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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Hydrogeologic Model for the Gable Gap Area, Hanford Site

BN Bjornstad
PD Thorne
BA Williams
GV Last
GS Thomas
MD Thompson
JL Ludwig
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September 2010

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[1]CH2M HILL Plateau Remediation Company
[2]MDT Associates
[3]Intera Inc.

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Gable Gap is a structural and topographic depression between Gable Mountain and Gable Butte within the central Hanford Site. It has a long and complex geologic history, which includes tectonic uplift synchronous with erosional downcutting associated with the ancestral Columbia River during both Ringold and Cold Creek time intervals, and by the later Ice Age (mostly glacial Lake Missoula) floods. The gap was subsequently partially backfilled by mostly coarse-grained, Ice Age flood deposits (Hanford formation). Erosional remnants of both the Ringold Formation and Cold Creek unit locally underlie the high-energy flood deposits. A large window exists in the gap where confined basalt aquifers are in contact with the unconfined suprabasalt aquifer.

Multiple paleochannels, of both Hanford and Ringold formation age, were eroded into the deformed basalt bedrock across Gable Gap. Groundwater from the Central Plateau presently moves through Gable Gap via one or more of these paleochannels. As groundwater levels continue to decline in the region, most groundwater flow may eventually be diverted from flowing through Gable Gap. However, the base of the aquifer is poorly constrained in the area of the basalt divide; other unidentified buried channels may exist across the divide that could provide flow paths across Gable Gap for an indefinitely longer period.

An updated hydrogeologic conceptual model of the Gable Gap area is presented in this report. This model is based on analysis of the old and new geologic, hydrologic, and groundwater chemistry data needed to understand groundwater and contaminant movement through the Gap. Because of the sparse and uneven distribution of boreholes in portions of Gable Gap, uncertainties in the model still exist. Therefore, the model presented herein is subject to refinement with the inclusion of more data in the future.

Acknowledgments

We appreciate the support of CH2M HILL Plateau Remediation Company and members of the Central Plateau Hydrogeology Working Group, including Pat Cabbage and Steve Airhart of Freestone Environmental Services, and Steve Miller. We also appreciate the helpful reviews of Virginia Rohay, John McDonald, Frank Spane, and Mickie Chamness. Lastly, we thank Steve Reidel and Karl Fecht for sharing their extensive knowledge on the structure and top of basalt within Gable Gap.

Acronyms and Abbreviations

BP-5	BP-5 Groundwater Operable Unit
BWIP	Basalt Waste Isolation Project
CCU	Cold Creek unit
CCUc	Cold Creek unit - caliche
CCUg	Cold Creek unit - gravel-dominated
CCUz	Cold Creek unit - silt-dominated
CRBG	Columbia River Basalt Group
H1	Hanford formation unit 1
H2	Hanford formation unit 2
H3	Hanford formation unit 3
HEIS	Hanford Environmental Information System
YFB	Yakima Fold Belt

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1.0 Introduction and Background

Gable Gap refers to a topographic and structural saddle that lies between Gable Mountain and Gable Butte (Figure 1.1) in the north-central portion of the U.S. Department of Energy's Hanford Site. The Gable Gap area lies north of the Central Plateau and is superimposed on the Cold Creek Bar north of the 200 East and 200 West Areas. The Central Plateau is where much of the hazardous and nuclear liquid wastes from the Hanford Site were discharged to the subsurface through various tanks, cribs, and trenches. Groundwater beneath the 200 Areas flows east to southeast; however, some groundwater also appears to flow northwestward through Gable Gap (DOE/RL 2010). This pathway is indicated by groundwater-contaminant plumes (uranium and technetium-99) that extend northwestward from the presumed source in the 200 East Area (Serne et al. 2010). As such, Gable Gap may represent a potential flow path to the Columbia River for some groundwater contaminants on the Hanford Site.

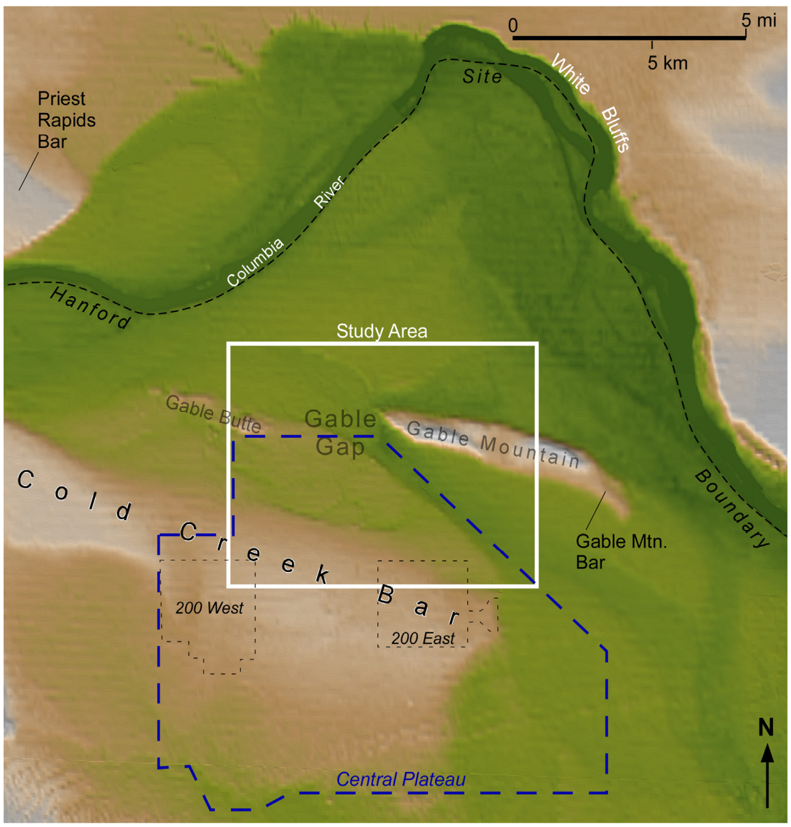


Figure 1.1. Shaded-relief map of the Gable Gap study area.

The purpose of this report is to present the latest hydrogeologic conceptual model for the area based on a comprehensive analysis of available stratigraphic, structural, geomorphic, and hydrologic information pertinent to understanding the groundwater flow and movement of contaminants within the Gable Gap region. Included are discussions of the stratigraphy and lithology of the various stratigraphic units and how these are used to interpret the geologic history of the central Pasco Basin. This information forms the basis for interpreting the complex erosional and tectonic history, as well as the geomorphology and hydrogeology of the Gable Gap area. Data used to support interpretations and conclusions are presented in five appendices:

- Appendix A – Five hydrogeologic cross sections
- Appendix B – EarthVision®-based structure contour maps
- Appendix C – EarthVision®-based isopach maps.
- Appendix D – Three-dimensional EarthVision® Model
- Appendix E - Borehole Information and Tops of Stratigraphic Unit Contacts

Numerous studies describing the hydrogeology of the area create the foundation from which the conceptual model has evolved (e.g., Tallman et al. 1979; DOE 1988; Last et al. 1989; Hoffman et al. 1992; WHC 1992; Lindsey et al. 1992; Lindsey 1995; Williams et al. 2000; Wood et al. 2000; Reidel and Chamness 2007; and Serne et al. 2010). Previous investigations focusing more specifically on Gable Gap include surface geologic mapping (Fecht 1978; Myers et al. 1979), subsurface geophysical investigations (Holmes and Mitchell 1981; Ault 1981, Repasky et al. 2009), and aquifer intercommunication studies between the unconfined aquifer and the Rattlesnake Ridge interbed (Strait and Moore 1982; Graham et al. 1984; Jensen 1987; Spane and Webber 1995). All these previous studies established the foundation for the conceptual hydrogeologic model presented in this report.

2.0 Methods

The present study included a re-evaluation of borehole data from ~160 boreholes drilled in the vicinity of Gable Gap since 1944 (Figure 2.1, Table 2.1), including a number of new borings drilled over the last few years. Data analyzed include all available drillers', geologists', and geophysical logs; archived sediment samples; and photographs, as well as field and laboratory characterization data. Aquifer-test results were also considered (Thorne et al. 2006) and in some cases were used in identifying the geologic formation exposed along the open intervals of monitoring wells. In addition, surface geophysical surveys were integrated to better define the surface of the top of basalt between boreholes. The uppermost basalt flow encountered in boreholes was interpreted based on chemical signatures for the different basalt flows using X-ray fluorescence reported in Graham et al. (1984) and Reidel and Fecht (unpublished data).

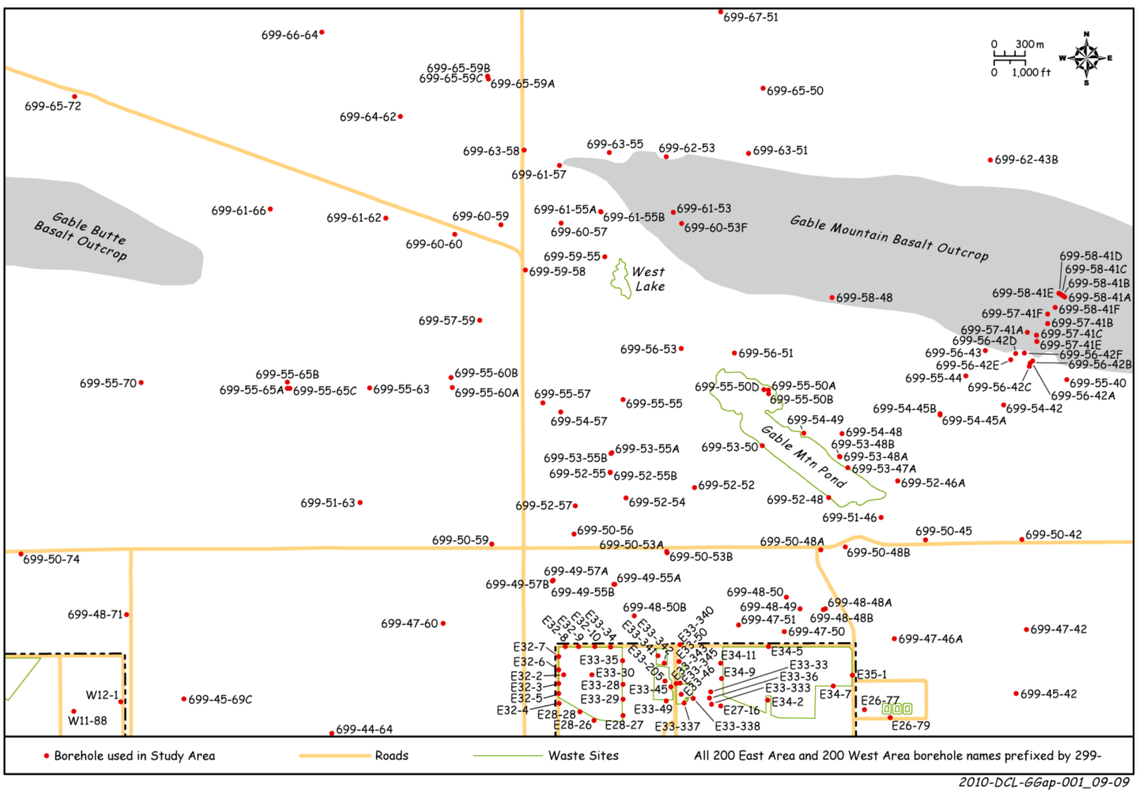


Figure 2.1. Borehole index map. Located are most of the ~160 boreholes used to construct the conceptual hydrogeologic model for the Gable Gap study area.

2.1 Borehole Data Used to Differentiate Lithologic/Stratigraphic Units

Common types of borehole data available to discriminate between lithologic and stratigraphic units include geologists' descriptions, drillers' descriptions, as-built diagrams, grain-size analyses, geophysical logs (i.e., natural gamma, spectral gamma, and/or neutron-moisture), sediment photographs, as well as drilling information (e.g., drill rate, ease of driving casing, open hole, heaving, etc.). These data were used to determine the lithologic and stratigraphic units present in each of the boreholes analyzed in the study area. Most boreholes are lacking in one or more of these datasets; many are lacking in all but one or two.

Table 2.1. Quality ranking of 160 boreholes, located in Figure 2.1, used in Gable Gap conceptual model.

Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^	Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^
299-E26-77	C6455	224.8	2008	1	299-E33-205	C5989	270.6	2008	1
299-E26-79	C6826	224.8	2008	1	299-E33-333	B8079	254	1998	2
299-E27-16	A4814	269	1990	3	299-E33-337	C3390	286	2001	2
299-E28-26	A4822	328.5	1987	2	299-E33-338	C3391	275.8	2001	1
299-E28-27	A4823	301.5	1987	3	299-E33-340	C5853	325.7	2008	1
299-E28-28	A4824	296	1990	3	299-E33-341	C5856	237	2008	1
299-E32-2	A4830	289.2	1987	2	299-E33-342	C5857	245.5	2008	1
299-E32-3	A4831	304	1987	2	299-E33-343	C5858	263.8	2008	1
299-E32-4	A4832	311	1987	2	299-E33-345	C6226	263.8	2008	1
299-E32-5	A4833	293.6	1989	2	299-E34-2	A4877	241.5	1987	2
299-E32-6	A4834	278.8	1991	3	299-E34-5	A4880	190.5	1987	2
299-E32-7	A4835	273.8	1991	2	299-E34-7	A4882	205.5	1989	3
299-E32-8	A4836	256.7	1991	2	299-E34-9	A4884	234.5	1991	2
299-E32-9	A4837	254.6	1991	2	299-E34-11	A4876	219.3	1991	2
299-E32-10	A5432	245.8	1992	2	299-E35-1	A4885	193.8	1989	2
299-E33-28	A4852	278.3	1987	3	299-W11-88	C5572	490.2	2008	1
299-E33-29	A4853	290	1987	2	299-W12-1	A4912	314	1956	4
299-E33-30	A4855	280.1	1987	2	699-44-64	A5188	452	1960	3
299-E33-33	A4858	252	1989	2	699-45-42	A5195	195	1948	4
299-E33-34	A4859	240	1990	2	699-45-69C	C5574	455	2007	2
299-E33-35	A4860	250	1990	3	699-47-42	A8749	1971	1979	5
299-E33-36	A4861	264	1990	2	699-47-46A	A5200	207	1961	3
299-E33-45	C3269	261	2001	1	699-47-50	A5201	295	1980	4
299-E33-46	C3360	264.4	2001	1	699-47-51	A8752	167	1959	4
299-E33-49	C4261	288.8	2004	1	699-47-60	A5202	287	1948	3
299-E33-50	C5195	381	2006	1	699-48-48A	A8768	5661	1972	5
					699-48-48B	A8769	3374	1977	4
					699-48-49	A8770	--	--	5
					699-48-50	A5212	197	1990	25

^1= best, 5 = worst.

Table 2.1. (contd)

Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^	Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^
699-48-50B	C5196	215.2	2006	1	699-52-57	A5237	165.5	1991	2
699-48-71	A5214	305	1956	4	699-53-47A	A5239	41.5	1966	4
699-49-55A	A5217	149	1961	4	699-53-48A	A5241	53	1984	4
699-49-55B	A5218	227	1982	4	699-53-48B	A5242	44	1984	4
699-49-57A	A5219	168	1956	3	699-53-50	A5243	194	1980	3
699-49-57B	A5220	230.4	1990	2	699-53-55A	A5244	455	1961	4
699-49-71	A9918	30	1993	5	699-53-55B	A5245	252	1975	4
699-50-42	A5224	125	1955	3	699-54-42	A5250	210	1948	4
699-50-45	A5225	178	1980	3	699-54-45A	A5251	105	1971	3
699-50-48A	A8812	1,165	1955/1969	3	699-54-45B	A8862	314	1980	4
699-50-48B	A5226	250	1980	3	699-54-48	A5252	101	1984	4
699-50-53A	A5227	185	1955	3	699-54-49	A8863	62	1984	3
699-50-53B	A5228	225	1990	2	699-54-57	A5253	321	1955, 1982	3
699-50-56	C5197	164.1	2006	1	699-55-40	A5255	145	1971	4
699-50-59	C4882	173.2	2005	2	699-55-44	A5256	160	1971	4
699-50-74	C4697	338.8	2005	2	699-55-50A	A8865	110	1948	3
699-51-46	A5230	168	1980	4	699-55-50D	A8867	100	1956	3
699-51-63	A5231	184.5	1956	3	699-55-55	A5258	312	1990	2
699-52-46A	A5234	225	1980	3	699-55-57	A5259	180	1975	3
699-52-46B	A8841	44	1980	4	699-55-60A	A8868	233	1943	4
699-52-48	A5235	197	1980	3	699-55-60B	A8869	288	1944	4
699-52-52	A8842	903	1974	3	699-55-63	A8871	198	1944	4
699-52-54	A5236	168.6	1990	2	699-55-65A	A8872	136	1944	4
699-52-55	C5861	183.3	2007	1	699-55-65B	A8873	146	1944	4
699-52-55B	C5862	292	2008	1	699-55-65C	A8874	146	1944	5
					699-55-70	A5260	205	1948	3

^1= best, 5 = worst.

