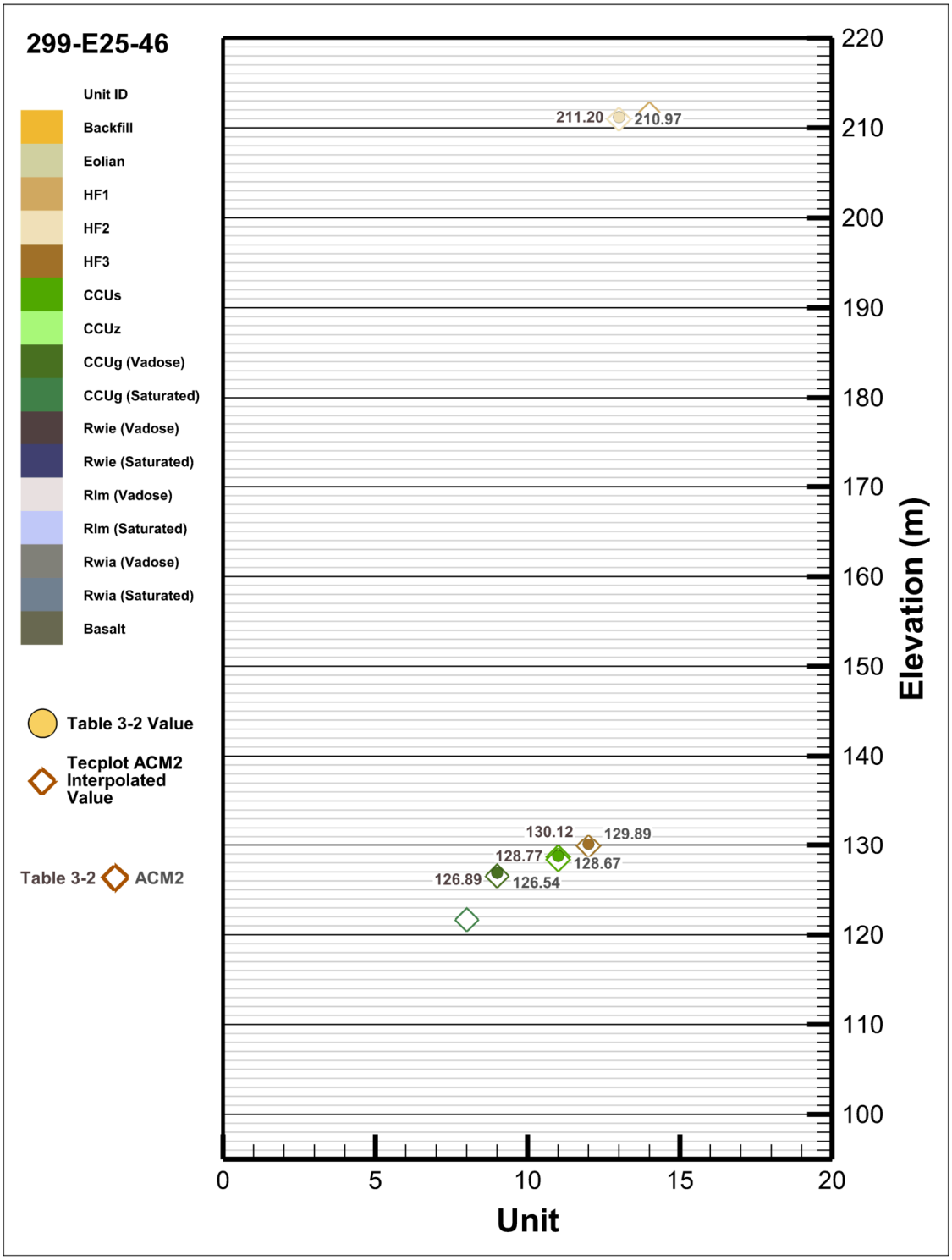
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-63. Well 299-E25-42 - Units Elevation Comparison (Table 3.2 vs GFM).



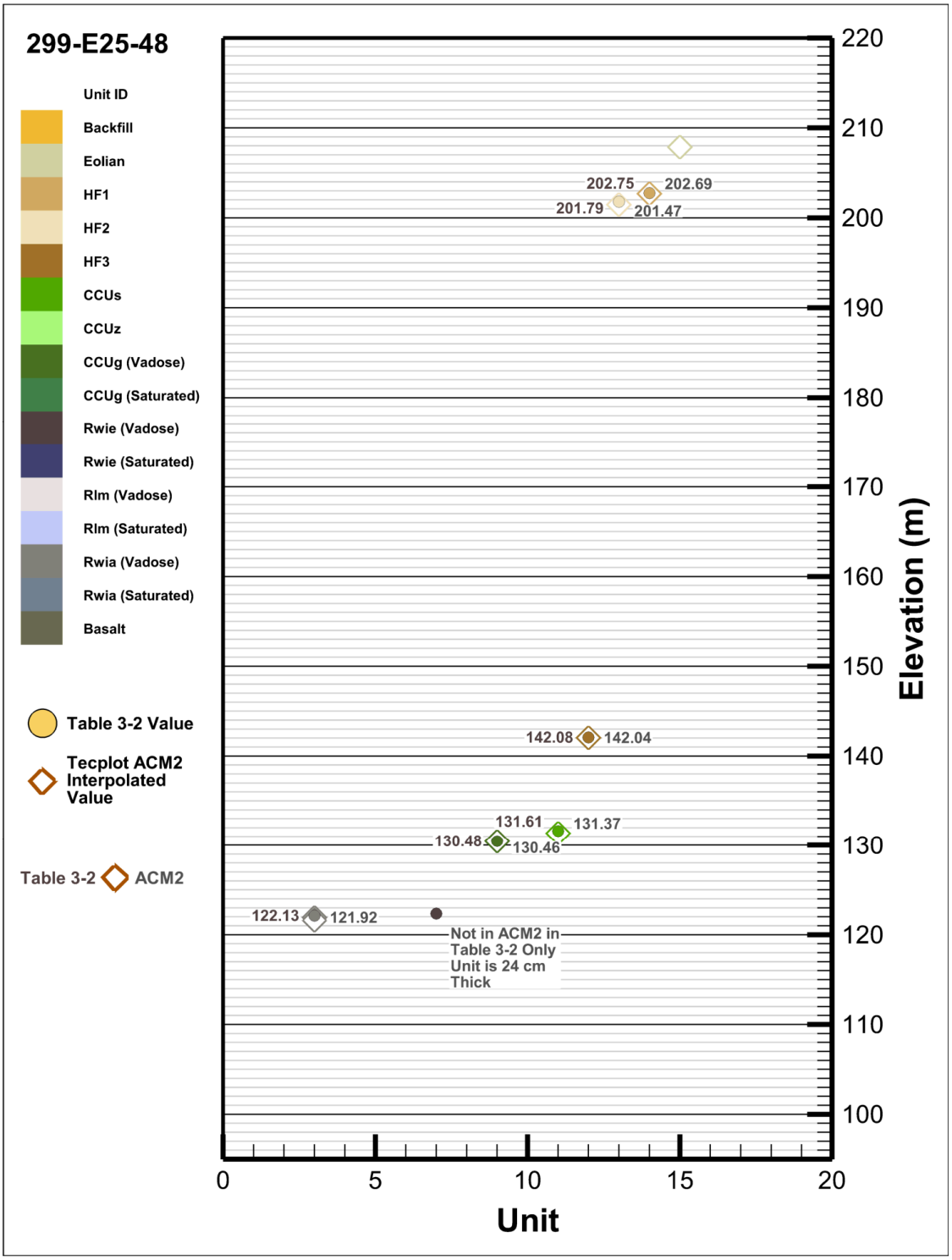
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-64. Well 299-E25-46 - Units Elevation Comparison (Table 3.2 vs GFM).



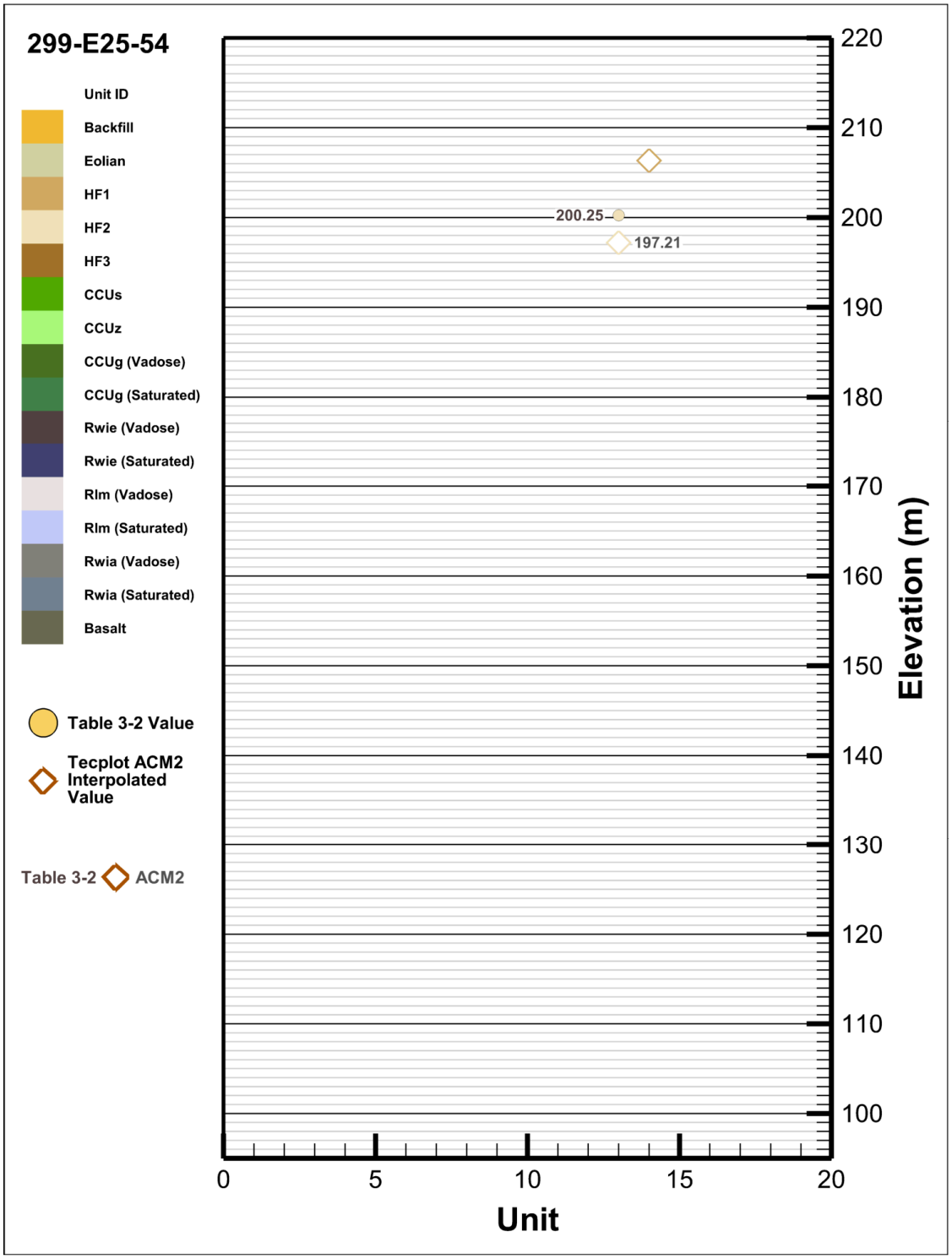
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-65. Well 299-E25-48 - Units Elevation Comparison (Table 3.2 vs GFM).