Table 2.1. (contd)

Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^	Well Name	Well ID	Total Depth (ft)	Completed	Data Quality Ranking^
699-56-42A	A8885	245	1981	2	699-60-60	A5282	133	1948	4
699-56-42B	A8886	250	1981	2	699-61-53	A8932	385	1978	3
699-56-42C	A8887	354	1981	2	699-61-55A	A8933	249	1976	3
699-56-42D	A8888	670	1981	3	699-61-55B	A8934	327	1976	5
699-56-42E	A8889	700	1981	3	699-61-57	A8935	589	1977	3
699-56-42F	A8890	520	1981	3	699-61-62	A5285	188	1972	2
699-56-43	A5264	155	1971	3	699-61-66	A5286	225	1955	3
699-56-51	A8891	105	1984	3	699-62-43B	A8940	68	1959	3
699-56-53	A5265	270	1982	3	699-62-53	A8953	456	1977	3
699-57-41A	A8896	512	1981	3	699-63-51	A5290	36	1971	3
699-57-41B	A8897	461	1981	3	699-63-55	A5291	121	1972	3
699-57-41C	A8898	430	1981	3	699-63-58	A5292	133	1972	3
699-57-41E	A8900	554	1981	3	699-64-62	A5296	116	1972	3
699-57-41F	A8901	608	1981	2	699-65-50	A5300	585	1955	3
699-57-59	A5269	190.5	1980	2	699-65-59A	A5301	200	1958	4
699-58-41A	A8908	274	1980	2	699-65-59B	A8960	200	1976	3
699-58-41B	A8909	225	1980	2	699-65-59C	A8961	140	1976	3
699-58-41C	A8910	130	1980	3	699-65-72	A5302	216	--	5
699-58-41D	A8911	79	1980	2	699-66-64	A5310	118	1972	4
699-58-41E	A8912	390	1981	3	699-67-51	A5312	250	1961	4
699-58-41F	A8913	600	1981	3	699-69-45	A8967	300	1961	3
699-58-48	A8914	--	--	5	699-70-68	A5319	149	1954	3
699-59-55	A8918	145	1976	5	699-71-52	A5321	210	1954	3
699-59-58	A5277	117	1972	3	699-72-73	A5323	200	1961	4
699-60-53B	A8922	160	1980	5	699-73-61	A5327	150	1962	3
699-60-53C	A8923	150	1980	5					
699-60-53F	A8926	290	1980	5					
699-60-57	A5280	155	1972	3					
699-60-59	A5281	1561	1986	2					

^1= best, 5 = worst.

Early boreholes drilled prior to 1980 generally have only drillers' logs and uncalibrated down-hole natural gamma geophysical logs, but were routinely analyzed for grain-size analysis and sometimes calcium-carbonate ($CaCO_3$) content (an indication of soil development). Drillers would collect sediment samples every 5 ft (1.5 m) and record general descriptions of the drill cuttings and other observations onto drilling-summary forms. Most of the archived sediment samples from these early (pre-1980) wells were subsequently analyzed in the laboratory for grain-size distribution and $CaCO_3$ content; these results are maintained in a database located within the Hanford Virtual Library (http://vlprod.rl.gov/vlib/app/index).

The quality of the grain-size distribution data largely depends on the drilling method used. Before the 1990s, most wells were drilled using a cable-tool drill rig. Those intervals drilled with a hard tool tend to produce more fines because of the pulverizing action of the hard-tool bit. An alternative method is the drive-barrel, which preserves much of the original grain-size distribution and is far superior in producing representative geologic samples.

Sample retrieval is sometimes difficult and often does not permit a determination of the exact depth of contacts. The gross-gamma log is useful for more accurately determining contacts and depths of fine-grained layers, especially those a meter or more thick. However, thin clay and/or silt layers often go undetected on gross-gamma logs due to volume averaging. Geophysical logs (e.g., gross-gamma ray), available for most of the boreholes, are useful for identifying some—but not all—stratigraphic contacts. Geophysical logs sometimes show lithologic differences because of differing amounts of natural gamma-ray emitters (most commonly ^{40}K). The proportion of ^{40}K generally increases with decreasing grain size; therefore, clay and silt generally emit more natural-gamma rays.

Another data source useful for the interpretation of the lithology is moisture content either measured directly in the laboratory on geologic samples or remotely via down-hole neutron logs (Figure 2.2). Within the vadose zone, moisture content generally increases along interfaces between materials with highly contrasting grain size. This is particularly true where high-permeability material (gravel and/or sand) overlies lower-permeability material (sand and/or silt). However, moisture may also concentrate along interfaces where a fine-grained unit overlies a coarse sand or gravel and in fine-grained units themselves due to their greater water-retention capacity.

Using neutron-moisture logs, in combination with gross-gamma logs, further aids in the lithologic interpretation. For example, a sudden moderate increase in gamma-ray activity coincident with an increase in moisture may be indicative of a fine-grained bed. An increase in moisture without an increase in the gross-gamma log may signify a sedimentary interface without the presence of a measurable, less-permeable fine-grained layer.

Most recent boreholes drilled after 1980 have overall better data (geologic descriptions recorded by field geologists, and calibrated geophysical logs) but generally lack any quantitative granulometric (grain size) information. Beginning in the mid-1980s samples were no longer routinely analyzed in the laboratory. Therefore, quantitative grain-size distribution and $CaCO_3$ data are not available for most boreholes drilled since the mid-1980s; these parameters are provided, qualitatively, in geologists' logs.

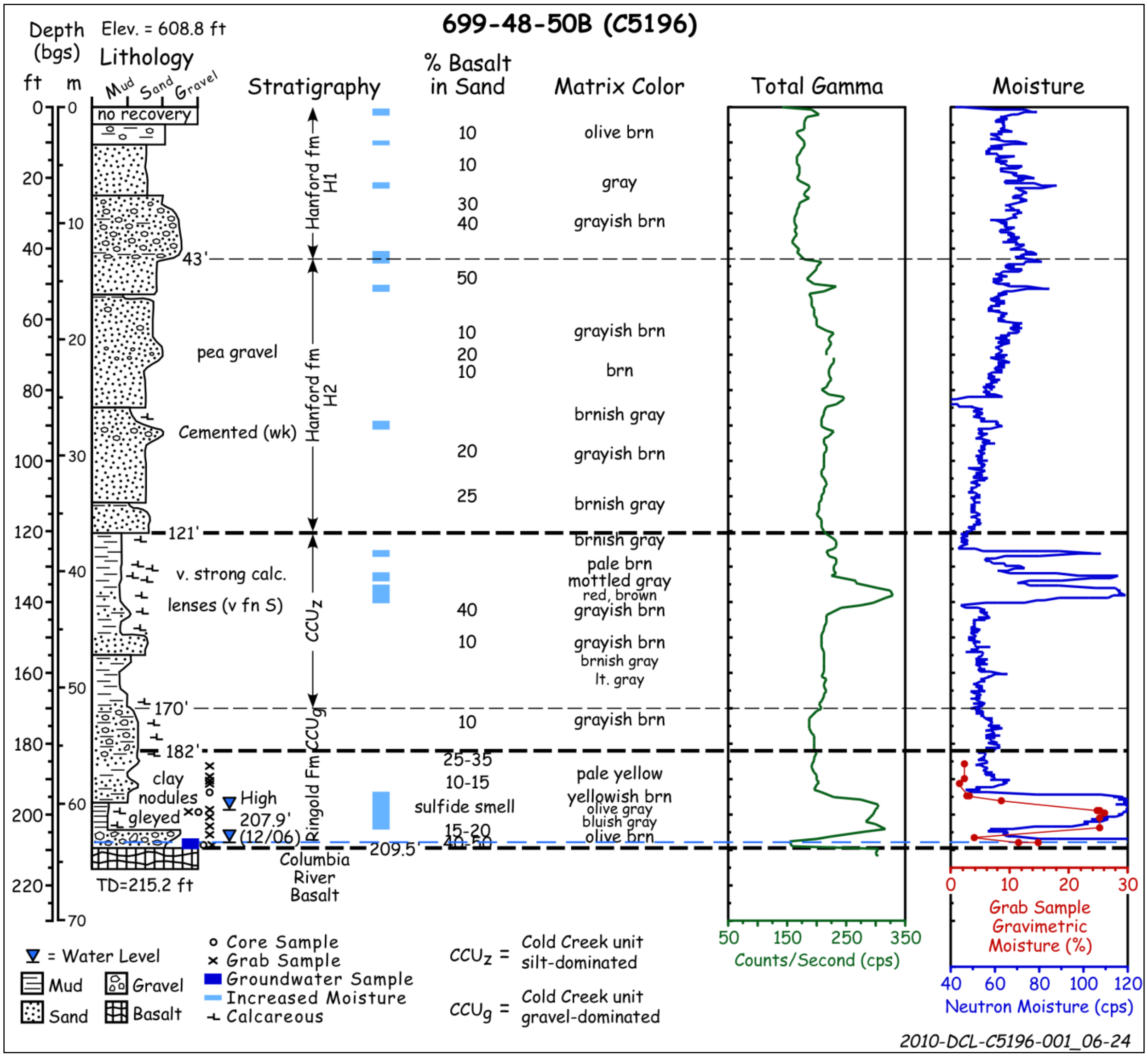


Figure 2.2. Example summary log for Gable Gap well 699-48-50B illustrating the various parameters used to distinguish among stratigraphic units.

Prior to the 1980s, many holes were at least partially drilled via the hard-tool (cable tool) method, which tended to pulverize sediment samples, especially those with high gravel content. Pulverization during drilling has the tendency to skew estimates of grain size and lithology by reducing the size of the coarse (gravel) sedimentary particles and artificially generating more fines. After 1980, there was an increased emphasis on collecting samples via the cable-tooled, core barrel (drive barrel) method, which provided samples that were less fragmented and more lithologically representative of the formation.

Since 2002, a small number of boreholes in the BP-5/Gable Gap area were characterized by collecting nearly continuous, intact sediment core via split-spoon, drive barrel, or direct-push methods. These core samples were described in detail within the laboratory to more accurately evaluate the types and vertical distribution of contaminants within the vadose zone (Brown et al. 2007; Lindenmeier et al. 2002, 2003;

Serne et al. 2002, 2003, 2010). Much of what researchers know about the intact character of the post-basalt sediments was derived from these recent, more-detailed characterization studies.

2.2 Quality Ranking of Boreholes

Because of the wide range in quality of these data associated with the multitude of wells drilled over the past 60 years, each borehole was first examined for the relative quality of the data. Each borehole was assigned a data-quality rank from 1 to 5, with #1 having the highest confidence and least uncertainty in the geologic interpretation (Table 2.1). Those boreholes ranked #5 (least confidence and highest uncertainty) are associated with boreholes with only a driller's log available. In contrast, boreholes ranked #1 (highest confidence and least uncertainty) may have geologist's logs accompanied by gamma and neutron-moisture logs, as well as grain-size, CaCO3, and/or other characterization data.

Boreholes with the highest ranking (#1) include more recently drilled boreholes possessing the most and best quality of data. Ranking is also strongly affected by the drill method, which can alter the original character of the sediments used to distinguish one stratigraphic unit from another. Thus, those boreholes drilled using the open drive-barrel, split-spoon, or direct-push methods generally received a higher ranking than those drilled via the percussion-type, hard-tool method. Data from 36% of the boreholes are considered good quality, while 38% are considered of moderate quality, indicating that overall the data are usable for developing the Gable Gap conceptual model (Figure 2.3).

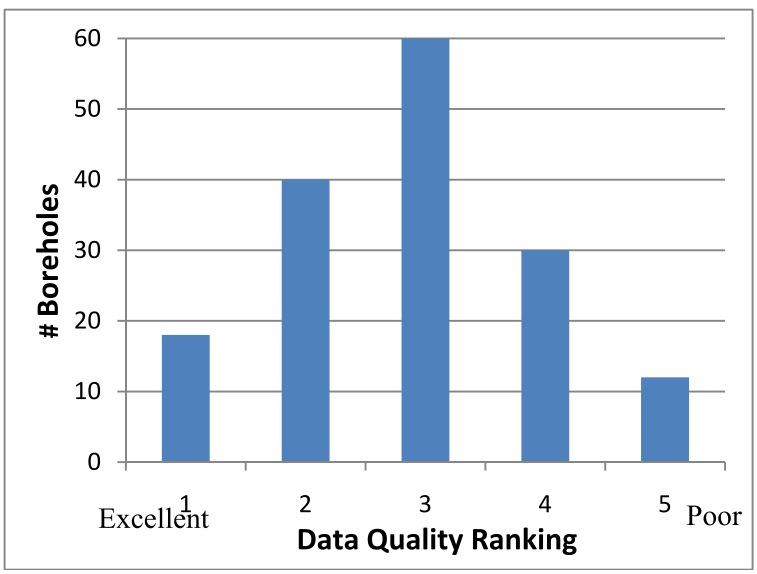


Figure 2.3. Quality ranking comparison of ~150 boreholes in the Gable Gap study area. 1 = highest quality and 5 = lowest quality. About 75% of the boreholes are considered to be of moderate to good quality. The remaining 25% are older boreholes with limited amounts of useful data for evaluating the hydrogeology of the study area.

Nearby boreholes frequently show conflicts in interpreted lithology and stratigraphy. In some cases, true differences may exist between the boreholes, but conflicts are often the result of comparing a sparse data set from an older well with a more robust data set from a modern well. The ranking system provides a way to resolve conflicts among wells; preference is simply given to the higher-ranking wells. Interpretations are therefore justifiably biased in favor of the wells with the greatest quantity and highest quality of data.

2.3 Development of Conceptual Hydrogeologic Model

Defining contact picks for stratigraphic units (Appendix E) from borehole data is an iterative process. The process of building the model followed a series of investigative steps that were designed to honor the data and give preferential treatment to the higher-ranked boreholes. First, the main stratigraphic units and contacts were identified in boreholes ranked #1 or #2. This was done by comparing available data and picking depths to major lithologic contacts (i.e., units with roughly uniform grain size or geologic character). Elevations and thicknesses of the major stratigraphic contacts were then calculated from the depths. The same procedure was next performed on the lower-ranked boreholes.

The next step in building a geohydrologic model of the subsurface was to construct scaled cross sections linking boreholes together. A total of five cross sections (located in Figure 2.4) are presented in Appendix A (Figures A.2 to A.6).

Subsequently, elevations and thicknesses of these major units were spatially plotted onto structure-contour (Appendix B) and isopach (Appendix C) maps. These maps were used to evaluate if the contacts appear realistic and make sense geologically. If the contacts are chosen correctly, the data should plot as relatively smooth surfaces, transitioning from one borehole to another. Isolated, large, steep-gradient "bull eyes" on contour maps indicate the contact may be miscalculated; in these cases, boreholes would be re-evaluated and contacts adjusted as necessary. Structure contour and isopach maps were replotted and further evaluated to ensure the best possible picks were made for each stratigraphic unit. The final spreadsheet of stratigraphic picks used to construct contour maps for the different units is presented in Appendix E. These data are now managed and maintained in the Hanford Geologic Contacts Database at PNNL, with future accessibility through the Hanford Environmental Information System (HEIS).