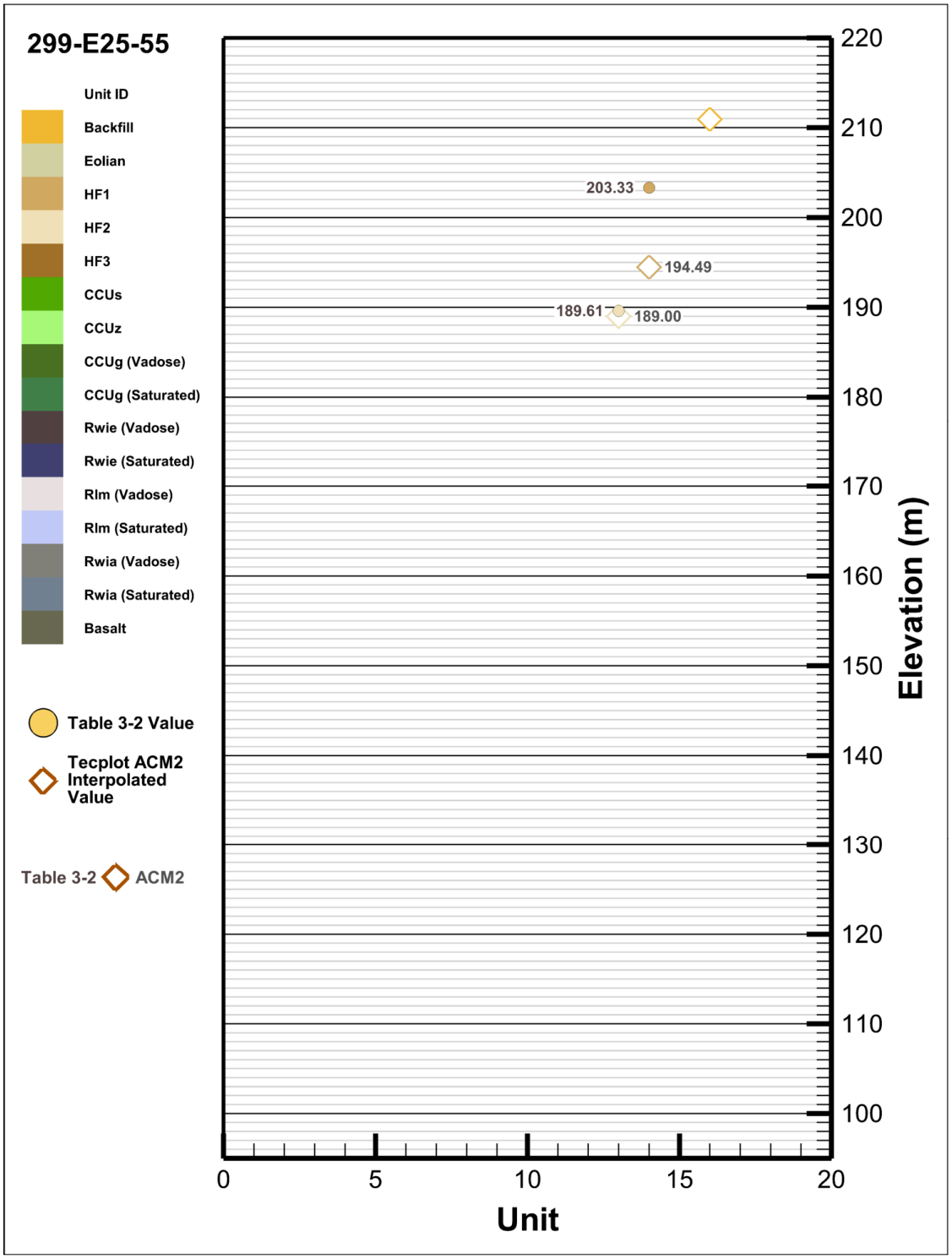
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-66. Well 299-E25-54 - Units Elevation Comparison (Table 3.2 vs GFM).



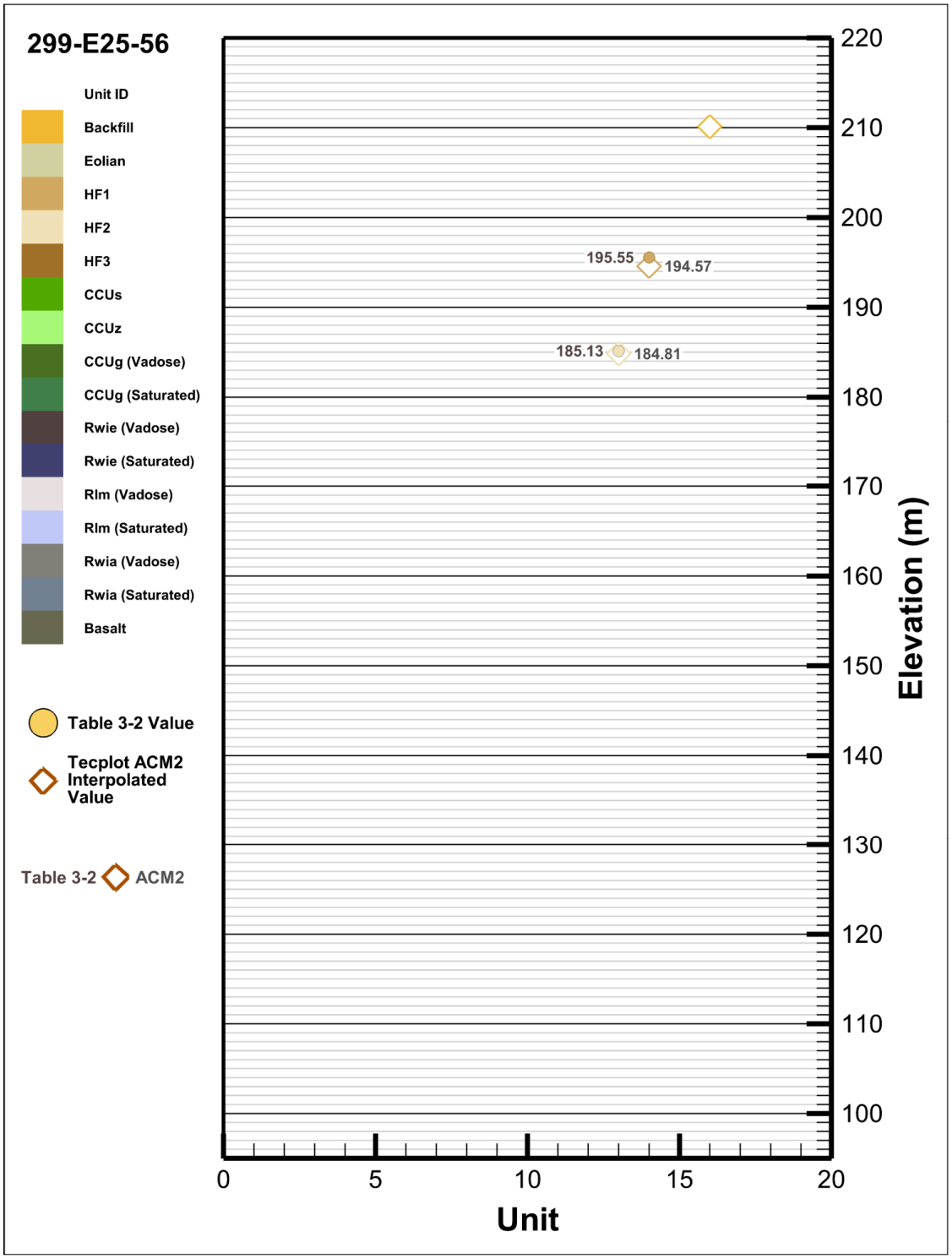
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-67. Well 299-E25-55 - Units Elevation Comparison (Table 3.2 vs GFM).



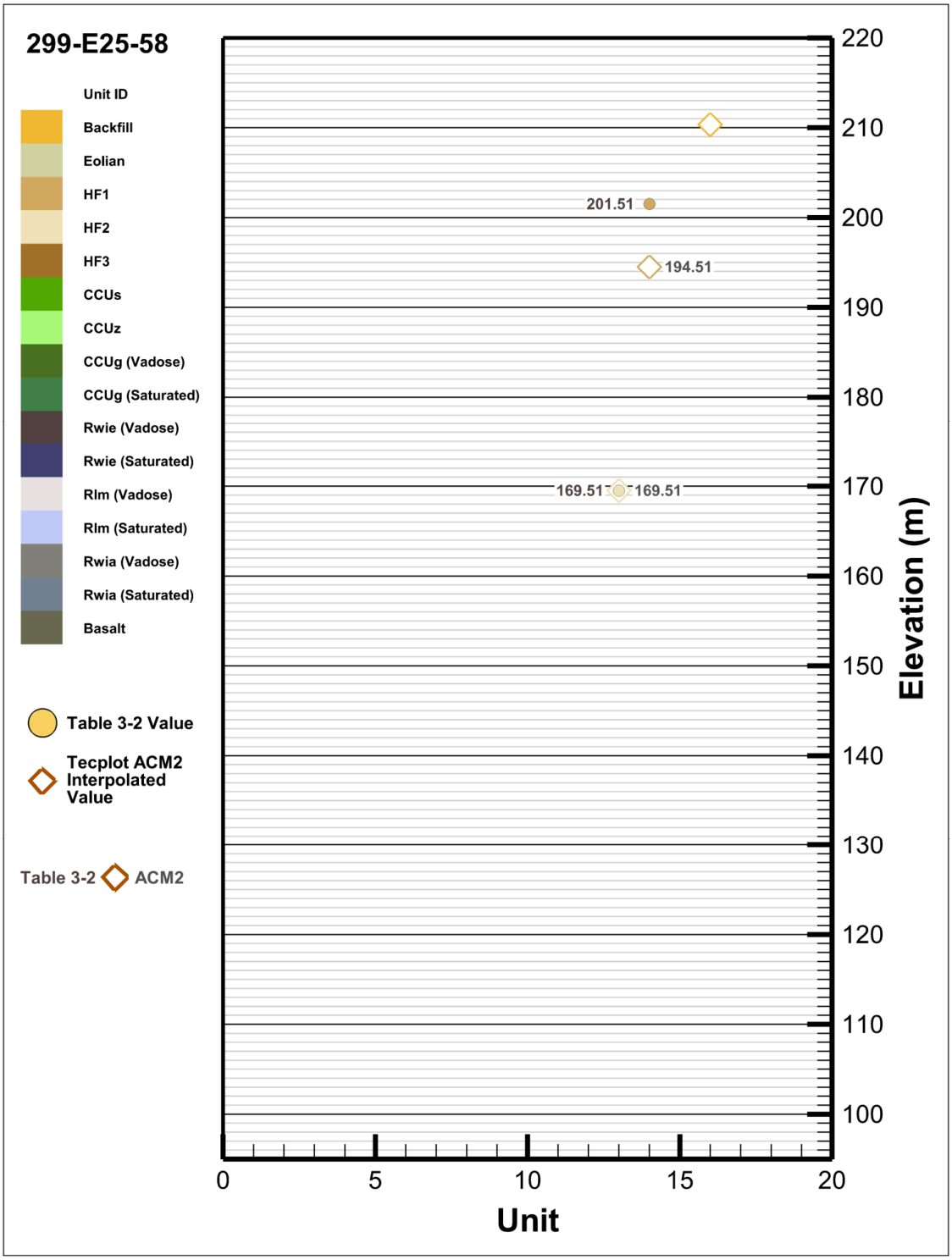
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-68. Well 299-E25-56 - Units Elevation Comparison (Table 3.2 vs GFM).