Another step in developing the hydrogeologic model is to evaluate groundwater-contaminant plumes from nearby waste-management areas. Contaminants are a type of tracer, which conveniently provide a means to evaluate the rate and direction of groundwater flow. Figure 2.5 shows the distribution of two contaminant plumes (uranium and ^{99}Tc) in the vicinity of Gable Gap. The plumes appear to emanate from waste facilities associated with the B-BX-BY Tank Farms (Serne et al. 2010), and move in a northwesterly direction via at least one paleochannel across a buried divide in the basalt bedrock.

2.4 Integration of Geophysics Data

Where available, surface-geophysical surveys (i.e., seismic-reflection profiles) were also used for interpolating the top of basalt between boreholes (Figure 2.5). These data were especially useful for estimating the top of basalt in hydrogeologic cross sections (Figure 2.3; Appendix A). One long and several shorter seismic-reflection lines collected in the late 1970s as part of the Basalt Waste Isolation Project (BWIP) (Holmes and Mitchell 1981; Ault 1981) were evaluated and reprocessed. These have been augmented with data from eight new shorter lines of seismic-reflection lines, totaling 11 km in length, via the Landstreamer device (Repasky et al. 2009). The uppermost reflector observed along seismic-reflection profiles is often interpreted as the top of basalt, which has significantly higher density than the overlying suprabasalt sediments. However, reflection surfaces and other anomalies on seismic profiles can be generated in many other ways, including erosional surfaces, lateral lithologic (i.e., facies) changes, unconformities, faults and folds, poor quality data, seismic-signal attenuation, and inconsistencies in data processing (Holmes and Mitchell 1981). Therefore, the uppermost seismic-reflector may not always represent the top of basalt, and the seismic data need to be carefully evaluated with other reflection sources in mind. Lithologic data collected in boreholes should always be honored foremost, and where present, used to effectively constrain and calibrate the seismic data.

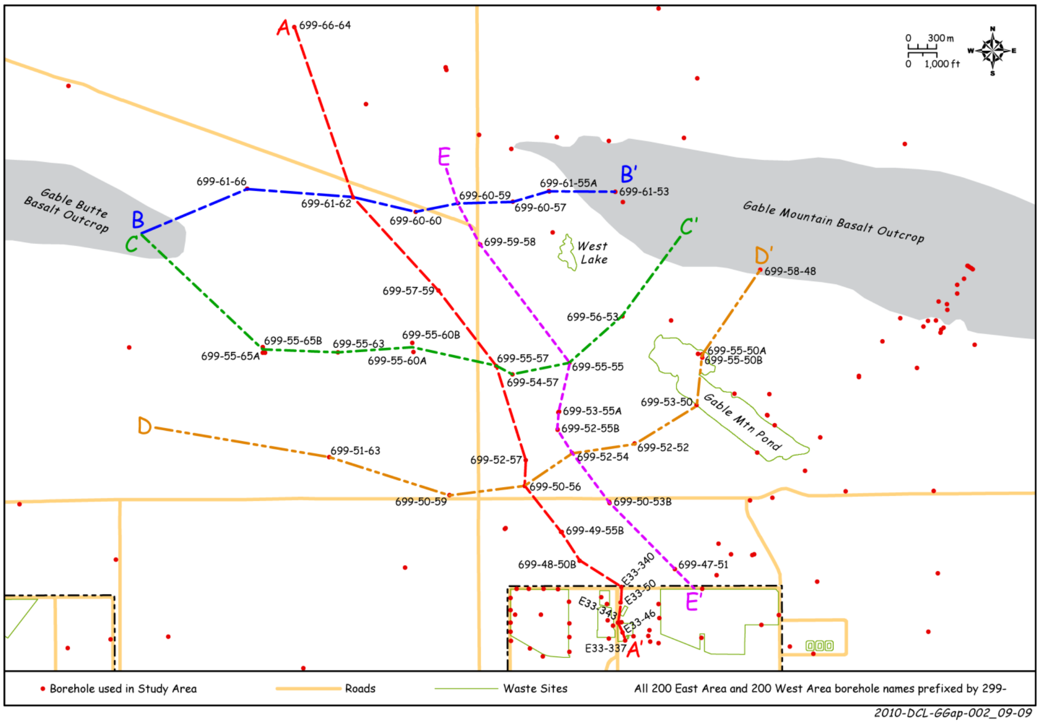


Figure 2.4. Locations of five hydrogeologic cross sections within the study area. See Appendix A for cross sections.

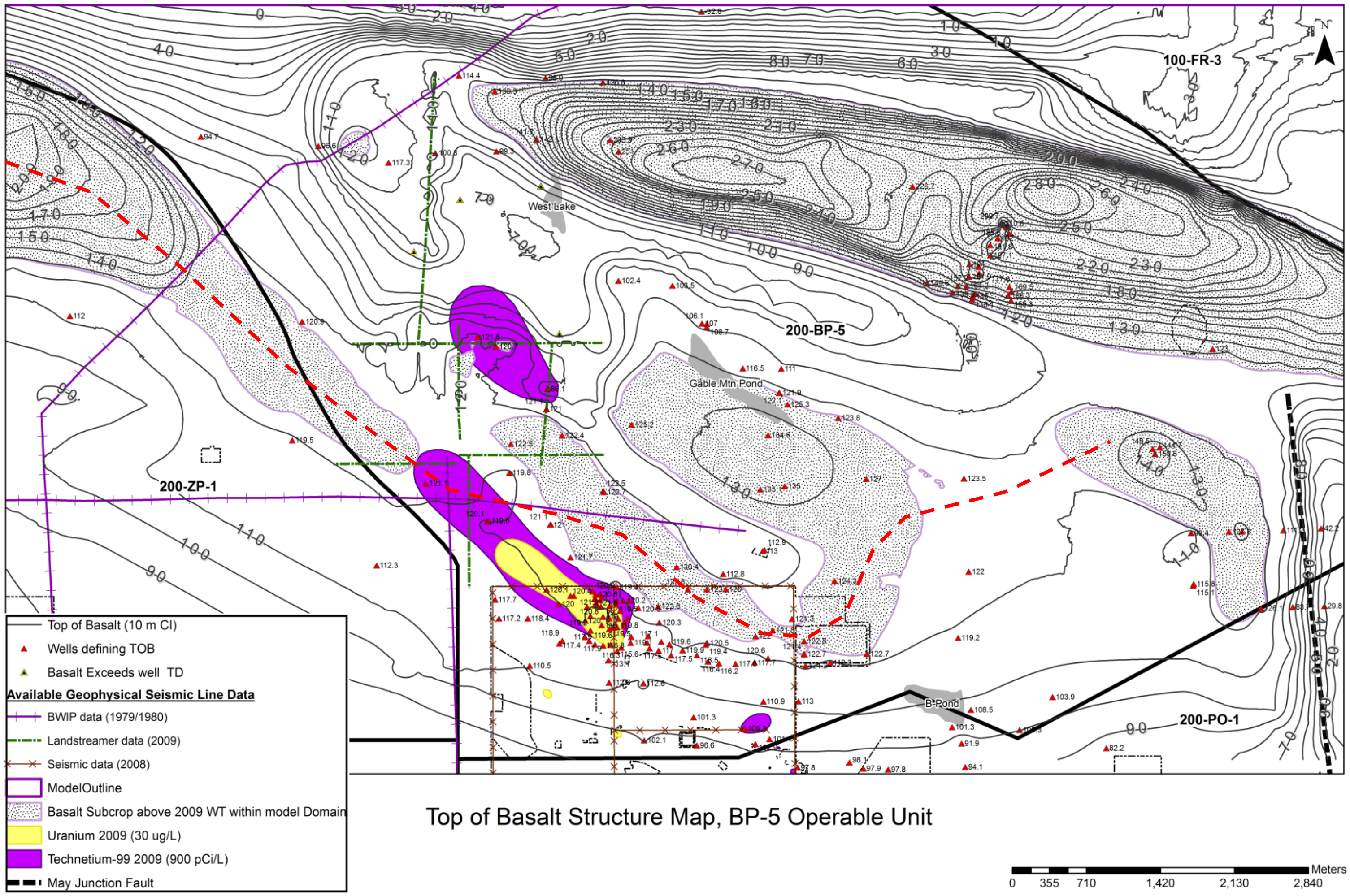


Figure 2.5. Latest top of basalt interpretation based on borehole and seismic-reflection-survey data in the Gable Gap area. Also shown are groundwater-contaminant plumes for uranium and ^{99}Tc in the vicinity of Gable Gap. Purple lines are seismic lines collected in 1979-1980 as part of the BWIP Project (Ault 1981); green lines show locations of Landstreamer seismic-reflection surveys (Repasky et al. 2009). Note: top of basalt contours are in meters. Dashed red line connects high points of basalt divide.

3.0 Regional Geologic Setting

The Hanford Site and Pasco Basin lie within the Columbia Plateau of southeastern Washington State. This broad plain, situated between the Cascade Mountains to the west and the Rocky Mountains to the east, is underlain by a thick sequence of volcanic Columbia River basalt, which forms the basement rock for the region.

The generalized stratigraphy beneath the Hanford Site consists of, in ascending order, the Columbia River Basalt Group (CRBG) and intercalated sediments of the Ellensburg Formation, the Ringold Formation, the Cold Creek unit (formerly named the Plio-Pleistocene unit), and the Hanford formation (Figure 3.1). The Cold Creek unit and Hanford formation are both informal designations. Thin veneers of Holocene alluvium, colluvium, and/or eolian sediments discontinuously overlie these principle geologic units. The regional suprabasalt stratigraphy is described in more detail elsewhere (DOE 1988; Lindsey 1995, 1996; DOE/RL 2002).

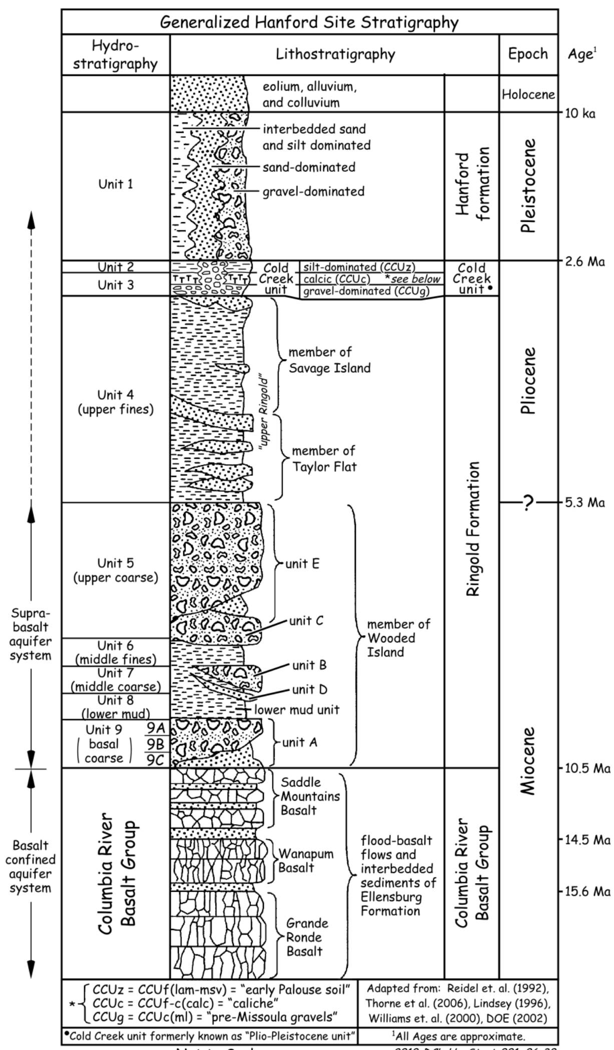


Figure 3.1. Regional stratigraphy for the Pasco Basin and Hanford Site. Modified after DOE/RL (2010).

3.1 Columbia River Basalt Group and Ellensburg Formation

The CRBG in eastern Washington is divided into three formations: 1) Grand Ronde Basalt, 2) Wanapum Basalt, and 3) Saddle Mountains Basalt (Figure 3.2). About 300 separate flows have been identified; the basalt reaches its maximum thickness, ~15,000 ft (4570 m), in the southern Pasco Basin. The last basalt flows to reach the Pasco Basin occurred between 8.5 to 10.5 million years ago (DOE 1988). The extrusion of volcanic basalt flows occurred very rapidly at first and then slowed down over time. More time between basalt eruptions allowed for more accumulation of sediments between the younger basalt flows (i.e., Saddle Mountains Basalt). The sedimentary interbeds of the Ellensburg Formation, along with the porous basalt flow tops and bottoms, form confined aquifers that may extend across the Pasco Basin (DOE 1988).

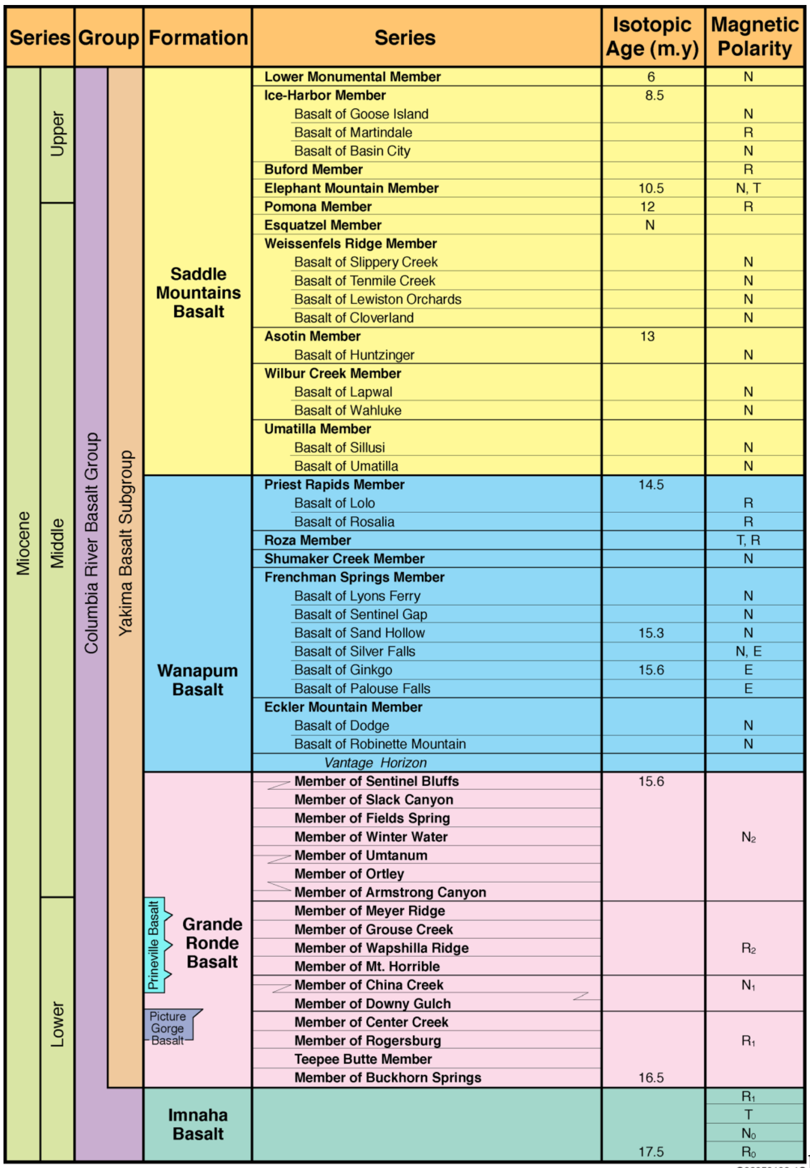


Figure 3.2. Stratigraphic nomenclature for the Columbia River Basalt Group. All basalt formations but the Imnaha Basalt are present in eastern Washington State. Source: Martin et al. (2005).

The basalt flows and interbeds have been folded and faulted, creating broad structural and topographic lows, separated by tighter asymmetric anticlinal ridges. Tectonic folding and faulting, which began with extrusion of the CRBG, continues to the present day (Reidel 1984; DOE 1988). Sediments of late Miocene, Pliocene, and Pleistocene age have accumulated up to 1700 ft (520 m) thick in the Pasco Basin, one of the larger structural basins. The Pasco Basin is partially bisected by the first-order Umtanum Ridge-Gable Mountain anticline creating two subordinate synclinal basins (Cold Creek and Wahluke synclines).

3.2 Suprabasalt Sediments

3.2.1 Ringold Formation

The Ringold Formation records fluvial-lacustrine deposition associated with the ancestral Columbia River drainage system, following the last eruption of basalt at the Hanford Site (Tallman et al. 1981; DOE 1988; Lindsey 1995, 1996). Deformation of the Yakima folds, which began in the middle Miocene Epoch coincident with emplacement of the Columbia River basalt flows, continued into Ringold time so the centers of down-warped basins received more sediment than the margins. The Ringold Formation is up to 600 ft (185 m) thick in the center of the basin and pinches out against the basin-bounding basalt ridges.

The Ringold Formation consists of semi-indurated clay, silt, fine- to coarse-grained sand, and variably cemented, multilithic, granule to cobble gravel. Ringold Formation sediments have been classified into five sediment facies associations:

1. fluvial gravel
2. fluvial sand
3. overbank deposits
4. lacustrine deposits
5. alluvial fan deposits.

See Lindsey (1995, 1996) for more detailed descriptions of these facies.

3.2.2 Cold Creek Unit

After a period of post-Ringold incision, the eroded surface of the Ringold Formation was locally weathered and/or covered with accretionary deposits of the Cold Creek unit. These deposits consist of fluvial, eolian and/or colluvial sediment, often pedogenically altered (DOE/RL 2002). The Cold Creek unit includes those deposits formerly referred to as the “Plio-Pleistocene unit” and “Pre-Missoula Gravels,” as well as the “early Palouse soil” and “caliche layer” within the 200 West Area. These deposits were renamed because of the uncertainty in their exact age, and to better reflect their geographic extent, which is generally confined to the boundaries of the Cold Creek syncline within the west-central Pasco Basin (DOE/RL 2002).

Five different facies of the Cold Creek unit have been differentiated based on grain size, sedimentary structure, sorting, roundness, fabric, and mineralogic composition (DOE/RL 2002). These facies include the following:

1. fluvial-overbank and/or eolian (early Palouse soil)
2. calcic paleosol (caliche)
3. mainstream alluvium (Pre-Missoula Gravels)
4. colluvium
5. sidestream alluvium.

3.2.3 Hanford Formation

The Hanford formation is an informal name used within the Pasco Basin to describe Pleistocene-age cataclysmic flood deposits (Tallman et al. 1979, 1981; DOE 1988; DOE/RL 2002). Ice-Age floods originated from outbursts of glacial Lake Missoula, as well as other ice-dammed lakes (Baker and Bunker 1985), pluvial lake Bonneville (O'Connor 1993), or possible subglacial floods (Shaw et al. 1999) associated with the Cordilleran Ice Sheet. At least one flood also occurred from the draining of glacial Lake Columbia at the very end of the Ice Age (Bjornstad 2006). The Hanford formation may include some minor fluvial, colluvial, and/or eolian deposits interbedded with flood deposits.

As mentioned above, the Hanford formation consists predominantly of unconsolidated sediments that cover a wide range in grain size, from boulder-size gravel to sand, silty sand, and silt. The sorting ranges from poorly sorted (for gravel facies) to well sorted (for fine sand to silt facies). Traditionally, the Hanford formation has been subdivided into three lithofacies (gravel dominated, sand dominated, and interbedded sand and silt-dominated), which grade into one another both vertically and laterally (DOE/RL 2002).

The interbedded sand- and silt-dominated facies (DOE/RL 2002) occurs in backflooded, slackwater areas marginal to the Ice Age floods. As such, this facies is not present in the vicinity of Gable Gap due to extremely high-energy, turbulent flood flow through the Gap. Sand-dominated facies of the Hanford formation consist of relatively thick ($\geq$1 m), predominantly horizontally laminated, loose, basalt-rich, fine- to coarse-grained sand, sometimes grading upward into a thinner sequence of ripple-laminated fine sand to silt. Typically, sand-dominated facies contain approximately equal amounts of mafic (i.e., basalt) and quartz-feldspar grains (Tallman et al. 1979); this composition gives the Hanford formation its characteristic "salt and pepper" appearance. Gravel-dominated facies consist of loose, massive to horizontal and large-scale, planar-tabular cross-bedded, poorly sorted mixtures of gravel, sand, and silt. Gravel clasts in flood gravels generally consist of 50% to 75% subangular to subrounded basalt (DOE/RL 2002). Rounded rip-up clasts of caliche and/or semi-indurated silt and clay are common in the gravel-dominated facies.

Below an elevation of approximately 1,000 ft (300 m) within the central Pasco Basin, the Hanford formation unconformably overlies the Cold Creek unit, and where the unit is not present, lies directly on the Ringold Formation or Columbia River basalt. Within the central Pasco Basin buildup of flood deposits occurred along Priest Rapids, Cold Creek and Gable Mountain flood bars, which developed as the floods initially expanded into the Pasco Basin (Figure 3.3). The bulk of the vadose zone at the Hanford Site lies within Ice Age flood sediments of the Hanford formation.

Ice-Age floods created the Cold Creek Bar, a giant, streamlined deposit of mostly gravel and sand that extends for 12 miles downstream of Umtanum Ridge (Figure 3.3). Gravel-dominated deposits, laid down under the strongest flood currents, are generally restricted to the north side of the bar. At the southern end of the bar, where flood currents were less vigorous, sand-dominated sediments were laid down. The Hanford formation reaches its maximum thickness (~300 ft [100 m]) in the sand-dominated facies beneath the Cold Creek Bar just south of the study area.

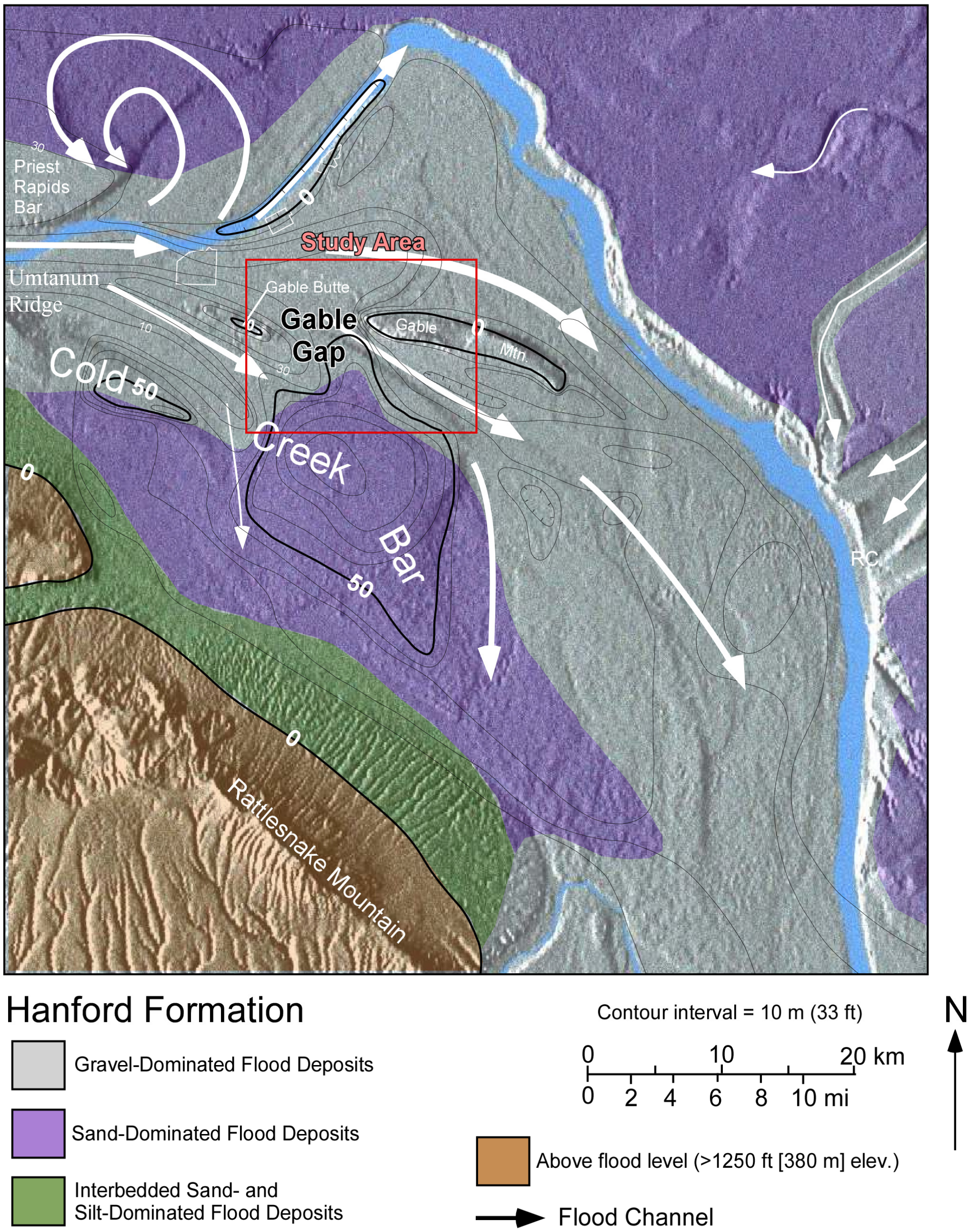


Figure 3.3. Thickness and distribution of cataclysmic flood deposits (i.e., Hanford formation) within the central Pasco Basin. Modified after DOE/RL (2002).

4.0 Stratigraphy and Lithology of Gable Gap

The following discussion on the hydrogeology of Gable Gap presents background information on the stratigraphy, lithology, structure, paleogeomorphology, and hydrology, which forms the basis for the three-dimensional hydrogeologic model developed herein.

A total of nine stratigraphic units are recognized in the Gable Gap area (Figure 4.1).

- Recent eolian or backfill material
- Hanford formation - upper gravel-dominated sequence (H1 unit)
- Hanford formation – sand-dominated sequence (H2 unit)
- Hanford formation - lower gravel-dominated sequence (H3 unit)
- Cold Creek unit – silt-dominated subunit
- Cold Creek unit – gravel-dominated subunit
- Ringold Formation (undifferentiated)
- Columbia River Basalt Group (CRBG)
- Sedimentary interbeds between Columbia River basalt flows (Ellensburg Formation).

Stratigraphic relationships and images for these units are illustrated in Figures 4.1 and 4.2, and tabulated in Table 4.1. Hydrogeologic cross sections (e.g., Figure 4.2) displaying more of the stratigraphic and structural relationships among lithologic units are presented in Appendix A. Structure-contour and isopach maps for most of the units are also presented in Appendices B and C, respectively. As illustrated in these appendices, all but the Hanford formation H1 unit are discontinuous across the Gable Gap study area. More detailed discussions of each unit, beginning with the oldest unit, are presented in the following sections.

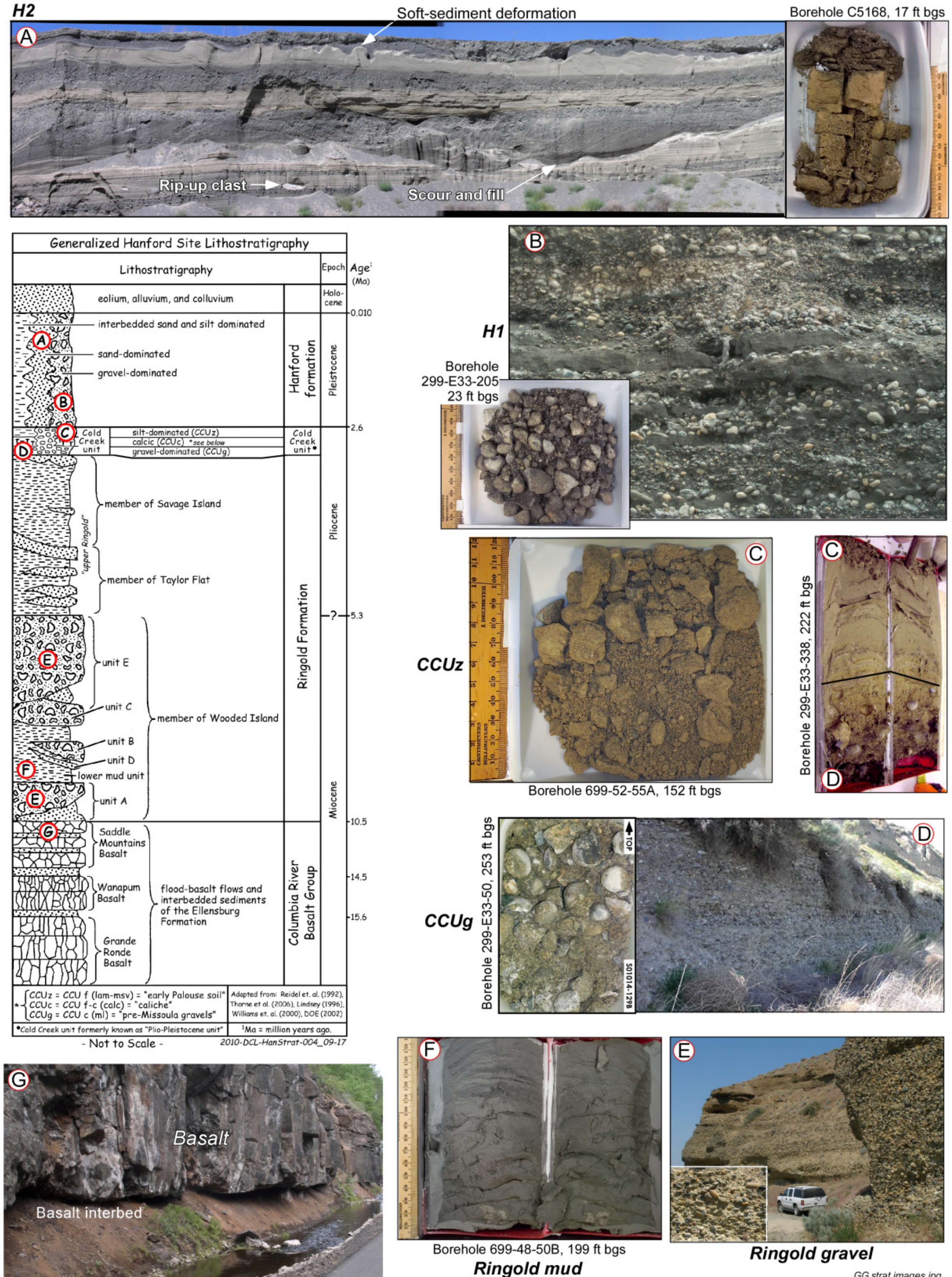


Figure 4.1. Hanford Site stratigraphy. Photos show examples of strata, both in drill core and outcrop, which are representative of the Gable Gap study area. Borehole number and depth of sample below ground surface (bgs) are shown where appropriate.

4.1 Columbia River Basalt Group and Interbedded Sediments of the Ellensburg Formation

The surface of the volcanic CRBG forms the bedrock base beneath sedimentary deposits over the Hanford Site. Volcaniclastic sedimentary interbeds of the Ellensburg Formation accumulated between basalt flow eruptions. Sediments of the Ellensburg Formation commonly thin or disappear in adjacent anticlines that lay above the ancient valley floors.