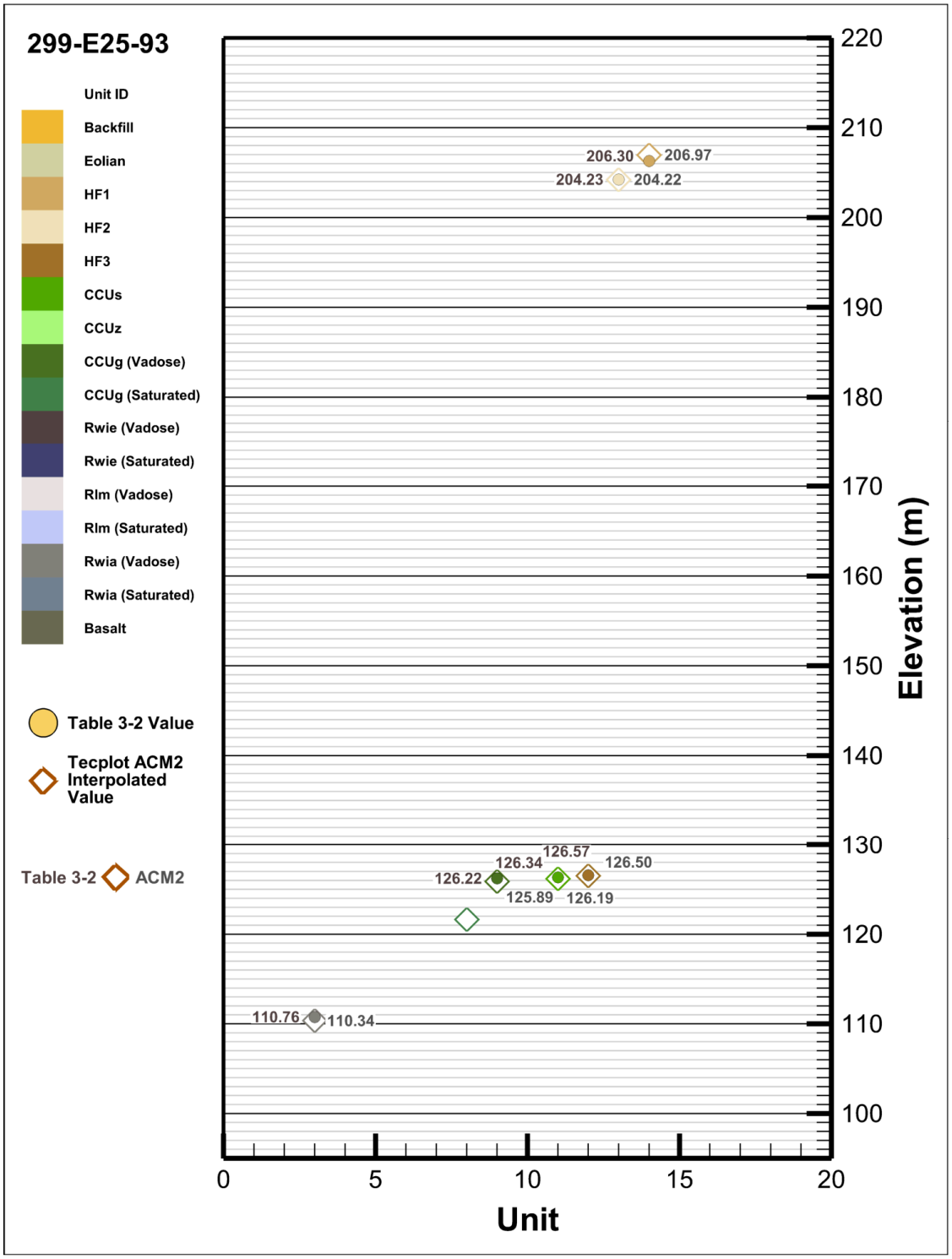
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-69. Well 299-E25-58 - Units Elevation Comparison (Table 3.2 vs GFM).



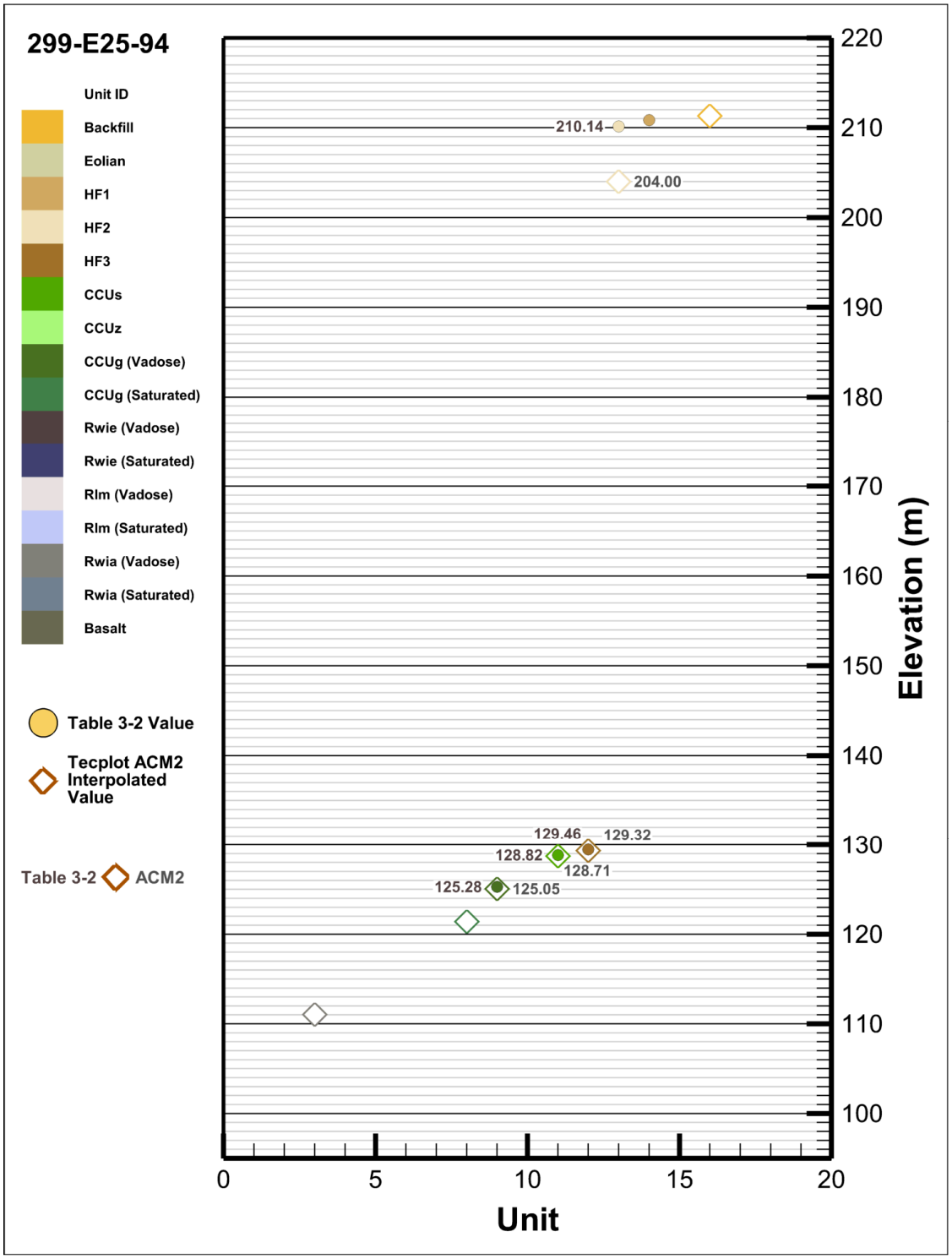
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-70. Well 299-E25-93 - Units Elevation Comparison (Table 3.2 vs GFM).



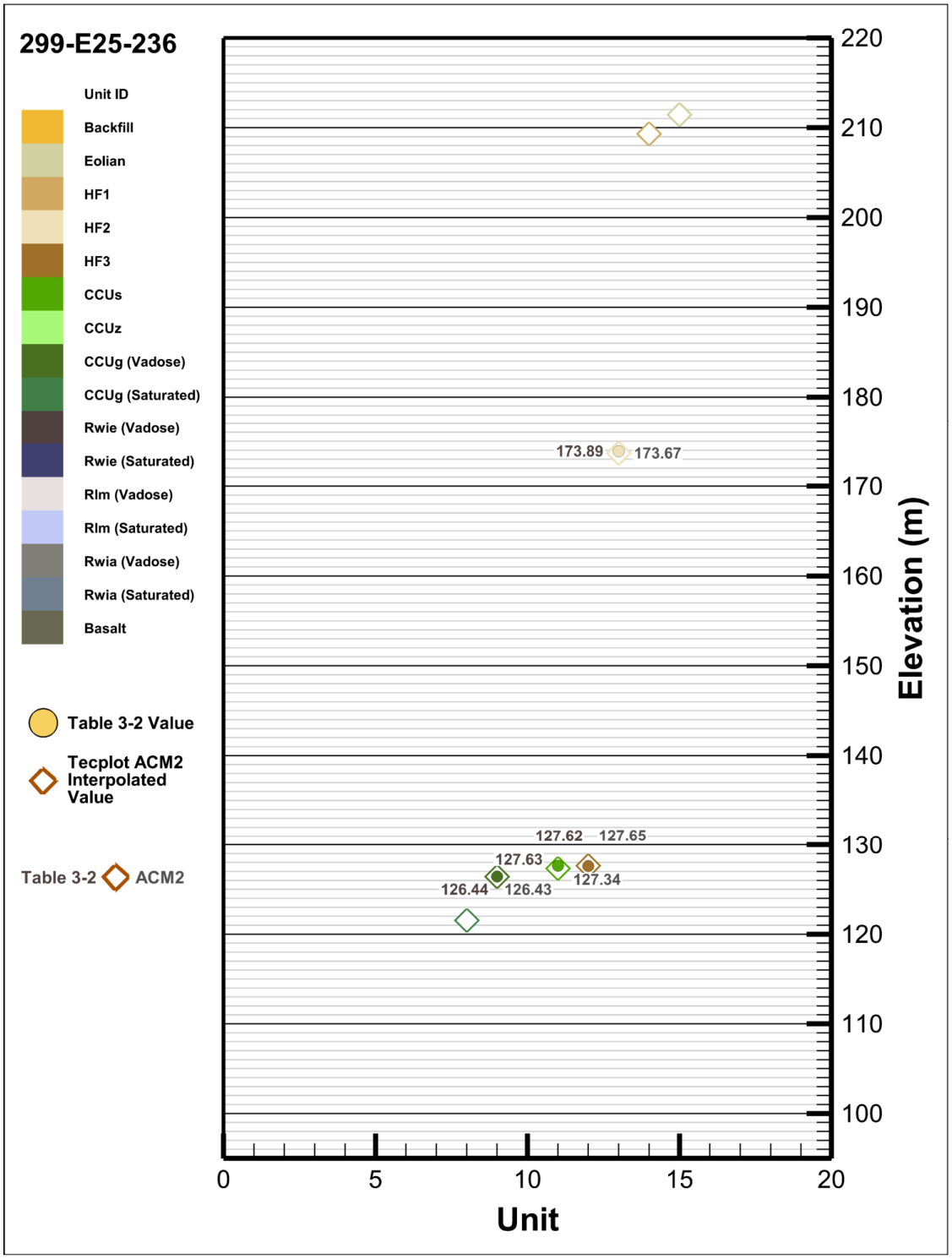
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-71. Well 299-E25-94 - Units Elevation Comparison (Table 3.2 vs GFM).