The Elephant Mountain Member of the CRBG's Saddle Mountains Basalt (Figure 4.2) is the youngest basalt flow within the Gable Gap study area and where present forms the basement rock (Figure 4.3). The Elephant Mountain Member has been dated by the K-Ar method to be about 10.5 Ma (McKee et al. 1977) and consists of two flows beneath the 200 East Area. However, within the northern portion of Gable Gap, the uppermost basalt flows that include the Elephant Mountain Member, were locally folded, faulted, and subsequently eroded by the ancestral Columbia River and Pleistocene Ice Age floods (Figures 4.3 and C.10). A large erosional window exists across a sizable portion of the gap where the Elephant Mountain Member was completely eroded, exposing older basalt flows and the Ellensburg Formation to the unconfined aquifer. Locally, this erosional window extends all the way down to the Umatilla Member of the CRBG. This deep cavity allows hydraulic communication between confined and unconfined aquifers in this area (Strait and Moore 1982; Graham et al. 1984; Jensen 1987). Both north and south of the anticlinal axis at Gable Gap, however, the basalt of the Elephant Mountain Member forms a continuous unit that dips uniformly into synclinal basins on either side.

The Ellensburg Formation consists mostly of fine-grained tuffaceous beds of clay and silt, interstratified with sandy layers (see Figures A.1, A.3, and A.5). No gravel facies are reported for the Ellensburg Formation within the study area, except locally within the uppermost interbed (Rattlesnake Ridge) along the basal contact with the Pomona Member (Jensen 1987). The Rattlesnake Ridge interbed is up to 60 ft (18 m) thick in the study area (see Figure C.10); however, it was totally removed by erosion associated with the ancestral Columbia River and/or Ice Age floods within Gable Gap where it crosses the axis of the Umtanum Ridge-Gable Mountain anticline.

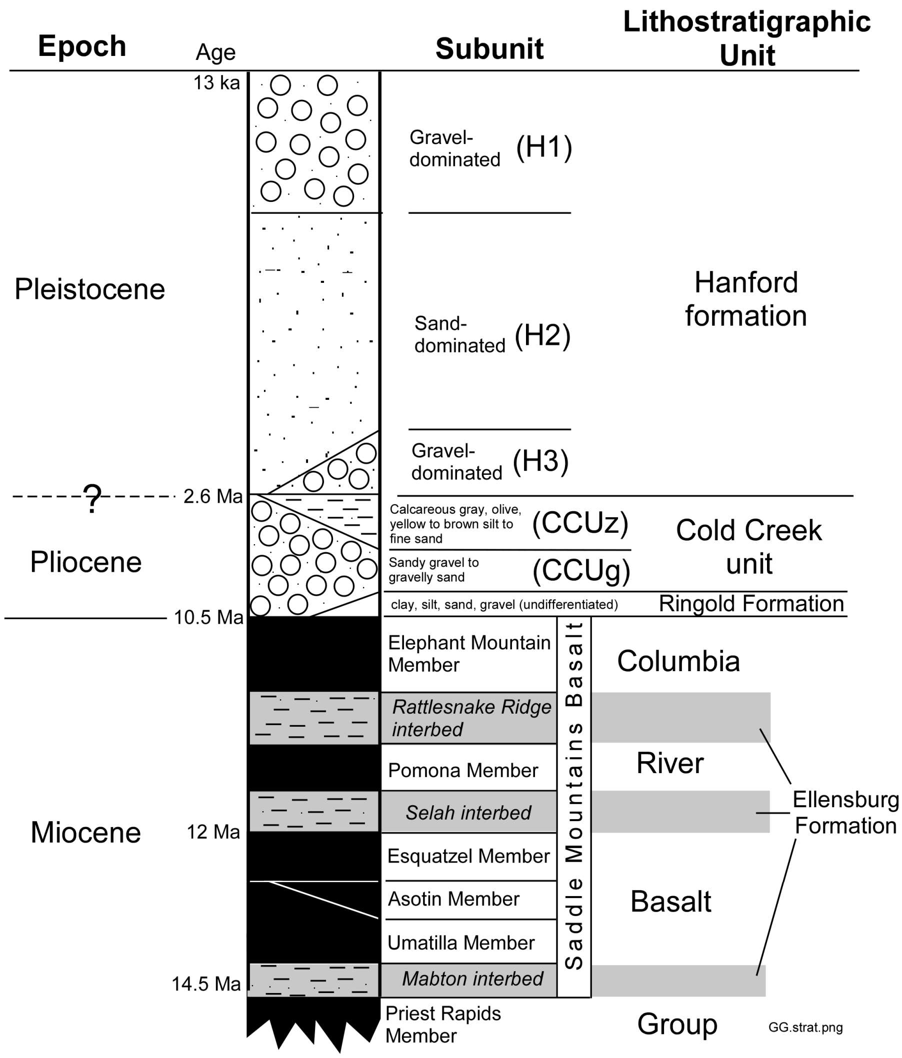


Figure 4.2. Stratigraphy in the vicinity of Gable Gap

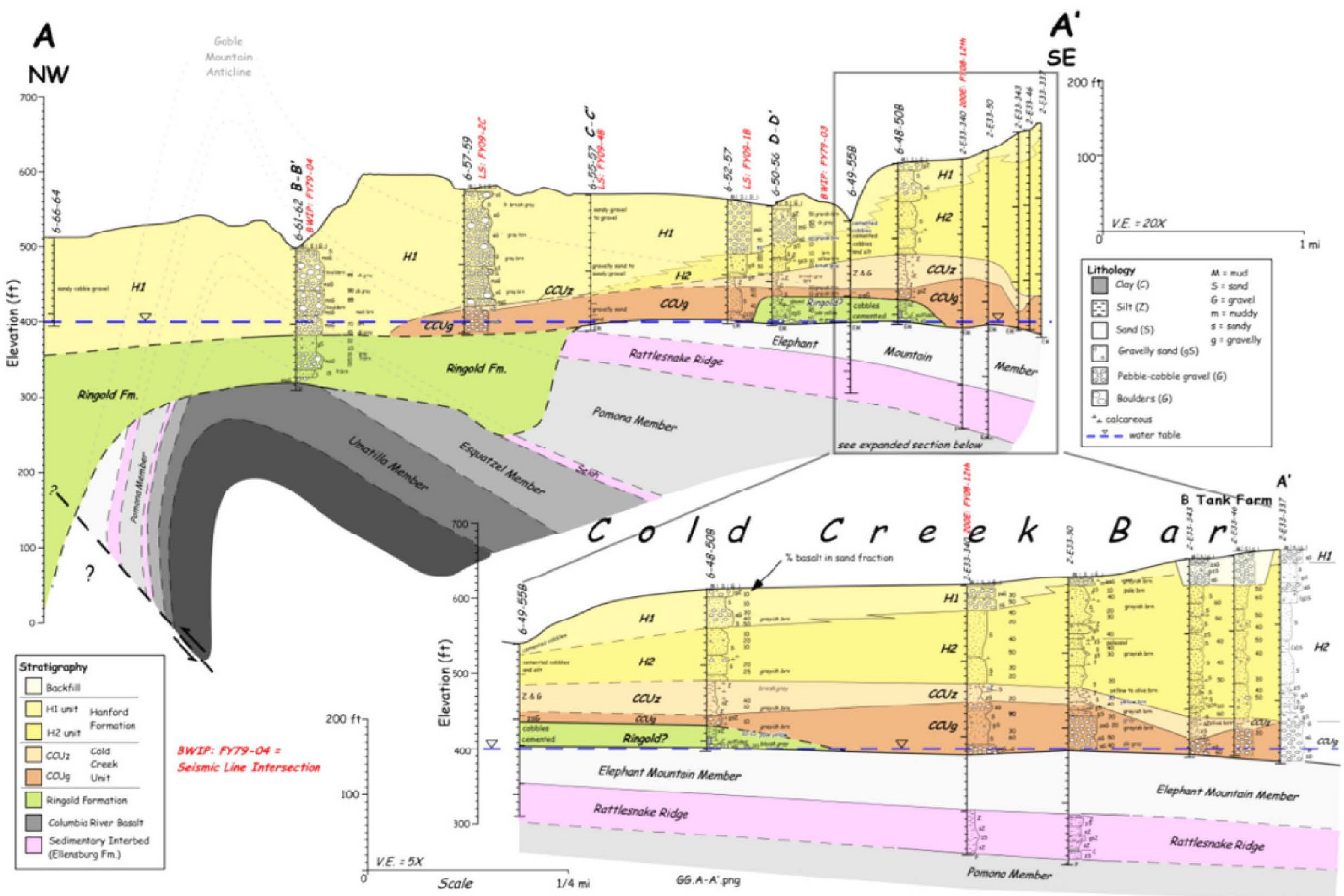


Figure 4.3. Example hydrogeologic cross section (A-A') for Gable Gap. See Figure 2.4 for location and Appendix A for other cross sections.

4.2 Suprabasalt Sediments

Suprabasalt sediments are those deposits that lie above and are younger than the basalt flows of the CRBG and interbedded sediments of the Ellensburg Formation. The suprabasalt sediments in Gable Gap include the Ringold Formation, the Cold Creek unit, and the Hanford formation. The characteristics of these stratigraphic units are summarized in Table 4.1. A thin veneer of Holocene sediments (eolian sand, slopewash, or manmade backfill) also locally covers the surface.

4.2.1 Ringold Formation

Only a few thin, erosional remnants of the fluvial-lacustrine Ringold Formation are preserved within Gable Gap; these lie mostly within Ringold-age paleochannels and beneath protective caps of the cohesive Cold Creek unit silt (CCUz) (see Figures A.2 to A.5). At one time, the Ringold Formation was much thicker and more widely distributed across the Gable Gap area when it filled the Pasco Basin to ~900 ft (274 m) elevation (Lindsey 1995) during the late Miocene to Pliocene time (10.5-3.4 Ma). However, either during, or since, Ringold time uplift of the Umtanum Ridge-Gable Mountain anticline caused subsequently incision and removal of the Ringold Formation. Additional downcutting occurred via the post-Ringold Columbia River, followed by scouring from multiple, cataclysmic Ice Age floods.

Figure C.8 shows the wells within Gable Gap that encountered the Ringold Formation. These wells are mostly restricted to lower-elevation paleochannels or margins of paleochannels within Gable Gap. In general, the Ringold sediments in Gable Gap wells represent a variety of different lithofacies (see Figures 4.3 and 4.4) from fine-grained silt and clay to sand and gravel. Because only a thin sequence and

gg.ringold.png

Figure 4.4. Erosional remnants of the Ringold Formation in Gable Gap well 699-48-50B (C5196). See borehole location map in Figure 2.1. Left: Weakly laminated, pale yellow, micaceous, well-sorted, fine- to medium-grained sand. Note the felsic composition with only a few percent dark mafic grains, 194 ft (59 m) depth. Right: Well-laminated, slightly plastic, clayey silt from 199-ft (61-m) depth. The gleyed (olive gray) color and sulfide smell of these sediments are indicative of ongoing chemical reduction within this facies. Both of these Ringold sediments are interpreted as fine-grained, fluvial-overbank deposits of the ancestral Columbia River. See also summary log for this well in Figure 2.2.

multiple lithofacies of the Ringold Formation are represented in Gable Gap, it is presently not possible to positively identify to which specific Ringold units (i.e., Lindsey 1995; Williams et al. 2000) these sediments belong. For this report, we are designating gravelly Ringold facies as belonging to Ringold Formation unit A, and overlying fine-grained strata to the Ringold lower mud unit. These units may or may not correlate with similarly named units outside the Gable Gap study area.

Distinguishing characteristics of the gravel-dominated Ringold facies (described in Table 4.1) are generally moderately sorted and bimodal consisting of rounded, clast-supported, pebble-cobble conglomerate in a sand to silt matrix. The sand fraction is predominantly light-colored and felsic (quartz, feldspar, and mica) with only a few percent mafic grains. Individual sediment grains and clasts in coarser Ringold facies are frequently coated with a red, yellow, orange, and/or brown cement that weakly to moderately binds particles together. Gravel clasts are normally described as multilithic and often display clay coatings. Gravels are composed of a mixture of mostly quartzite, granitic, gneissic, and basalt clasts. Basalt clasts in particular often show significant weathering rinds while granitic/gneissic clasts can be strongly weathered and friable—all signs of significant in-situ weathering caused by millions of years of contact with groundwater. Ringold gravel clasts are typically highly rounded and polished, characteristic of a fluvial setting (i.e., ancestral Columbia River). Another characteristic of the gravel-dominated Ringold Formation is its ability to maintain an open-hole during drilling due to its older age, which produces sediments that are more compacted, cemented, and/or consolidated.

Finer-grained Ringold strata are also present in Gable Gap; these are composed of interstratified beds of massive to laminated clay, silt, and sand (Figure 4.4).

4.2.2 Cold Creek Unit

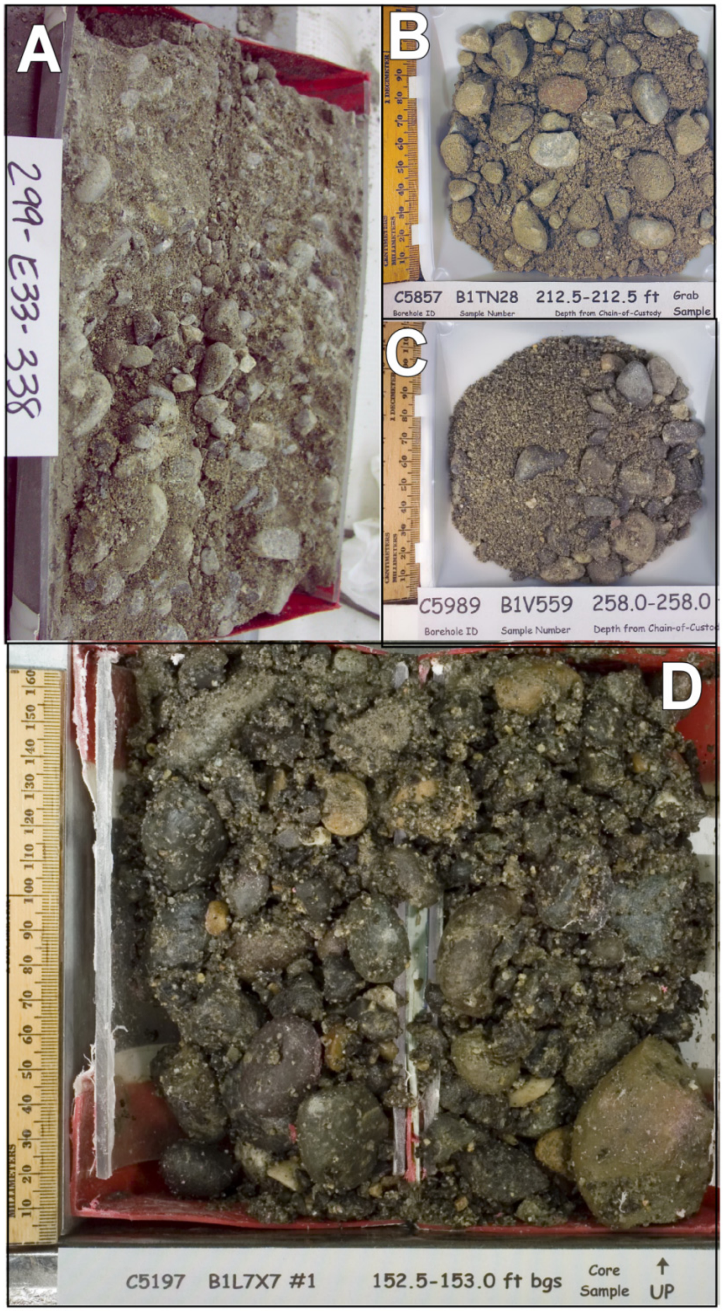
A geologic unit of late Pliocene to possibly early Pleistocene age is also present in the vicinity of Gable Gap. The unit consists of a thick (up to 55 ft [17 m] in well 699-49-55A) layer of fine-grained, well-sorted, calcareous silt and/or fine sand that generally lies several tens of feet above the top of basalt. Two different facies of the Cold Creek unit (DOE/RL 2002) appear to be present in Gable Gap: 1) a gravel-dominated subunit (CCUg), overlain by 2) a fine-grained, silt-dominated subunit (CCUz).

Gravel-Dominated Subunit (CCUg). The lower portion of the Cold Creek unit in Gable Gap typically consists of multilithic sand and gravel, similar to the Ringold Formation, except for a higher concentration of basalt clasts (Figure 4.5). However, unlike the Ringold Formation, the Cold Creek unit gravels (CCUg) subunit generally lacks significant weathering and/or consolidation, due to its generally younger age (~2 to 3 million years, compared to up to 10 million years for the Ringold Formation) (see Figure 4.1). The CCUg contains a moderate amount (generally 20-50 vol%) of basalt in the sand fraction. This is an intermediate composition between that of the Ringold Formation (generally 0-10%) and the Hanford formation (40-90%), although there can be some overlap in the mafic content for the different stratigraphic units. The loose, unconsolidated, and generally unweathered nature of CCUg suggests this subunit is post-Ringold Formation in age. These facies likely represent fluvial deposits from the main channel of the ancestral Columbia River, which incised into and reworked the older, more felsic Ringold Formation, which was mixed with alluvium from other, more-local, basalt-dominated sidestreams. The CCUg typically displays various shades of gray, including brown and olive.

Table 4.1. Characteristics used to distinguish between suprabasalt stratigraphic units within Gable Gap

Stratigraphic Unit	Lithofacies	Age	Principal Lithology	Subordinate Lithology	Depositional Process	Depositional Environment/ Spatial Distribution	Matrix Color	% Basalt (Mafic) in Sand Fraction	General Gravel Roundness	Sorting	Structure	Calcium Carbon-ate (wt%)	Induration	Natural-Gamma Response	Other Characteristics
Hanford formation	Sand-dominated (H2 unit)	Pleistocene	Fine- to coarse-grained sand (S)	Lenses of pebbly sand (gS), silty fine sand (mS), fine sandy silt (sM); thin, weakly developed paleosols	Ice-age cataclysmic flood	Moderate to high-energy flood deposition in areas marginal to high-energy flood currents, including most of Cold Creek bar (200 Area Plateau)	Brownish gray to olive gray	40-90	Subangular to subrounded	Moderate to well sorted	**Low-angle horizontal laminations;** normal and reverse gradations (rhythmites); occasional cut and fill	2-10	Loose	Consistently low	**"Salt and pepper"-like appearance; graded, rhythmic bedding;** clastic dikes; soft-sediment deformation along bed contacts; where exposed individual beds can be traced laterally for tens of meters or more; localized minor cut and fill channels; occasional rip-up clasts
	Gravel-dominated (H1 and H3 units)	Pleistocene	Sandy gravel (sG) to silty sandy gravel (msG)	Lenses and sheets of pebbly sand (gS); fine- to coarse-grained sand (S)	Ice-age cataclysmic flood	High-energy flood deposits within and along cataclysmic flood channels	Dark gray, brownish gray, to olive gray	40-90	Subangular to subrounded	Poor to moderately sorted	Horizontal to **large-scale planar-tabular (i.e., foreset) cross-bedding;** cut and fill	2-5	Loose	Consistently very low	**Basaltic; silt coatings** on gravel clasts; laterally discontinuous beds with **ubiquitous cut and fill channels;** unconsolidated, fine-grained, angular **rip-up clasts** common; **boulders**, **caving hole**
Cold Creek unit	CCUz	Late Pliocene to early Pleistocene	Fine sand and silt, (S, mS, sM, M)	Thin, weakly developed paleosols	Fluvial and/or eolian	Fluvial overbank to eolian deposits; mostly limited to beneath 200 West Area	**Buff, pale to dark brown, olive brown**	<5	NA	**Well sorted to very well sorted**	Laminated and bedded to massive	5-20	Moderately to very strongly cohesive/ compact	**Consistently high**	**Micaceous;** weakly to moderately calcareous
	CCUg	Late Pliocene to early Pleistocene	Sandy gravel (sG) to silty sandy gravel (msG)	Well sorted, medium- to coarse-grained sand (S) to pebbly sand (gS)	Mainstream fluvial	Alluvial deposits from ancestral Columbia River found in central Pasco Basin near Southeast Anticline and southeast of Gable Gap	Light gray to olive gray, **"whitish" or "bleached" clast coatings**	20-50	**Subrounded to well rounded**	Moderately sorted, bimodal	Unknown because unit is has only been described from drill cuttings, which do not preserve sedimentary structure	0-5	Loose to weakly compacted and/or cemented	Consistently low to moderate	**Multilithic** gravels; unaltered to slightly altered, locally carbonate cemented; open hole possible
Ringold Formation	Coarse	Miocene to Pliocene	Sandy gravel (sG) to silty sandy gravel (msG)	Gravelly sand (gS) to sand (S)	Mainstream fluvial	Alluvial channel and crevasse-splay deposits	Rusty brown, orange, or yellow	0 to 10%	**Subrounded to well rounded**	Moderately sorted, bimodal	Bedded to massive	0-3	Weakly to semi-consolidated	Variable	**Weathering rinds, clay skins, multilithic; pervasive rusty brown color, felsic matrix; open hole common**
	Fine	Miocene to Pliocene	Clay (C) to silt (Z)	Sand lenses, paleosols	Fluvial-lacustrine	Overbank alluvial or lake	**Brown, orange, yellow to gleyed grey, olive, green, or blue**	0	N/A	Well sorted to very well sorted	Laminated to massive	0-15	Cohesive and compact	Consistently high	**Gleyed color**

Note: Diagnostic features in red type.
N/A = Not applicable.



GG.CCUg.png

Figure 4.5. Gravel-dominated facies of the Cold Creek unit (CCUg) from boreholes in the vicinity of Gable Gap. A) Grayish brown, silty sandy gravel in core from well 299-E33-338; 233 ft (71 m) depth. B) Comparable drill cuttings from well 299-E33-342; 212.5 ft (65 m) depth. C) 299-E33-205; 258 ft (78 m) depth). D) 699-50-56; 153 ft (47 m) depth. Note the general lack of consolidation and moderate amount of basalt in the sand fraction. The few very well rounded and polished pebbles and cobbles are likely older, reworked Ringold Formation clasts.

Silt-Dominated Subunit (CCUz). A locally thick, silt-dominated sequence preserved in Gable Gap is dissimilar to either the Ringold Formation or the overlying Hanford formation. Drill samples show the unit to be well-sorted, weakly stratified silt to micaceous, silty fine sand (Figure 4.6). Colors are various shades and combinations of olive and brown. Calcareous horizons within the unit appear to represent periods of calcic soil development during accumulation of the strata. Owing to the high silt content, the CCUz subunit is generally cohesive and compact, which likely prevented complete disintegration and erosion by Ice Age floods. This subunit is interpreted to represent deposition within an overbank-fluvial environment, associated with the ancestral Columbia River. Massive intervals in the CCUz may also be present, suggesting eolian deposition may also have occurred locally. These silt-dominated deposits could be equivalent or partially equivalent to the similar-appearing deposits of the Cold Creek unit that overlie the calcrete horizon(s) (Cold Creek unit - caliche [CCUc] facies) in the 200 West Area (DOE/RL 2002).

GG.CCUz.png

Figure 4.6. Cold Creek unit silt (CCUz). Left: Percussion core of micaceous, olive-brown, laminated silt from borehole 299-E33-45; 224 ft (68 m) depth. Note: Original stratification of drab-colored silt still preserved. Right: Drill cuttings of compact and cohesive CCUz from borehole 299-E33-343; 235 ft (72 m) depth.

The CCUz subunit exists as an unusual, elongated buried mound that begins near the B Tank Farm in the northern 200 East Area and trends northwest toward Gable Gap (Figures 4.7, A.2, A.5, B.5, and C.6). The buried mound is elongated parallel to the direction as the floodwaters that swept through Gable Gap, suggesting the mound may be a streamlined landform molded by the floods. Similar streamlined landforms are a common occurrence on the surface of the Channeled Scabland (Figure 4.8) where the floods eroded through the silt-dominated Palouse Formation (Baker 1978). Minor beds of sand may also occur within the CCUz, especially in the thicker, silt-dominated sequences (see Figure 2.2).

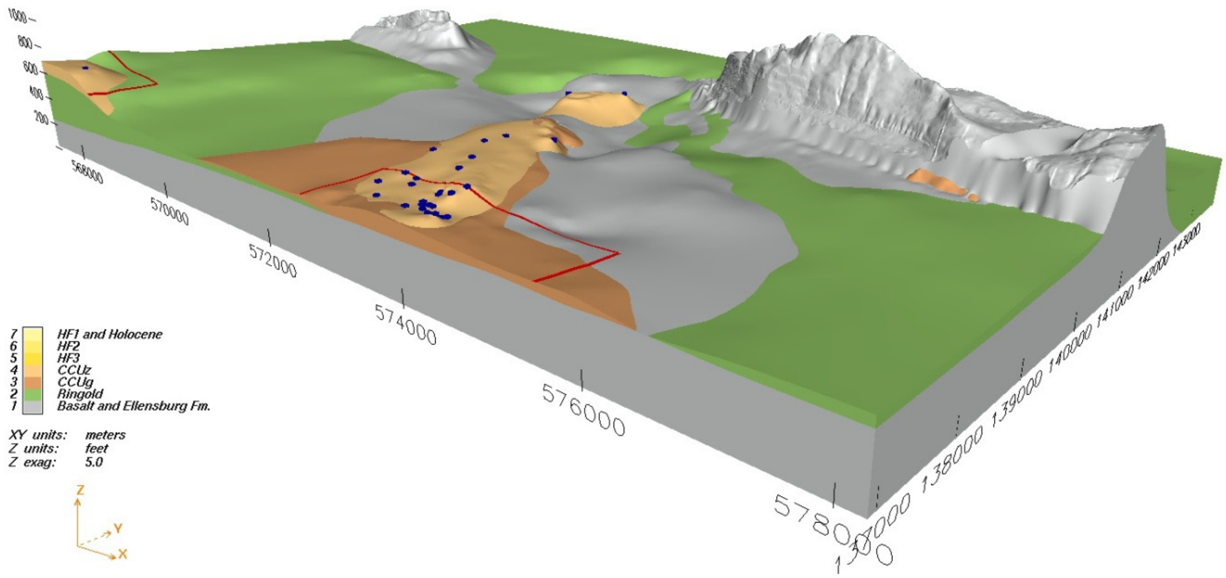


Figure 4.7. EarthVision® model showing the mound-like form of the Cold Creek silt (CCUz) subunit extending south from Gable Gap. View looking northwest. Vertical exaggeration = 5X.

Figure 4.8. Example of high-relief, streamlined and scarped hills of silty Palouse Formation located in the eastern Channeled Scabland. Ice Age floods, moving toward viewer in this image, eroded through a once-continuous blanket of windblown silt, leaving behind these streamlined remnants. The streamlined hills rest on basalt bedrock, eroded into scabland by the floods. These are analogous to the elongated, isolated ridge of Cold Creek unit silt (CCUz) buried near Gable Gap (see Figure B.5 and C.6).

The transition from the mainstream fluvial gravel facies (CCUg) to overbank facies (CCUz) during the Cold Creek period may signify the shift of the Columbia River out of Gable Gap northward toward the horn of the Columbia River. Such a shift may have been the result of ongoing tectonic uplift along the Umtanum Ridge-Gable Mountain anticline, which perhaps defeated the river and forced it northward towards the end of Cold Creek time.

4.2.3 Hanford Formation

The Hanford formation in the vicinity of Gable Gap is subdivided into either 1) gravel-dominated, or 2) sand-dominated lithofacies, which transition laterally into one another depending on distance from the main, high-energy flood currents (see Figure 3.3).

1. *Gravel-Dominated Lithofacies*. This facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits display an open framework texture, massive bedding, plane to low-angle bedding, and large-scale planar cross bedding in outcrop. Gravel-dominated beds sometimes grade upward into thinner, laterally discontinuous beds of sand- and/or silt. Gravel clasts are dominantly basalt with lesser amounts of mostly reworked Ringold Formation clasts, including granite, quartzite, and gneiss. In the Gable Gap study area, two gravel-dominated sequences are recognized—the H3 and H1 units.
2. *Sand-Dominated Lithofacies*. This facies consists of fine- to coarse-grained sand and granule gravel. The sands typically consist of 40-90% basaltic rock fragments (Table 4.1). They may contain small pebbles and rip-up clasts, pebble-gravel interbeds, and often grade upward into thin (<1 ft [0.3 m]) zones of silt-dominated facies. Sand-dominated facies commonly display plane lamination and bedding, and less commonly, channel cut-and-fill sequences. The facies transitions laterally into gravel-dominated facies northward into Gable Gap. In the Gable Gap study area, only a single thick sand-dominated sequence (H2 unit) is recognized in the southern portion of the study area (Figures A.2, B.2, and C.3).

The higher basalt content for the Hanford formation is due to the flow path of the Ice Age floodwaters, which passed over the purely basaltic terrain of the Columbia Plateau (e.g., Channeled Scabland). In contrast the origin for the older strata of the Ringold and Cold Creek units were derived from rivers draining over non-basaltic rocks around the perimeter of the plateau. This mineral assemblage gives the Hanford formation its distinctive "salt and pepper" appearance, often noted in drillers' and geologists' logs.

The Hanford formation in the Gable Gap area is informally subdivided into three main subunits: H1, H2, and H3. The H2 unit is the sand-dominated sequence, which frequently separates upper and lower gravel-dominated flood sequences. The H2 unit is generally restricted to the southern third of the study area (Figure C.3), where it is almost 200 ft (61 m) thick. This unit rapidly transitions into the gravel-dominated H1 unit northward, where floodwaters increased in velocity through Gable Gap.

It is important to note that H1, H2, and H3 units are purely lithostratigraphic units and NOT time-stratigraphic units—thus, they are flood facies that may have been deposited simultaneously or may represent a composite of similar facies from different flood events. From one place to another, the type of sediment deposited was strongly dependent on its location relative to the changing energy level of the floods, which transitioned laterally from high energy to lower energy southward to southeastward through

Gable Gap. Thus, the H1, H2, and H3 units recognized in the Gable Gap area do not necessarily correlate with similarly named units of the Hanford formation recognized elsewhere within the Hanford Site.

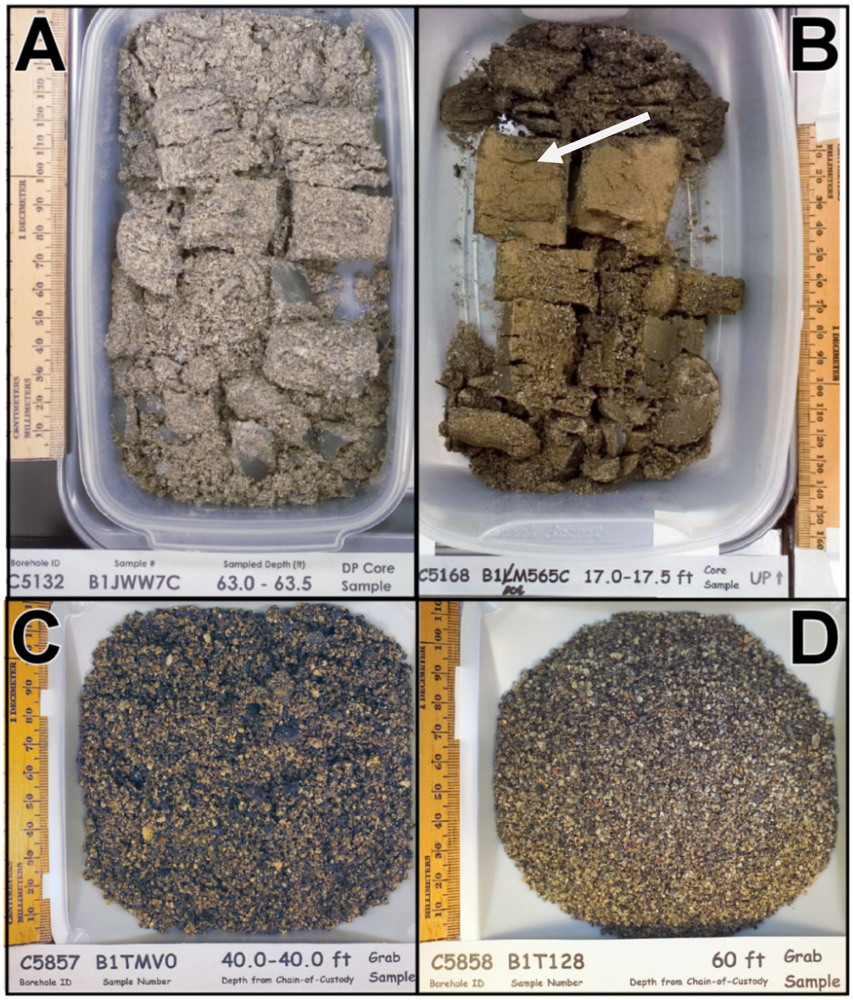
Lower Gravel-Dominated Sequence (H3 Unit). The Hanford formation lower gravel-dominated sequence is only present in the extreme southern and western margin of the study area (Figure C.4). It consists of predominantly gravelly sand with some gravel and sandy gravel. The basaltic gravels are poorly sorted and subrounded to subangular. The pebble-to-boulder gravels are clast- to matrix-supported with an occasional open-framework fabric, with massive bedding, horizontal to low-angle bedding, and cross-bedding. The H3 unit was likely deposited during one or more of the earlier floods that created Cold Creek Bar as it prograded toward the east and south. Where the CCUz subunit is missing, it may be difficult to distinguish the H3 unit of the Hanford formation from gravel-dominated facies of the Cold Creek unit (CCUg).