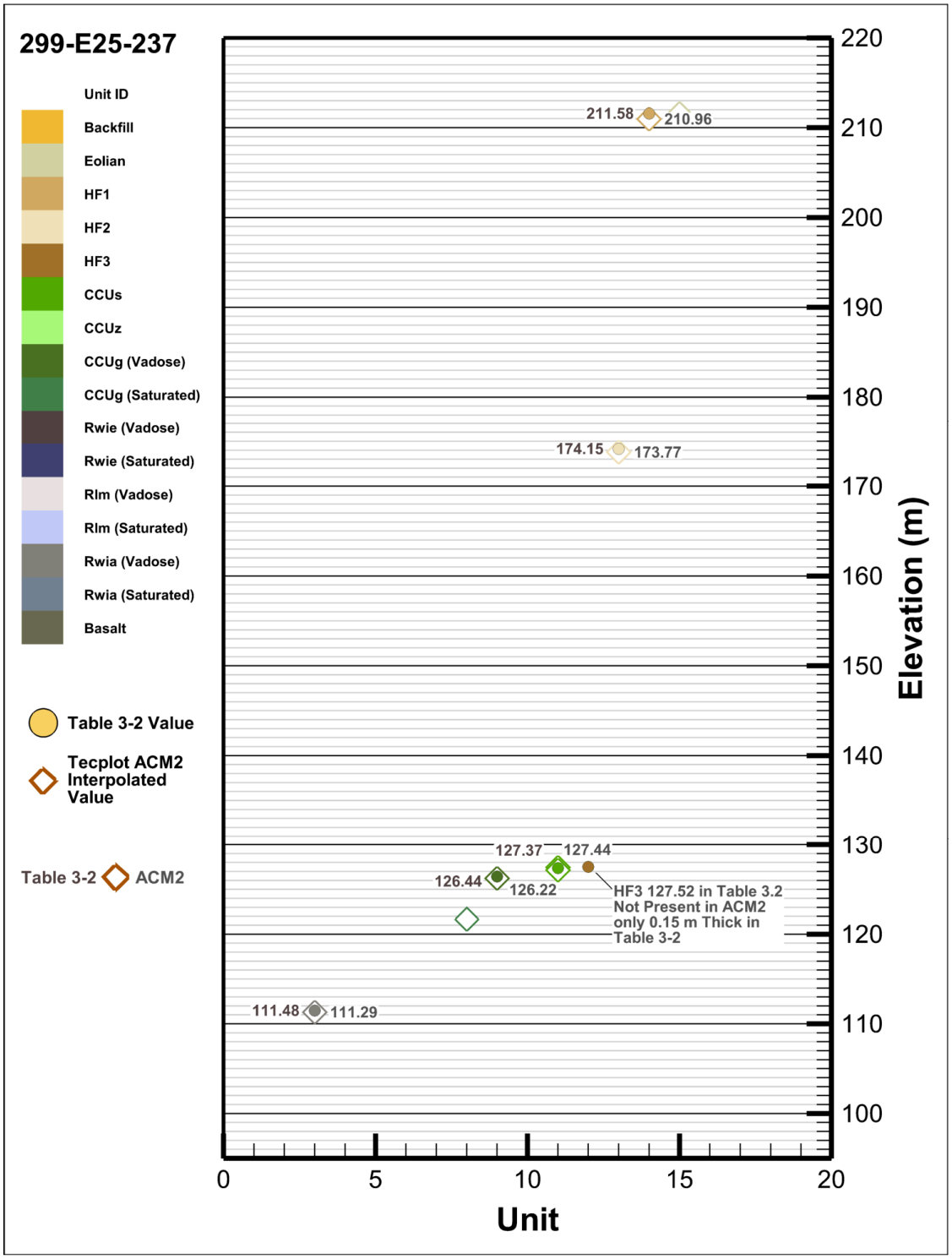
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-72. Well 299-E25-236 - Units Elevation Comparison (Table 3.2 vs GFM).



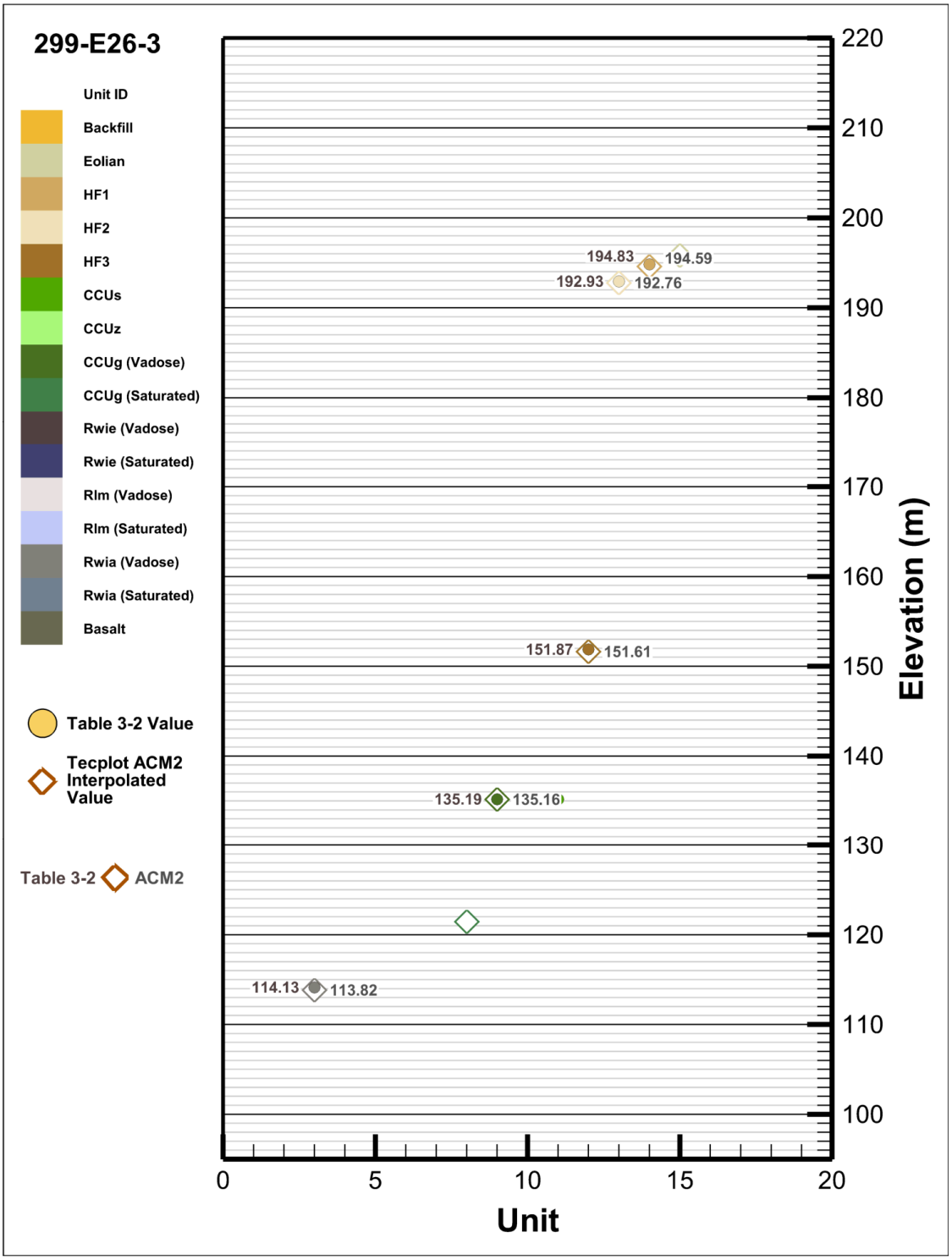
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-73. Well 299-E25-237 - Units Elevation Comparison (Table 3.2 vs GFM).



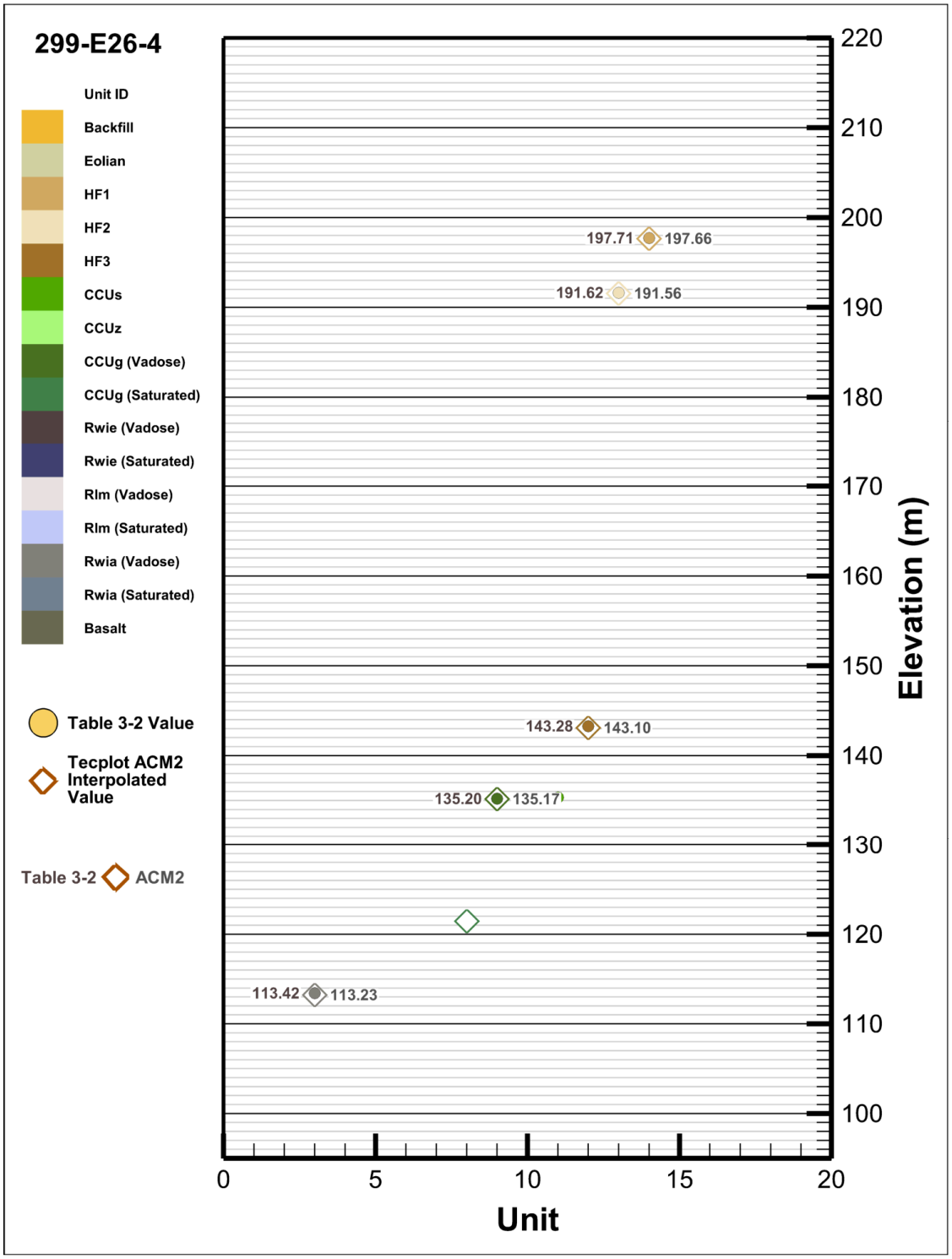
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-74. Well 299-E26-3 - Units Elevation Comparison (Table 3.2 vs GFM).



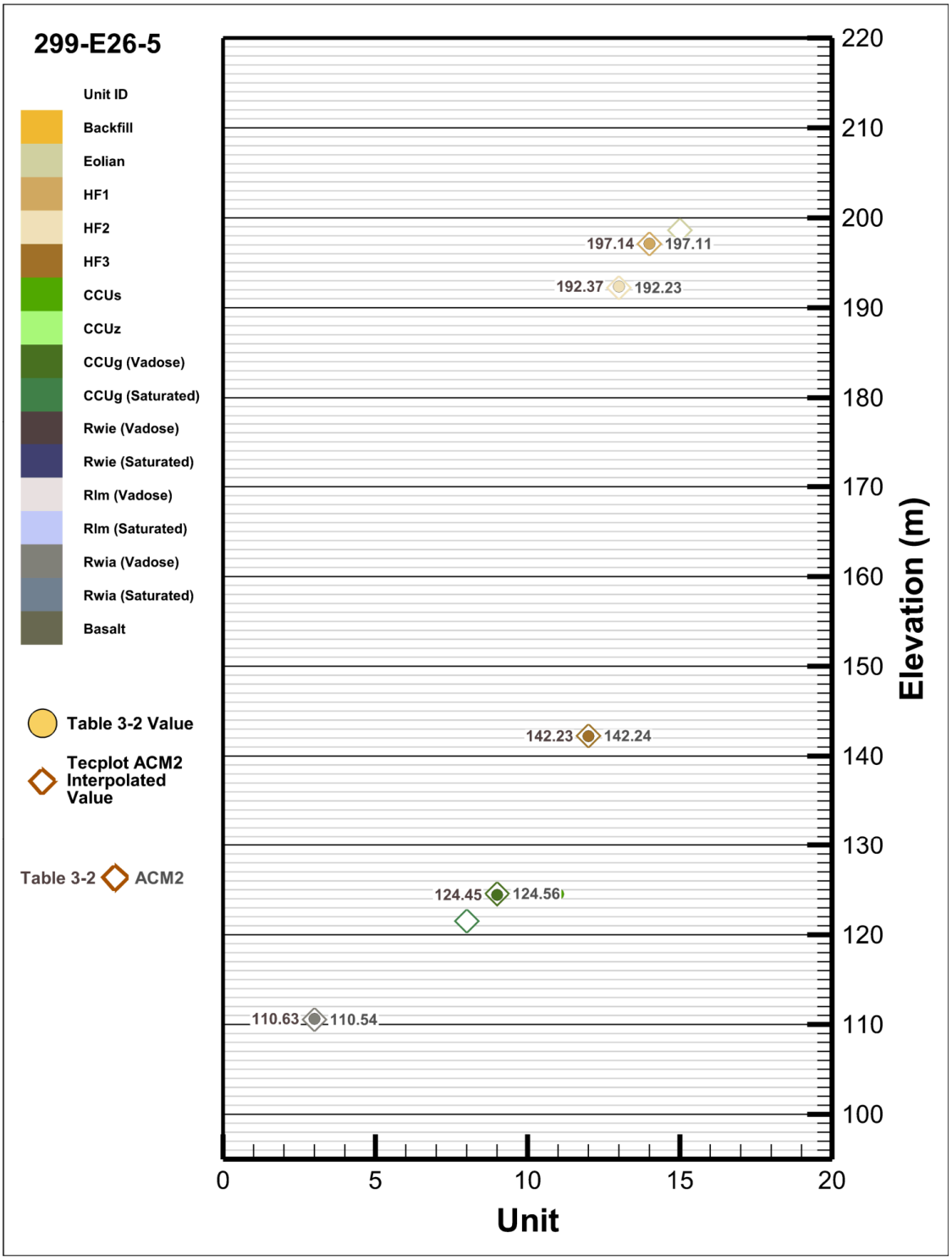
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-75. Well 299-E26-4 - Units Elevation Comparison (Table 3.2 vs GFM).



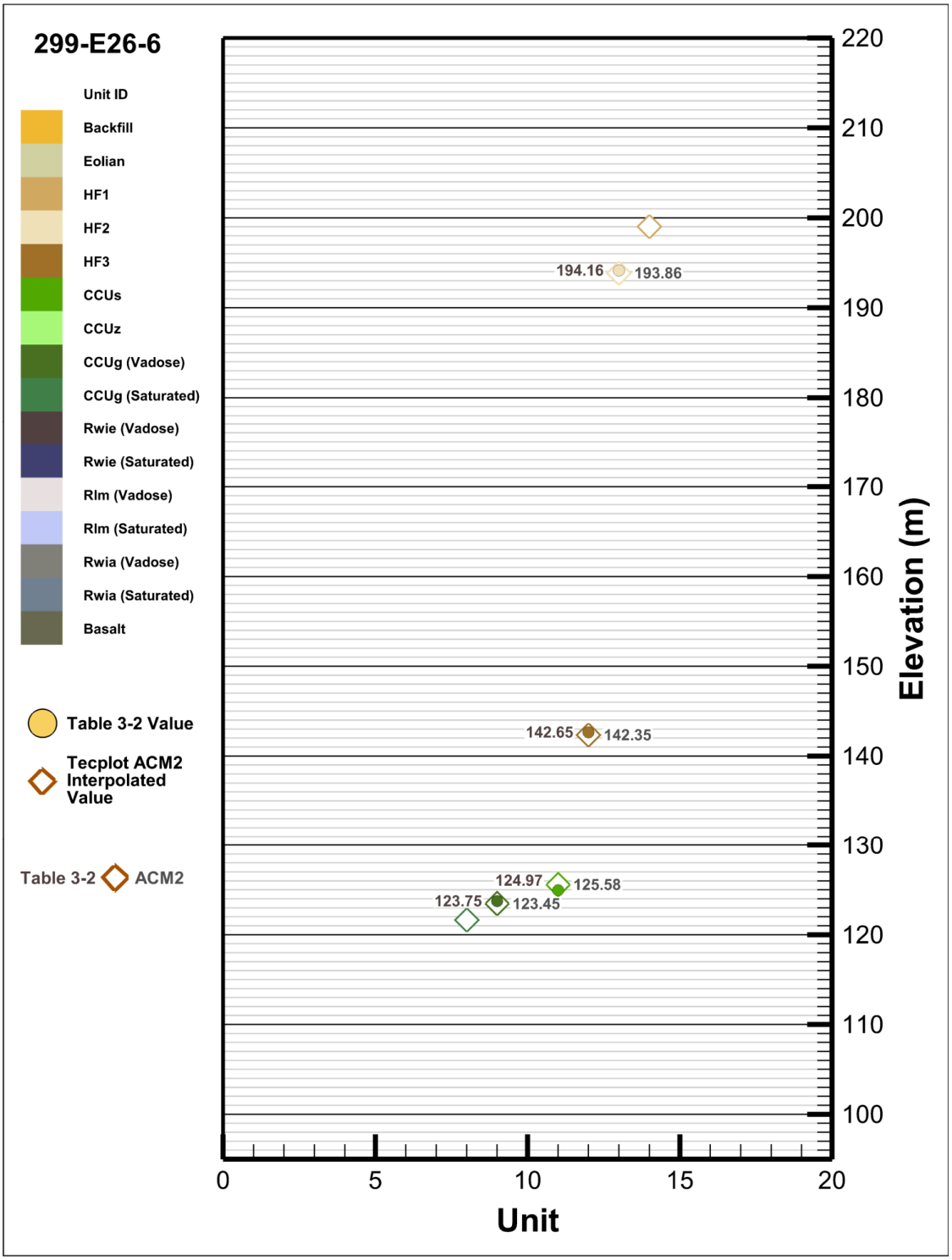
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-76. Well 299-E26-5 - Units Elevation Comparison (Table 3.2 vs GFM).



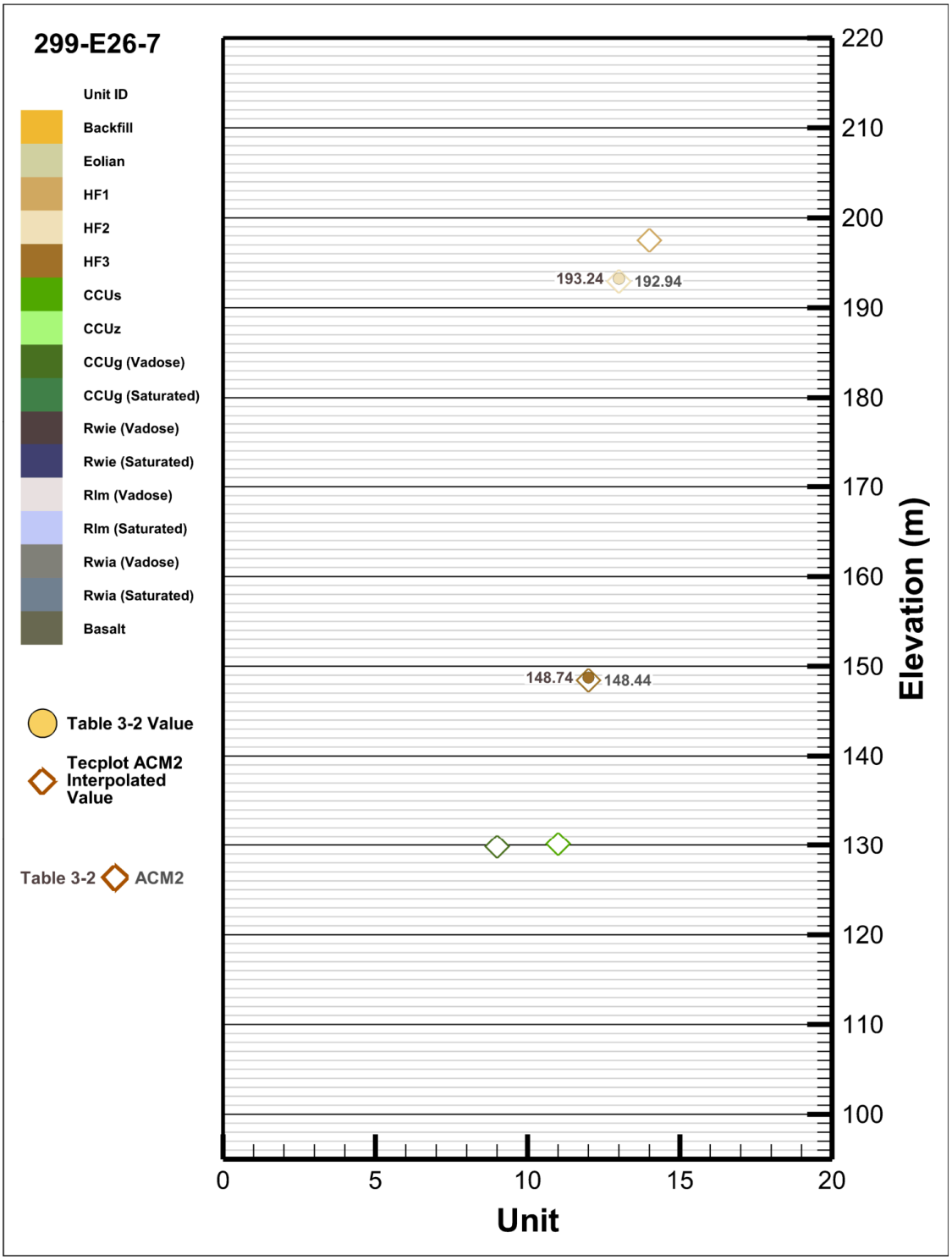
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-77. Well 299-E26-6 - Units Elevation Comparison (Table 3.2 vs GFM).