Sand-Dominated Sequence (H2 Unit). The H2 unit consists of predominantly sand-dominated facies of the Hanford formation (Figure 4.9). Internally, this sequence probably contains multiple-graded beds of plane- to foreset-bedded sand or gravelly sand several or more feet thick, which sometimes grade upward into silty sand or silt similar to that observed in Figure 4.9B (see also Figure 4.1). The H2 unit is described on borehole logs of cuttings from the study area as silty sand, sand, and slightly gravelly sand. A total of 40-90% of the grains are dark basalt; the remainder are mostly light-colored quartz and feldspar, giving the characteristic "salt and pepper" appearance. Calcium carbonate occurs in the Hanford formation sand-dominated sequence as disseminated grains of detrital caliche or calcite to weakly weathered zones containing secondary carbonate filaments and/or nodules. The amount of calcium carbonate is generally small—usually less than 1 wt%.

Sandy beds may be fine and grade upward into thin beds of sandy silt to silt (see Figures 4.9B and 4.1); graded beds such as these are sometimes referred to as "rhythmites." Each rhythmite may represent the deposition from a separate flood (Waitt 1980, 1985; Smith 1993), or perhaps surges from a single flood (Bjornstad 1980, Baker et al. 1991). Most rhythmites go undetected in boreholes; however, because drill cuttings are generally collected at 5-ft intervals, the scale of the rhythmic bedding is much finer. Therefore, many more silt-capped rhythmites may be present in the subsurface than are reported in drillers' and geologists' logs.

Within the study area the Hanford formation sand-dominated sequence (H2 unit) is limited to the area south of Gable Gap (see Figure C.3). Here, the flow of the Ice Age floods expanded beyond the confines of Gable Gap where flood currents slowed, allowing for the deposition of predominantly sand. The structure-contour map of the top of the Hanford formation H2 unit (Figure B.2) shows that the Hanford formation sand sequence is thickest (almost 200 ft [61 m]) beneath Cold Creek Bar along the southern boundary of the study area and quickly pinches out north of Cold Creek Bar. Figure B.2 shows an unusual finger of the H2 unit that protrudes north a short distance toward the gap. The finger of sand may have been deposited in the slightly quieter water that existed between two buried flood channels flowing through Gable Gap and then modified (eroded) by later floods.

Upper Gravel-Dominated Sequence (H1 Unit). The Hanford formation upper gravel sequence (H1 unit) covers all of the study area except for the elevated basalt ridges of Gable Mountain and Gable Butte (Figure C.2). Poorly sorted mixtures of silty sandy basaltic gravel textures in the H1 unit are similar to those of the H3 unit. The loose, gray to brownish gray sediments are typically fresh appearing with little or no observed weathering or alteration (Figure 4.10).



GG.H2.png

Figure 4.9. Hanford formation H2 unit in 200 East Area. A) Laminated, "salt and pepper" sands from 63 ft (19 m) depth in direct push core from C5132, BX Tank Farm. B) Direct-push core 17 ft (5 m) depth from C5168, B Tank Farm. Notice graded-bed contact between flood rhythmites; brown silt marks the top of one rhythmite (arrow), overlain by coarse sand at the base of the succeeding flood rhythmite. C and D) Drill cuttings of typically loose, moderately sorted, medium- to coarse-grained, basaltic sand in wells 299-E33-342 and -343, respectively.

Basalt boulders are another characteristic of the coarse-grained Hanford formation, both within the H1, as well as the H3 units. Boulder-sized clasts (>10 in. [256 mm] diameter) are rarely—if ever—reported for either the Ringold Formation or the Cold Creek unit. Unlike huge Ice Age floods, normal rivers are not swift enough to transport boulder-sized clasts; boulders are therefore diagnostic of the Hanford formation.

Based on observations of outcrop (see Figure 4.1) and intact core samples, the Hanford formation upper gravel sequence is interpreted to consist of the high-energy, gravel-dominated facies with discontinuous lenses of the sand-dominated facies. Occasionally, silt-lenses are draped between flood sequences, but these constitute a relatively small percentage of the total volume of the H1 unit. Within the Gable Gap study area, this unit is well exposed in the northeast corner of the 200 East Area in the 50-ft (15-m) deep 218-E-12B Burial Ground (Figure 4.11).

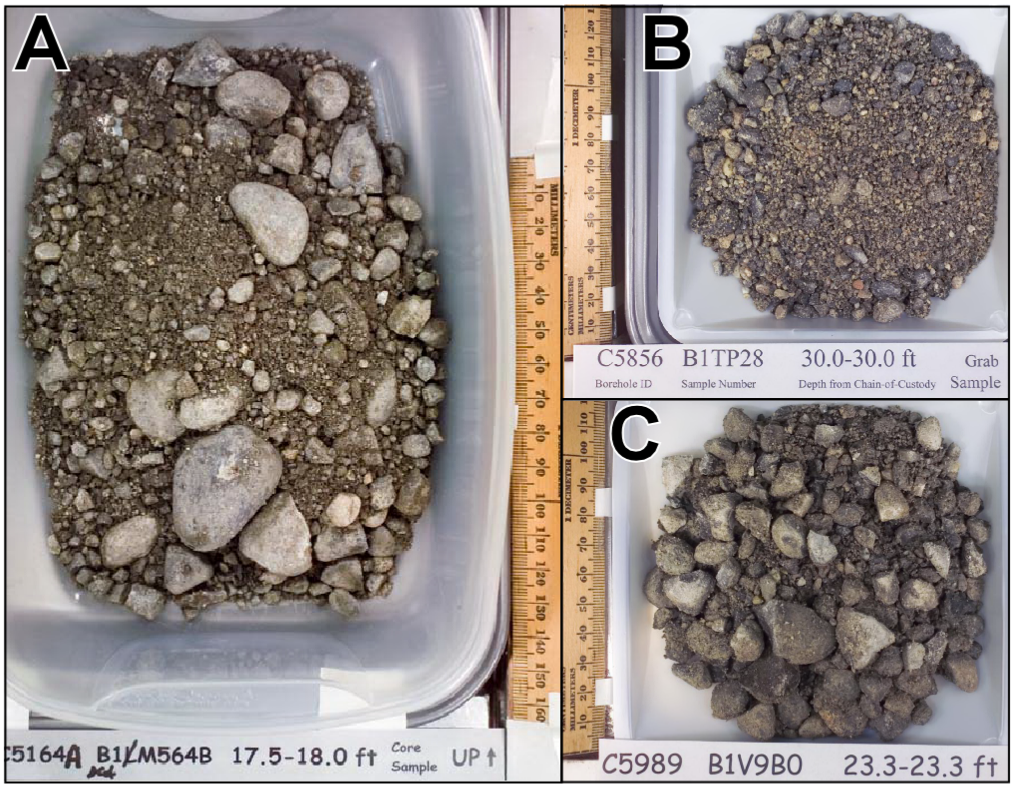


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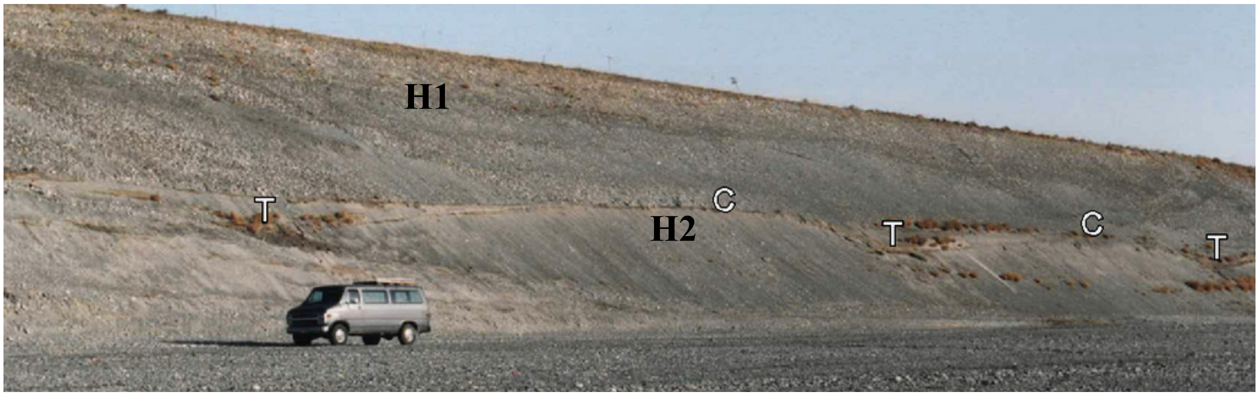
Figure 4.10. Hanford formation H1 unit from the B-BX-BY Tank Farm, 200 East Area. The H1 unit is a loose, gravel-dominated, poorly to moderately sorted unit composed of mostly unweathered, subangular basalt rock fragments in a matrix of sand and silt. A) Boring C5164; B) 299-E33-341; and C) 299-E33-205.

4.2.4 Holocene Deposits

Holocene deposits within the study area consist of up to 30-50 ft (10-15 m) of backfill material within tank farms, cribs, and trenches located in the northern 200 East Area. This backfill material is composed mostly of gravel-dominated deposits of the Hanford formation H1 unit removed during construction of the waste facilities. In places, such as the BY Tank Farm within the north-central 200 East Area, all the Hanford formation H1 unit was removed and replaced with backfill (e.g., see Figure B.1). Thin (few feet [1-2 m]) sheets of eolian sand also locally cover the surface. Holocene-age debris in the form of slopewash and talus has also been shed off the higher-relief slopes of Gable Mountain and Gable Butte.



Subpit.ripples.jpg

Figure 4.11. Outburst-flood deposits of the Hanford formation exposed along the north wall of the 218-E-12B Burial Ground located along the north flank of the Cold Creek Flood Bar (Wood et al. 2000; Bjornstad 2006). The upper half of the exposure is composed of gravel-dominated (H1) flood deposits, underlain by sand-dominated (H2) deposits of the Hanford formation. In between are a series of buried, long-amplitude, giant current ripples; ripple crests are indicated by the letter "C" and ripple troughs by the letter "T." Slackwater deposits of silt (indicated by vegetation growth) drape over the ripples, thickening in the ripple troughs and thinning over the crests.

4.2.5 Clastic Dikes

Clastic dikes are vertical to subvertical sedimentary structures that crosscut normal sedimentary layering, especially in Ice-Age flood deposits of the Hanford formation (Black 1979; Fecht and Weekes 1996; Fecht et al. 1999). The dikes are believed to result from dewatering of saturated, rapidly deposited sediment and/or hydraulic injection into overlying sediment layers associated with sudden lowering of flood levels immediately following Ice Age flood events. Clastic dikes are common to the sand-dominated facies of the Hanford formation, but rarely identified in the gravel-dominated facies based on observations of outcrop exposures. Thus, clastic dikes may be mostly absent in the Gable Gap study area except along the southern boundary where up to 200 ft (61 m) of the sand-dominated Hanford formation H2 unit is located (Figure C.3).

5.0 Structure

Structural features in the vicinity of Gable Gap include first- and second-order folds, as well as faults (Figure 5.1) associated with the Yakima Fold Belt (YFB). East-west trending ridges of the YFB resulted from tectonism via north-south compression of Earth's crust since the Miocene Epoch (Reidel and Fecht 1981; DOE 1988). Structures exposed at the surface were mapped by Fecht (1978) and Myers and Price (1979); subsurface structures are inferred from the basalt units and elevations of top of basalt in geologic cross sections (Appendix A). Subsurface structures have also been interpreted based on a combination of geophysical techniques, including magnetic, gravity, and seismic-reflection surveys (Ault 1981; Repasky et al. 2009). Most recently, the structural relief on the top of basalt between known points (i.e., boreholes) in Figure 2.5 was interpolated from an integration and re-evaluation of the seismic-reflection data.

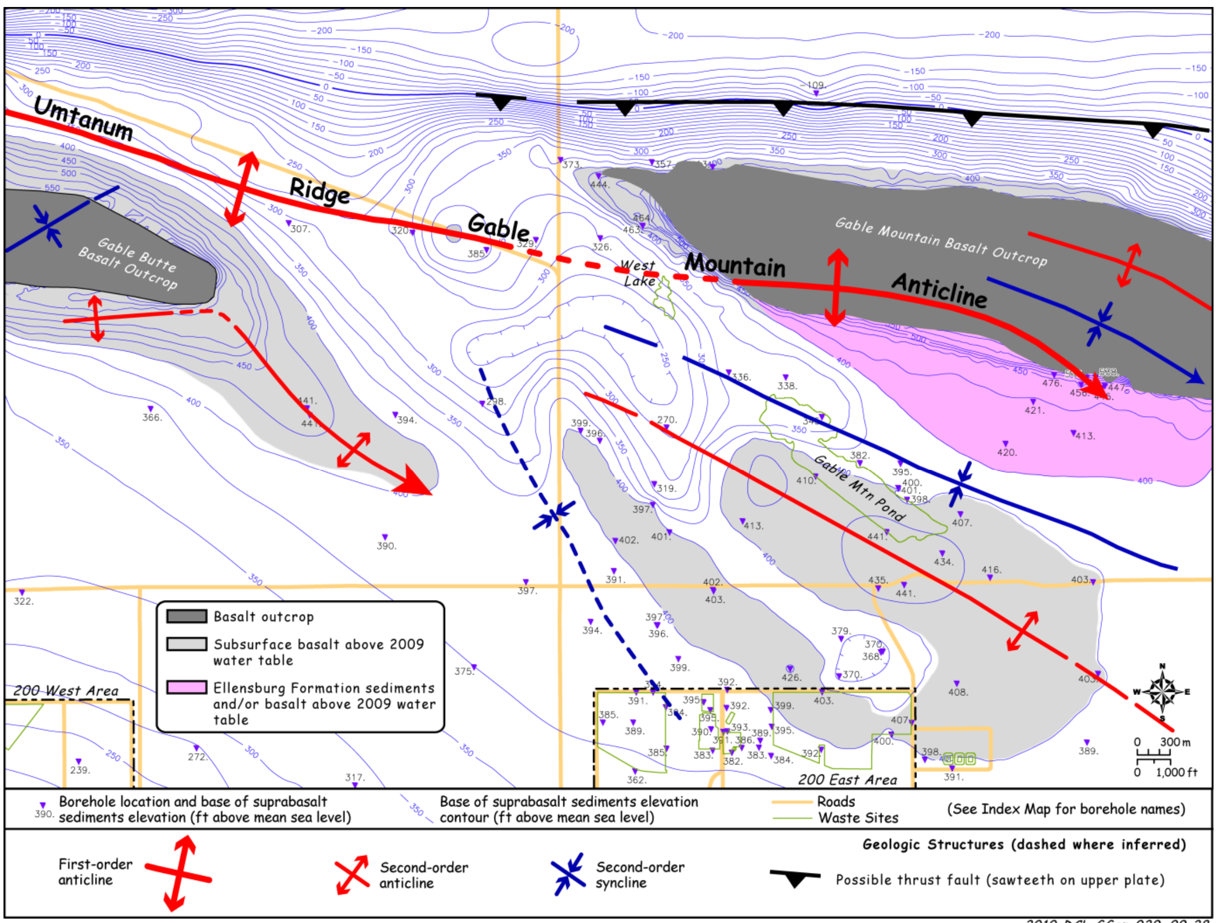


Figure 5.1. Geologic structures in the vicinity of Gable Gap. Compiled from surface and subsurface maps in Fecht (1978), Ault (1981), Myers and Price (1979), and Graham et al. (1984).