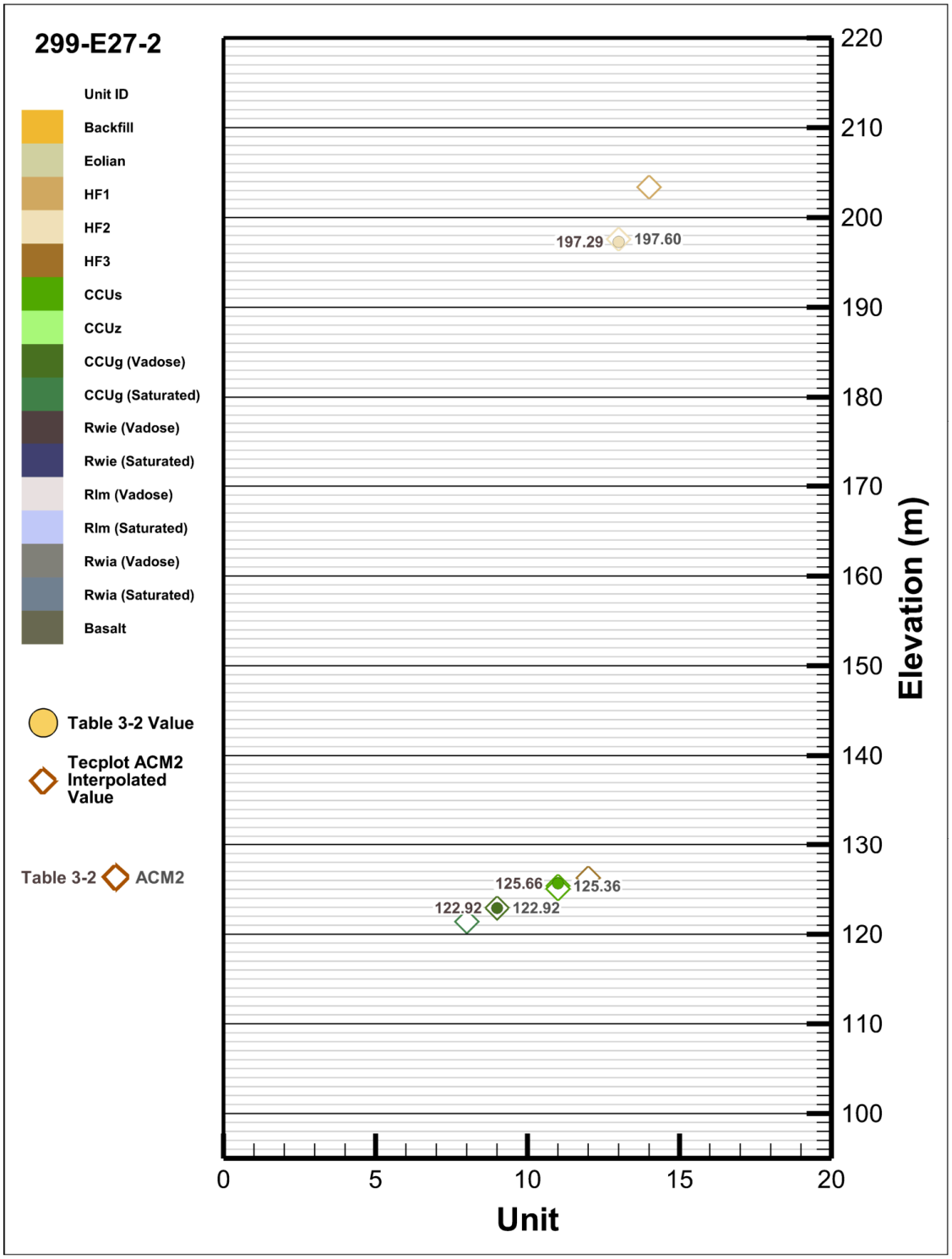
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-78. Well 299-E26-7 - Units Elevation Comparison (Table 3.2 vs GFM).



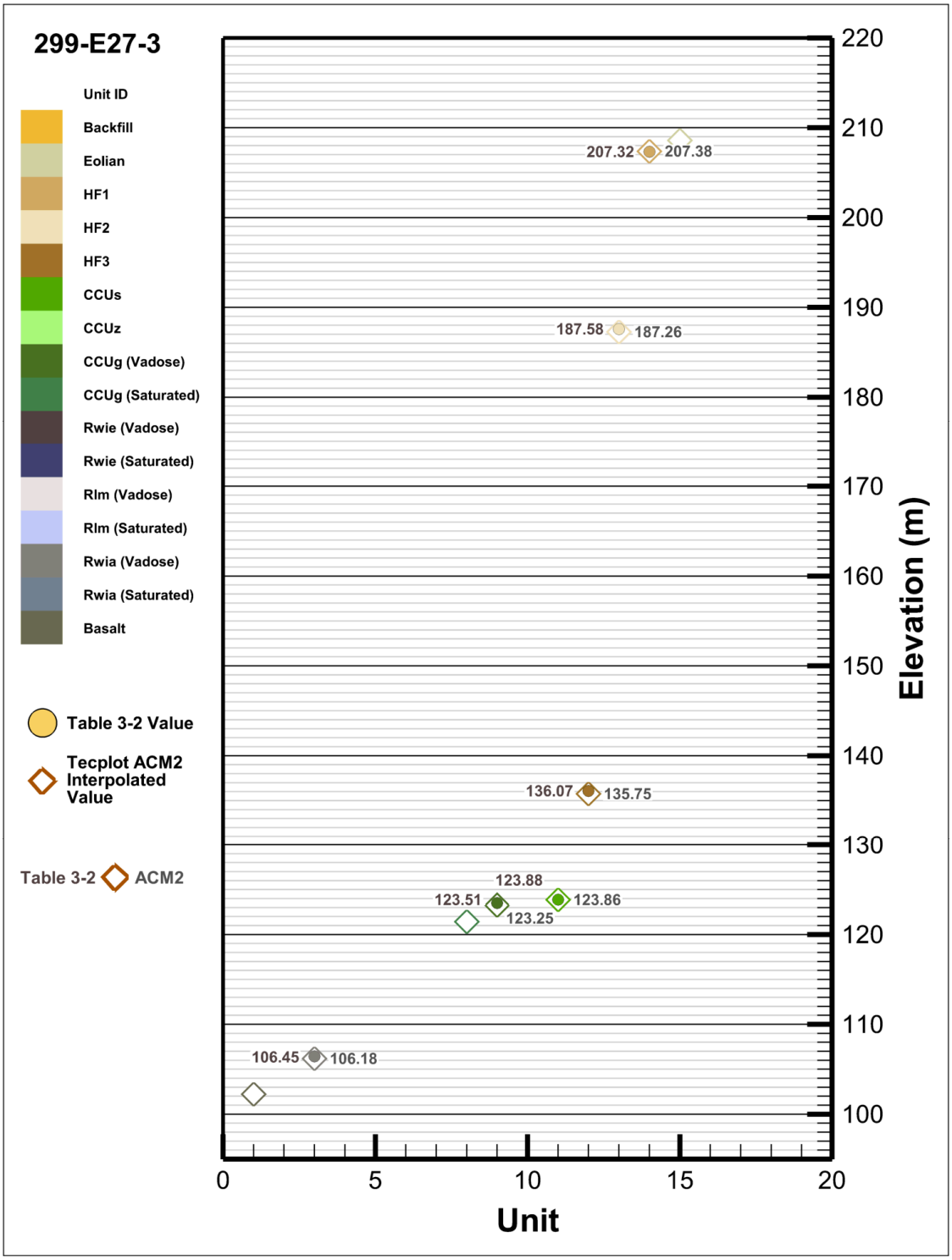
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-79. Well 299-E27-2 - Units Elevation Comparison (Table 3.2 vs GFM).



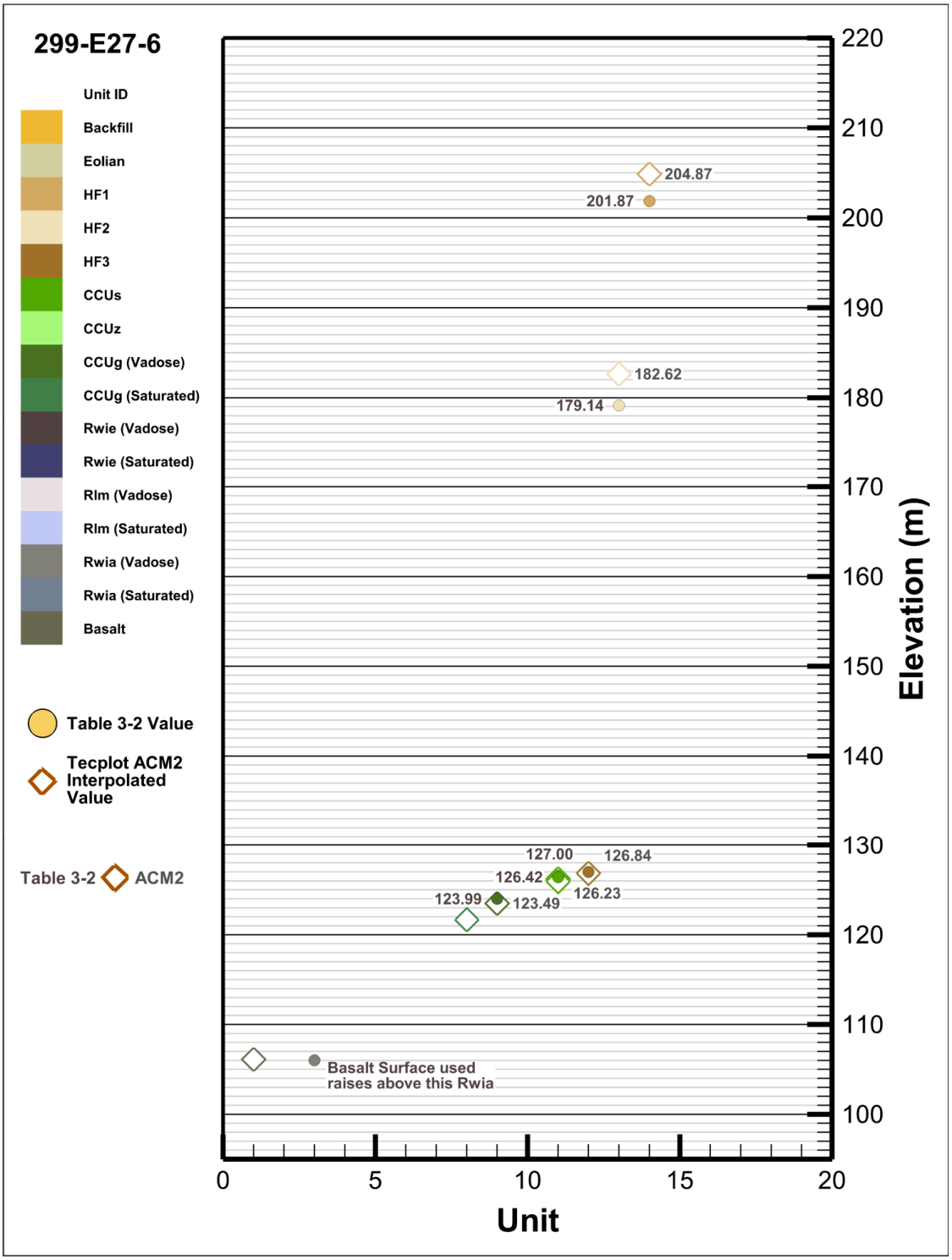
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-80. Well 299-E27-3 - Units Elevation Comparison (Table 3.2 vs GFM).



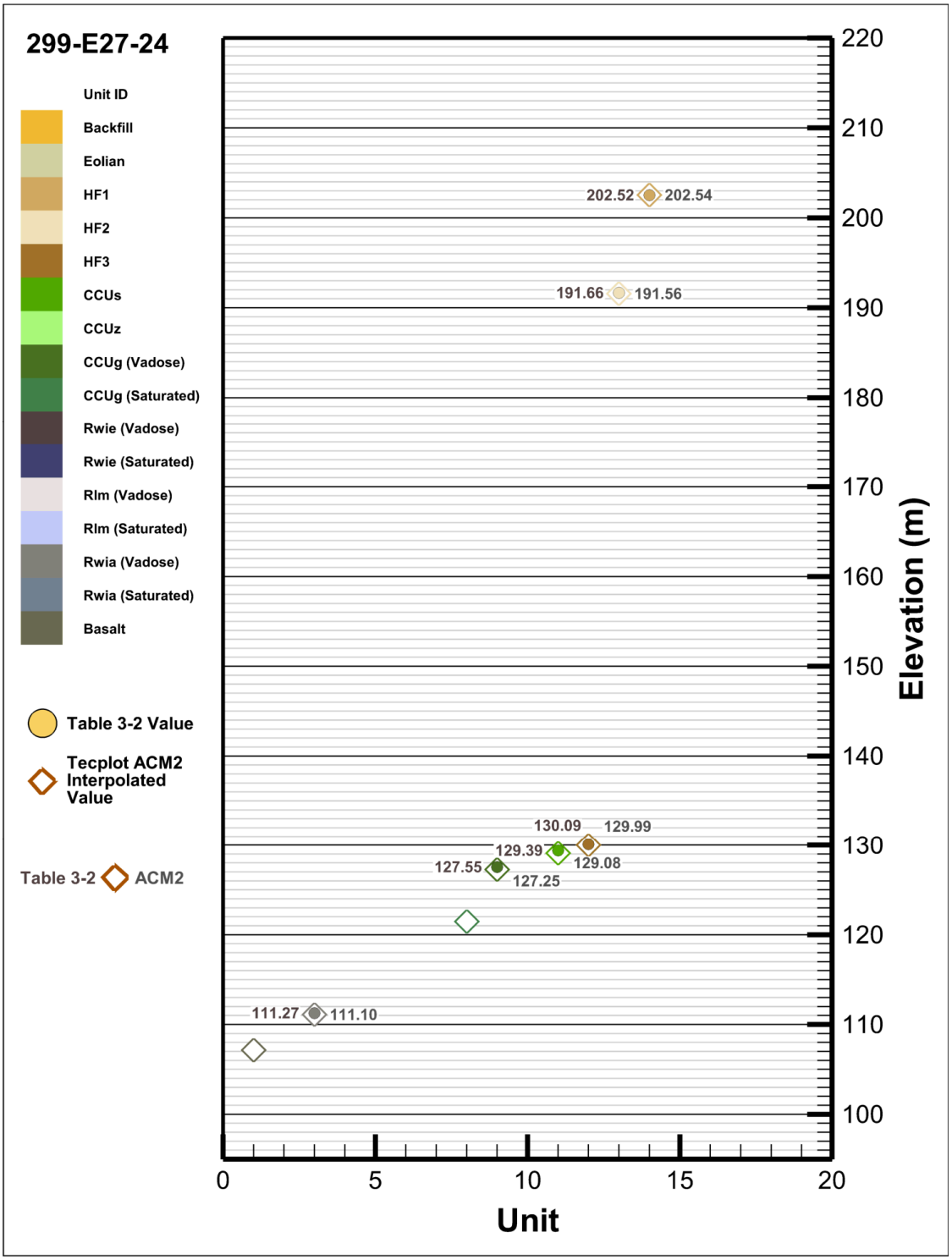
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-81. Well 299-E27-6 - Units Elevation Comparison (Table 3.2 vs GFM).



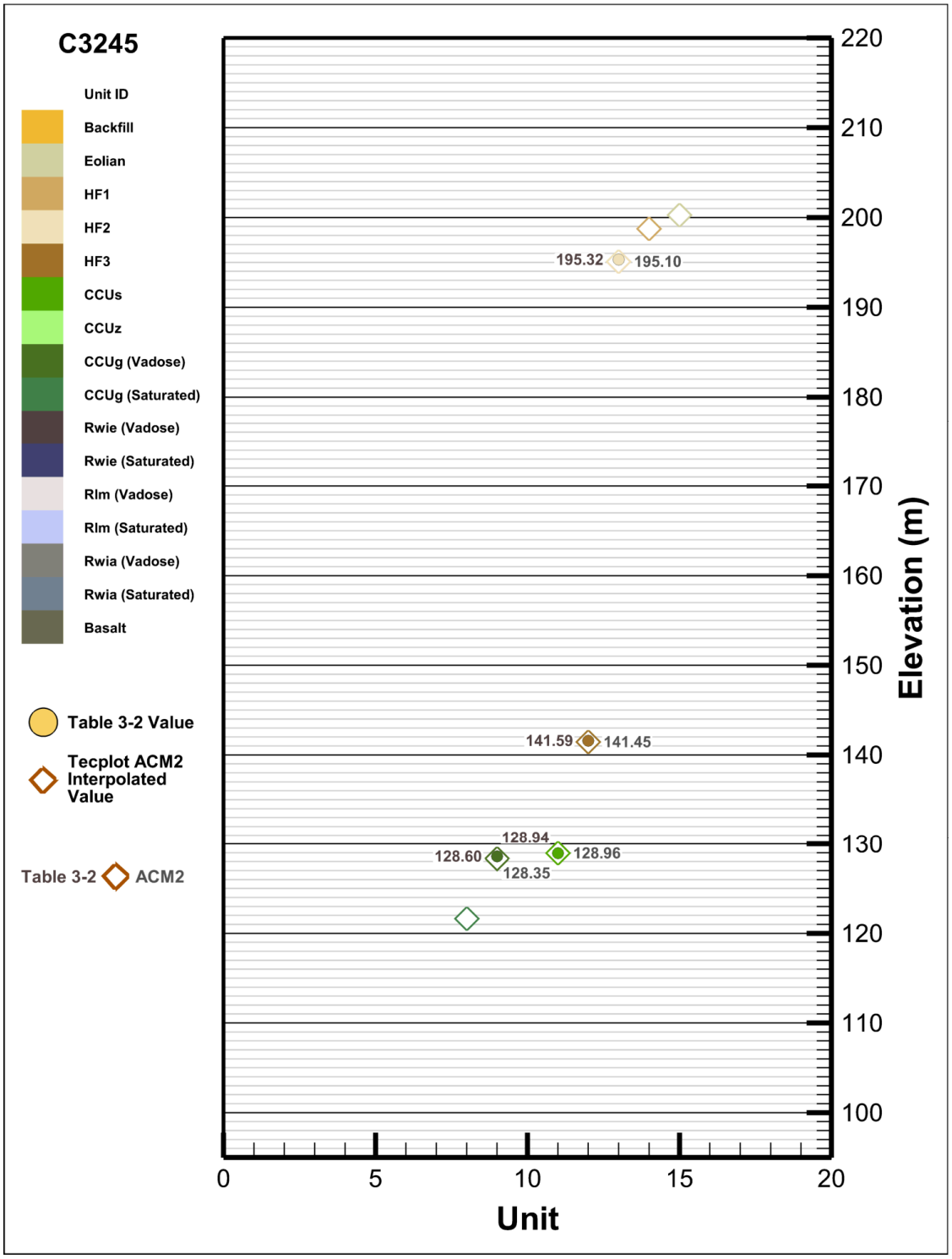
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-82. Well 299-E27-24 - Units Elevation Comparison (Table 3.2 vs GFM).



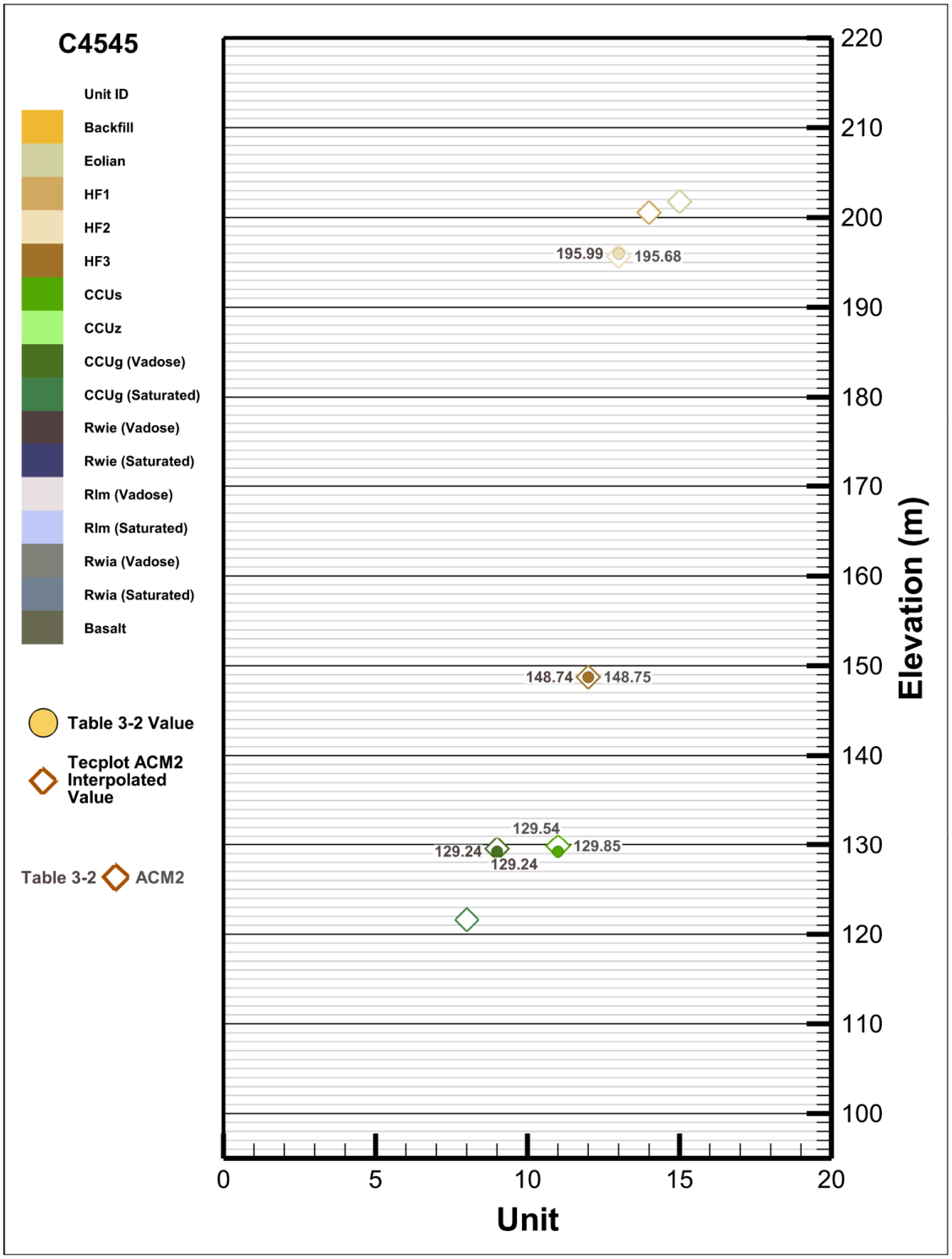
ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-83. Well C3245 - Units Elevation Comparison (Table 3.2 vs GFM).



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

Figure H-84. Well C4545 - Units Elevation Comparison (Table 3.2 vs GFM).



ACM = alternative conceptual model
CCUg = Cold Creek Unit gravels
CCUs = Cold Creek Unit sand
CCUz = Cold Creek Unit silt
GFM = geologic framework model
HF1 = Hanford formation Unit 1
HF2 = Hanford formation Unit 2
HF3 = Hanford formation Unit 3
Rlm = Ringold Formation Wooded Island Lower Mud Unit
Rwia = Ringold Formation Wooded Island Unit A
Rwie = Ringold Formation Wooded Island Unit E

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RPP-RPT-60171: Attachment I

Supporting Information for

WMA A-AX Geologic Framework Model Package Report (RPP-RPT-60171)

1. Identification of Need for RPP-RPT-60171:

This Model Package Report (MPR) is needed to provide documentation of the development of the primary conceptual model of the vadose zone and saturated zone geologic units, their character and configuration beneath WMA A-AX tank farm. For the preliminary Performance Assessment (PA) of WMA A-AX the groundwater analysis will be performed with the system model, rather than the process model, however since the process model computes the vadose zone water flux terms, it is utilized to provide groundwater flux terms and to compare contaminant transport results with the system model. This document provides a complete description of the STOMP model construction.

2. Identification of MPR Lead Document Originator, Checker, and Subject Matter Expert (SME)/Senior Reviewer (SR)

RPP-RPT-60171 Draft C (*WMA A-AX Geoframework MPR*) Originator(s):

Sunil Mehta, INTERA, Inc.

Ph.D., Earth Sciences (Hydrogeology specialization), University of Kentucky
M.S., Geosciences, University of Louisiana at Monroe
M.Sc., Geology, University of Poona, India
B.Sc., Chemistry, Zoology, and Geology, University of Jodhpur, India

Mr. Mehta's professional experience as a hydrogeologist has focused on flow and transport modeling under variably saturated conditions, reactive transport modeling, performance assessment, and uncertainty analysis. He has gained this experience on projects involving deep geologic isolation of high-level radioactive wastes, shallow disposal of low-level radioactive waste, and environmental restoration activities in accordance with local and federal regulations. His experience includes designing, developing, and applying numerical models to evaluate the performance of radioactive waste storage and disposal facilities. His work has encompassed developing flow and reactive transport models for transuranics, conducting process and component modeling (e.g., unsaturated and saturated zone flow, colloid facilitated transport, waste form degradation) and combining these models into a comprehensive probabilistic assessment tool used to forecast post-closure performance of a storage facility. He has completed all reading assignments that are procedurally required to perform environmental fate and transport calculations.

Michael P. Connelly, TecGeo, Inc

B.S., Geology, University of Utah
M.S., Geology, University of Utah

Mr. Connelly has over 16 years of experience in environmental geohydrology including project management, groundwater modeling, and using computer techniques to analyze and interpret field data for remedial action and site characterization activities.

Marcel P. Bergeron, Washington River Protection Solutions, LCC

M.A., Geology, Indiana University, Bloomington, IN
B. A., Geology, University of Vermont, Burlington, VT

Mr. Marcel Bergeron has more than 35 years of experience in a wide variety of subsurface investigations and studies at radioactive and hazardous waste facilities and contaminated sites. He is experienced in planning and implementation of environmental characterization and risk assessment investigations in a variety of roles including as a technical contributor, a project and task manager, and a line manager. He has performed quantitative analysis of subsurface systems using analytical and numerical models and visualization tools. He has significant technical project experience in managing technical teams, schedules, and budgets for multi-disciplinary projects and communication of project results with clients, regulators, and stakeholders.

A. Pappas, M.Sc., PG, PMP; Washington River Protection Solutions, LCC

Mr. Pappas is a Project Manager Professional, technology maturation leader, and professionally licensed geologist with a diverse background in technology field solution integration, geosciences, along with research and development; evolving effective technical teams to tackle unique and challenging projects and feasibility investigations through program leadership, innovative solutions, new program evolution and execution.

Checker:

Praveena Allena, INTERA, Inc.

MS, Civil Engineering, New Mexico State University, 2008
BS, Civil Engineering, Andhra University, 1999

Praveena Allena's current focus is on developing and applying groundwater flow and contaminant transport models to support the environmental investigation and remediation of soils and groundwater impacted by past industrial operations and waste disposal practices. Ms. Allena has also worked for several state agencies responsible for the development, management, and protection of water resources, where her activities have included water rights permitting and administration, modeling and monitoring of regional and local groundwater levels, maintaining GIS databases, updating hydrographic and GIS survey maps, and reviewing driller reports and well logs. She also brings experience in assessing the structural damage to buildings caused by earthquakes and performing quality assurance and quality control activities for the construction of new buildings.

Subject Matter Expert/Senior Reviewer:

Raziuddin Khaleel, INTERA, Inc.

Ph.D., Soil and Water Engineering, Texas A&M University
M.S., Water Science and Engineering, Asian University of Technology
B.S., Civil Engineering, Bangladesh University of Engineering and Technology

Dr. Khaleel has over 25 years of experience in groundwater hydrology and numerical simulations of subsurface flow and transport. He was a key contributor to the Hanford Site Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds, the Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds, and the Hanford Immobilized Low-Activity Tank Waste Performance Assessment. His contributions have been in the area of conceptual model development, direction of modeling, and in writing the document.

Responsible WRPS Technical Project Lead:

Robert A. Hiergesell, Washington River Protection Solutions, LCC

M.Sci., Hydrogeology from Univ. of Nebraska-Lincoln.
B.Sci., Geology from Virginia Polytechnic Institute, Blacksburg, Va

Mr. Hiergesell is a Senior Scientist in the SST Closure & Interim Measures Department of WRPS. He has over thirty years of experience in the areas of groundwater monitoring, subsurface flow and transport simulation, environmental remediation and performance assessment for low-level radioactive waste disposal. Prior to joining WRPS, he was employed at the DOE Savannah River National Laboratory where he was the lead technical investigator for numerous environmental restoration and waste management projects.

K Pat Lee Digitally signed by K Pat Lee
Date: 2020.10.13 06:11:41 -07'00'

Robert A. Hiergesell Date

Signed by Kearn P Lee for RAH (retired)

CHECKER LOG FOR GEOLOGIC FRAMEWORK MODEL PACKAGE REPORT (MPR)

Project and MPR Specific Information

Project: WMA A-AX Performance Assessment and RCRA Analysis

Responsible Manager or Designee and Position: Robert Hiergesell

Originating Group or Department: Washington River Protection Solutions | Date: 06/07/2018

Model Package Report and Revision Number: RPP-RPT-60171, Draft C

Model Package Report Title: Geologic Framework Model used in WMA A-AX Performance Assessment

Check: Geologic Framework MPR Elements

Geologic Framework MPR Elements	Is Element included?			Is Element Content Sufficient and Complete?			Checker's signature
	Yes	No	Section or page numbers	Yes	No	If "No" Briefly Describe all Deficiencies.	
Executive Summary	yes		iii	yes			
Table of Contents, Lists of Attachments, Figures, Tables	yes		iv to ix	yes			
List of Abbreviations Used	yes		x to xi	yes			
Purpose and Report Organization	yes		1-1 to 1-2	yes			
Approach and Model Development Objectives	yes		2-1	yes			
Model Conceptualization	yes		3-1 to 3-24	yes			
Data Sources	yes		1-3	yes			
GFM Development and Construction	yes		4-23 to 4-31	yes			
Model Limitations	yes		5-1 to 5-4	yes			
Model Development Software – Installation and Checkout Forms	yes		6-1 to 6-2 & G-1 to G-5	yes			
Model Configuration Management	yes		7-1	yes			
References	yes		8-1 to 8-3	yes			

CHECK: Geologic Framework MPR Figures				
	Is the Criteria met? *(if "No", describe deficiency)*		If "No," Identify Figure Number and Describe Deficiencies	Checker's Signature
	Yes	No		
Are All Figures Complete? (e.g., Figure title and proper figure number plus relevant figure explanation (e.g., inset location map, horizontal or vertical scales, north arrow, explanation of symbols)	yes			
Are All Figures included in the MPR Document Cited in the Text?	yes			

CHECK: Geologic Framework MPR Tables				
	Is the Criteria met? *(if "No", describe deficiency)*		If "No," Identify Table Number and Describe Deficiencies	Checker's Signature
	Yes	No		
Are All Tables Complete? (e.g., Table title and proper table number plus relevant Table explanation (e.g., footnotes describing abbreviations, source of information used)	yes			
Are All Tables included in the MPR Document Cited in the Text?	yes			

CHECK: Geologic Framework MPR Attachments				
	Is the Criteria met? *(if "No", describe deficiency)*		If "No," Identify Attachment Number and Describe Deficiencies	Checker's Signature
	Yes	No		
Are All Attachments Complete? (e.g., Attachment title and proper number plus inclusion of relevant information	yes			
Are All Attachments included in the MPR Document Cited in the Text?	yes			

CHECK: Controlled Software Use					
	List where Information is Described in MPR	Is the Criteria met? *(if "No", describe deficiency)*		If "No," Identify and Describe Deficiencies	Checker's Signature
		Yes	No		
Software Used to Develop and Construct GFM is Appropriate for Application	Sec 4, Attachment C	yes			
Software Used is Approved and Properly Validated in Accordance with Approved Software Management Plan	Attachment H	yes			
Software Use is Properly Described and Documented	Attachment H	yes			

CHECK: Geologic Framework Model Development and Verification					
	List where Information is described in MPR	Is the Criteria met? *(if "No", describe deficiency)*		If "No," Identify and Describe Deficiencies	Checker's Signature
		Yes	No		

Verify Source(s) of Data Used and Data Was Input Correctly to Approved Software or Spreadsheets	Section 4 and 6	yes			
If Data Unit Conversion Was Required Verify Calculations to Ensure Accuracy	Section 4	yes			
Are original borehole log picks included in analysis adequately represented in final geologic framework model?	Section 3	yes			
The Limitations and Sources of Error Associated With the Construction of the GFM documented?	Section 5	yes			
Are Sources of Error Associated With the Construction of the GFM evaluated by Quantitative Methods and Documented?	Section 5	yes			

CHECK: Geologic Framework MPR - Additional Review Comments

List Any Additional Review Comments or Suggestions to Improve MPR:

Any "lessons learned" or recommendations for improving MPR development and review process:

Checker Signature _____ **Date** 06/07/2018

Review Draft

SENIOR REVIEWER'S LOG
GEOLOGIC FRAMEWORK
MODEL PACKAGE REPORTS

Project and MPR Specific Information	
Project: WMA A-AX Performance Assessment and RCRA Closure Analysis	
Responsible Manager or Designee and Position: Robert Hiergesell	
Originating Group or Department: Washington River Protection Solutions	Date: June 7, 2018
Model Package Report and Revision Number: RPP-RPT-60171, Draft C	
Model Package Report Title: Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment	
CHECK: Geologic Framework Model Package Report Elements	

Geologic Framework MPR Elements	Is Element Included?			Is Element Content Sufficient?		
	Yes	No	Section or Pages Nos.	Yes	No	If "No" Briefly Describe all Deficiencies.
Executive Summary	Yes		p. iii	Yes		
Purpose	Yes		Section 1	Yes		
Approach						
Is FEPs utilized and explained?	Yes		Section 3	Yes		
Are GFM development objectives and goals clearly defined and described?	Yes		Section 2	Yes		
Was the appropriate methodology (and software) employed to achieve GFM objectives and goals?	Yes		Sections 4 and 6	Yes		
Are the GFM domain boundaries (lateral & vertical) adequate for stated purposes and goals?	Yes		Section 4	Yes		
Data Sources and Limitations						
Are the sources of both existing						

Review Draft

Geologic Framework MPR Elements	Is Element Included?			Is Element Content Sufficient?		
	Yes	No	Section or Pages Nos.	Yes	No	If "No" Briefly Describe all Deficiencies.
and new data used in constructing the GFM adequately identified and from approved sources?	Yes		Sec 3 and 4, Att. B	Yes		
Was any assumptions or limitations associated with the data used identified and explained?	Yes		Section 5	Yes		
GFM Development						
Is technical approach used for construction of GFM clearly and adequately documented and described?	Yes		Section 4, Attachments C and F	Yes		
Does the description of the GFM construction methodology provide sufficient detail to allow the GFM to be reproduced?	Yes		Sections 3 and 4, Attachments C and F	Yes		
Was software or ECFs used to construct the GFM approved and properly validated in accordance with approved software management plan?	Yes		Section 6	Yes		
Were the created GFM unit surfaces subject to any comparative analysis with subsurface geologic control points?	Yes		Appendix H	Yes		
References						
Were any important or critical references that were not cited in the GFM-MPR?		No	Section 8			

Review Draft

Geologic Framework MPR Elements	Is Element Included?			Is Element Content Sufficient?		
	Yes	No	Section or Pages Nos.	Yes	No	If "No" Briefly Describe all Deficiencies.
Were there any irrelevant references cited that should be deleted?		No	Section 8			
Tables and Figures						
Are the included Tables relevant and complete?	Yes		Relevant Sections	Yes		
Are the included Figures relevant and complete?	Yes		Relevant Sections	Yes		
Attachments						
Are all included Attachments relevant and complete?	Yes		Attachments	Yes		
Are there any portions of earlier sections of the GFM-MPR text that could be moved to an Attachment to improve the readability of the document?		No				

OTHER GENERAL COMMENTS

Any general suggestions to improve MPR? Any "lessons learned" or recommendations for improving GFM-MPR development and review process?

The methodology presented in appendix H is an excellent approach to verify the contacts for geologic units and check the accuracy of the GFM construction. As discussed in appendix H, the version of Kingdom® Geology used to interpolate individual stratigraphic unit surfaces recognized the Hanford formation as the youngest stratigraphic unit present and did not account for the presence of either backfill or eolian sand. This resulted in a "gap" between the top of the upper-most Hanford formation unit and ground surface where either backfill materials or eolian sand deposits are present. The issue was addressed in Tecplot® where both recent backfill materials and eolian sand were included as

Senior Reviewer Signature Raziuddin Khaleel **Date** 6/7/2018