Gable Gap lies along a major first-order structure (Umtanum Ridge-Gable Mountain anticline) of the YFB. Gable Gap formed between two, second-order, en echlon, asymmetric folds (Gable Mountain and Gable Butte) superimposed onto the larger structure. Overall, the first-order structures appear to plunge downward to the southeast (Figure 5.1). A series of en echelon folds lies along either side of the first-order Gable Butte-Gable Mountain anticline (Myers and Price 1979; Ault 1981). From the upfolded ridges, the top of basalt dips north into the Wahluke syncline and south into the Cold Creek syncline.

In general, basalt flows and the overlying suprabasalt sediments thicken to the north and south into the synclinal basins. In addition, sedimentary interbeds of the Ellensburg Formation thin or disappear over the anticlinal ridges, indicating these structures were actively growing during eruption and emplacement of Columbia River basalt flows. Cumulative deformation on the suprabasalt sediments suggest development of the Yakima Folds has continued at a long-term, low-average rate to the present (Reidel 1984; DOE 1988).

At Gable Mountain, the more fractured hinge area and steeper south limb of the fold were preferentially eroded away during massive Ice Age floods (Figures 5.1 and 5.2). Considerable relief appears to exist in the subsurface on the top of basalt north of Gable Mountain, some of which may be the result of a high-angle reverse and/or thrust fault in this region. Reverse or thrust faults commonly develop on the steeper, overstrained sections of other Yakima folds (Myers and Price 1979).

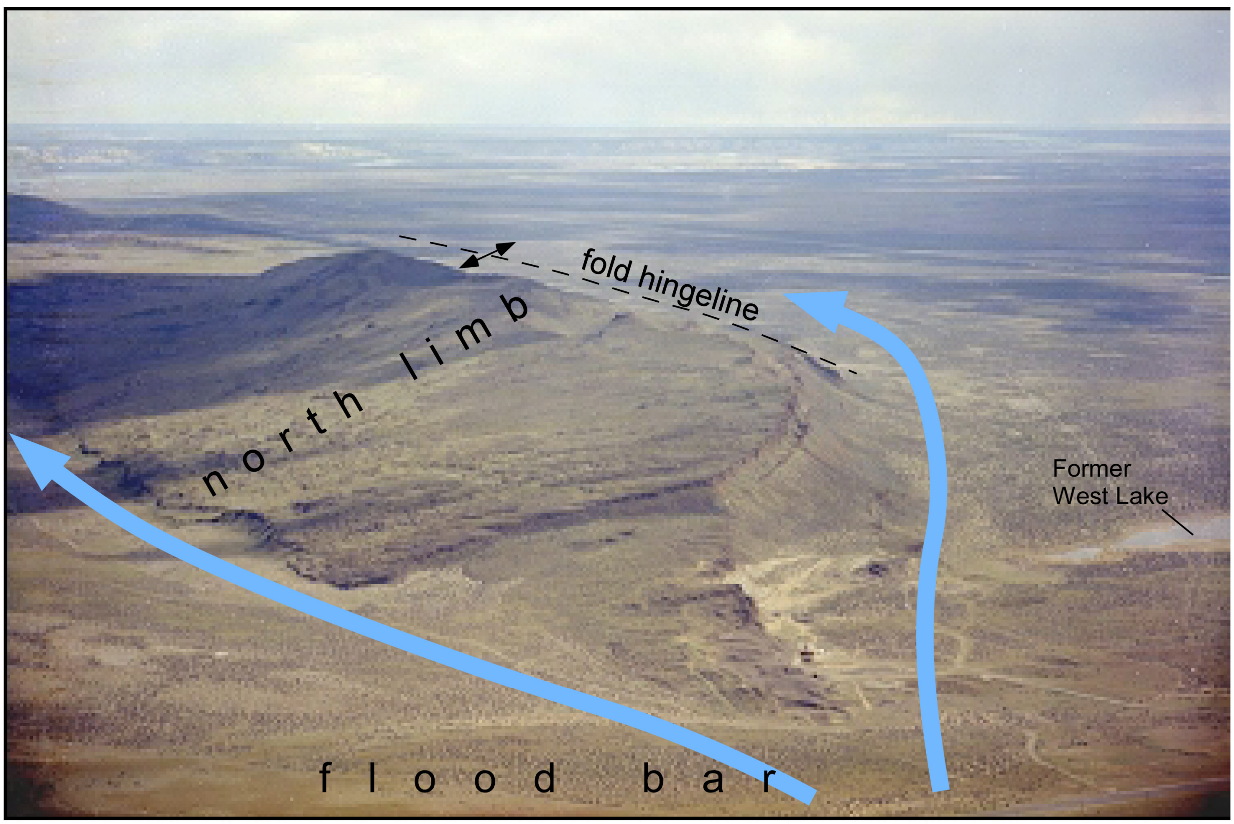


Figure 5.2. Flood-swept, hogback ridge of western Gable Mountain, looking southeast. Low-angle (10-20 degree) tilt of the Columbia River basalt flows show prominently along the gentler north limb of the anticline. Ice Age flood channels (blue arrows) run along both sides of Gable Mountain. Floods racing down the right side of the ridge completely removed the hingeline and steeper south limb of the anticline, leaving only the north limb exposed as a hogback. The largest Ice Age floods rose another 100 ft (30 m) over the ridge crest. A number of other Ice Age flood landforms, including channels and potholes, lie buried within Gable Gap, located in the foreground.

6.0 Geomorphology

Landforms in the Gable Gap area are primarily the result of structural deformation and cataclysmic Ice Age floods (Fecht 1978), the earliest of which occurred 1 to 2 million years ago (Bjornstad et al. 2001). Outburst floods continued intermittently until about 14,000 to 15,000 years ago (Bjornstad 2006). Little or no change has occurred to the land surface since that period except for localized eolian (i.e., wind) reworking of flood deposits and manmade constructional activities. Figure 1.1 shows the major landforms surrounding the Gable Gap study area and Figure 6.1 as an EarthVision® model representation of the surface topography within the study area.

Gable Gap lies along the northern flank of Cold Creek Bar, a large compound flood bar formed during cataclysmic, Ice-Age floods (see Figure 3.3). The upper surface of the bar in the 200 East Area forms a broad plain at about 700 ft (210 m) elevation, otherwise known as the "Central Plateau" (see Figure 1.1). The bar extends westward for several miles; the northern boundary of the bar is flanked by a series of younger northwest-southeast trending flood channels (Fecht 1978; DOE 1988).

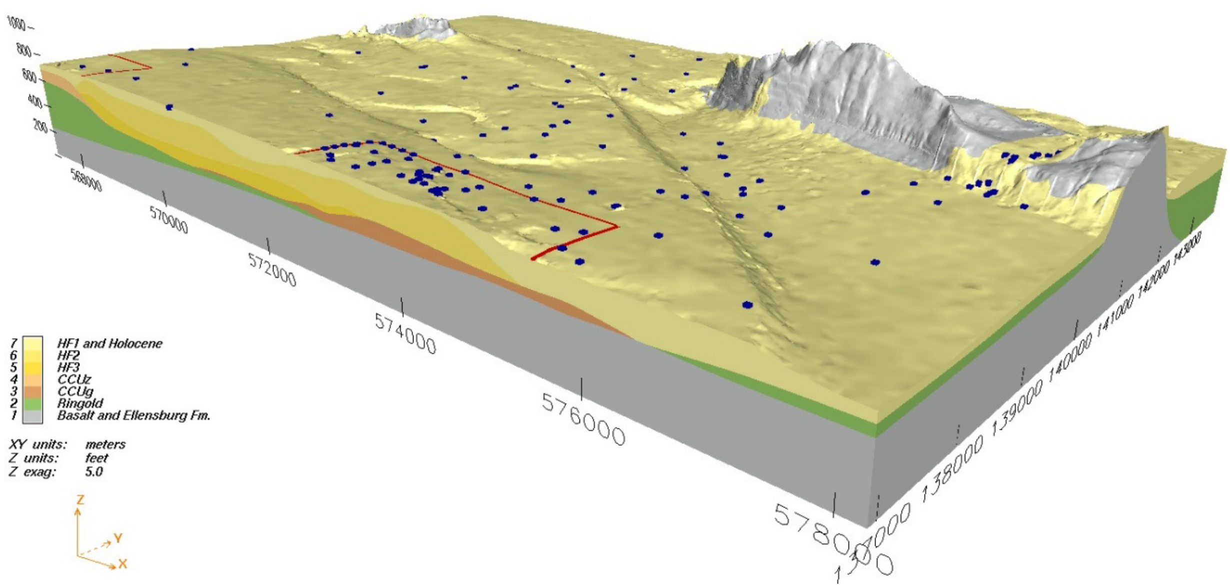


Figure 6.1. EarthVision® model of the present-day surface topography within the Gable Gap study area. Oblique view looking northwest. Vertical exaggeration = 5X.

6.1 Late-Pleistocene Flood Channels and Bars

Multiple channels and bars from the last Ice Age floods trend northwest to southeast through Gable Gap. Bars and channels of at least three different ages are preserved in this location. The oldest preserved flood surface is Cold Creek Bar (north end of which is represented by "B" in Figure 6.2). Cold Creek Bar developed as flood deposits prograded to Gable Gap from the eastern end of Umtanum Ridge (see Figure 3.3). North of Cold Creek Bar, later smaller floods (or later stages of the last flood) that did not flood Cold Creek Bar created the "south terrace" and "north bar" geomorphic surfaces ("C"). These surfaces were last incised by the most recent flood (i.e., Lake Columbia flood) that created the West Lake channel and scour depressions at the head of Gable Mountain ("D"). This last flood that created the West Lake channel occurred sometime between 14,000-15,000 calendar years ago (Bjornstad 2006).

The oldest surfaces (indicated with the letter "A" in Figure 6.2) are the basalt uplands of Gable Mountain and Gable Gap. All subsequent landforms developed during Ice Age flooding, starting with Cold Creek Bar ("B"). Floods decreased in size toward the end of the Ice Age; these floods were responsible for the development of the south terrace and north bar ("C"). A secondary, sinuous flood channel (dashed arrow) appears to have developed atop the south terrace during the end of a flooding event. The south terrace and north bar, once connected, were subsequently incised by the last flood(s) that created the West Lake and north channels ("D"). Several depressions were also scoured out around the nose of Gable Mountain by the last of the floodwaters that squeezed through these channels.

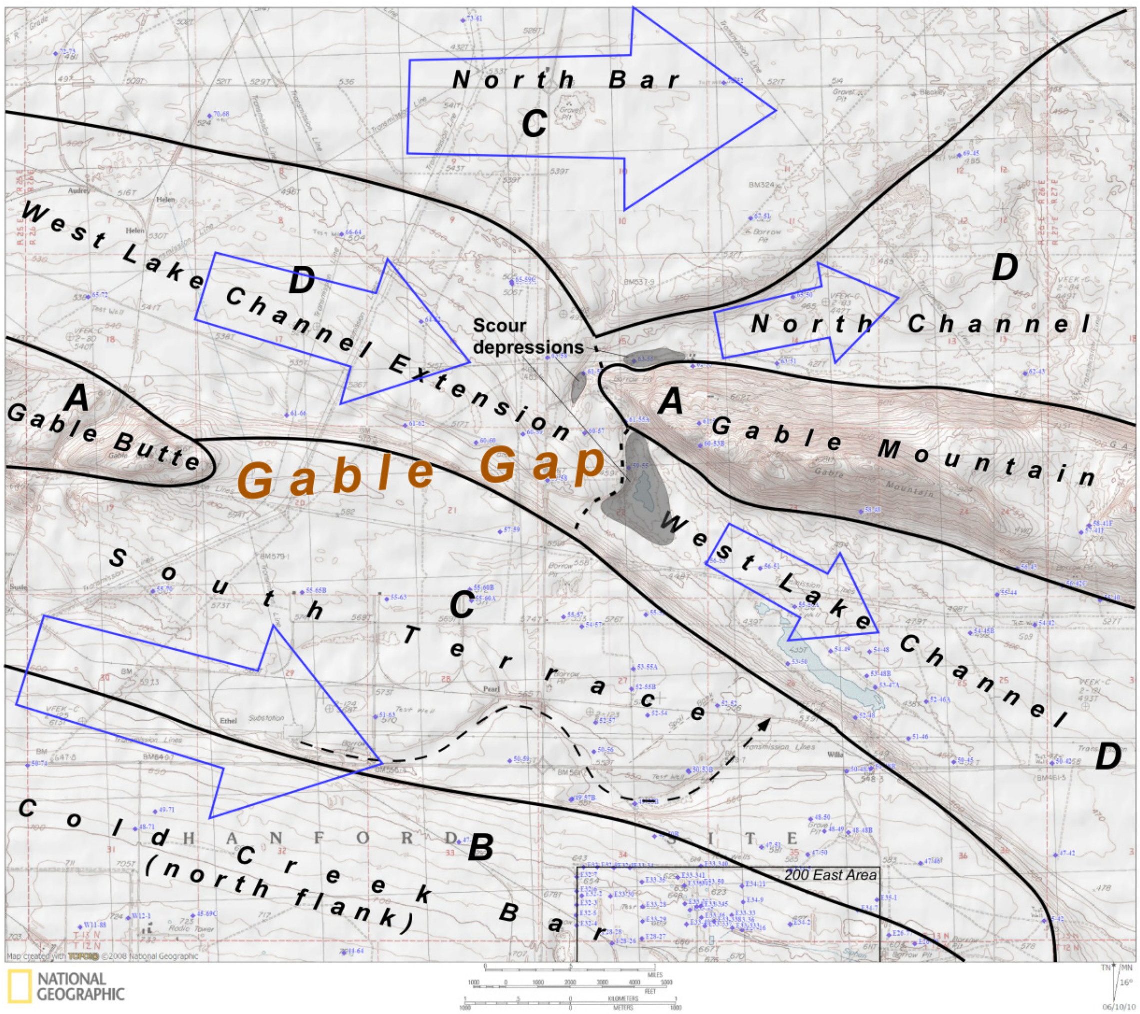


Figure 6.2. Surface-geomorphic map of the Gable Gap study area. Entire area was underwater during multiple Ice Age floods. Block arrows show general flow direction for the last Pleistocene megafloods through Gable Gap.

6.2 Buried Paleochannels

Multiple paleochannels lie within Gable Gap area (Figure 6.3) buried beneath younger flood deposits of the Hanford formation. Locations for these channels are inferred from dozens of boreholes and seismic-reflection data collected within Gable Gap. The age of a paleochannel can be inferred based on the age of the sediments that fills the base of the channel. At least one channel (Channel F) was formed during Ringold time since it holds remnants of the Ringold Formation preserved within it. The remaining five paleochannels (A through E) are filled with coarse-grained, highly permeable flood deposits of the Hanford formation. These paleochannels may have initially formed during Ringold time, but if so, were further deepened during cataclysmic flooding, which removed all Ringold-age deposits from the channel. Paleochannel D, which has a remnant of Ringold Formation along its east side, might be an example of a Ringold-age channel that was cut deeper during Ice Age flooding. Figure 6.4 shows an example of the types of extreme erosion that can occur associated with Ice Age flooding, analogous to the erosional environment of Gable Gap.

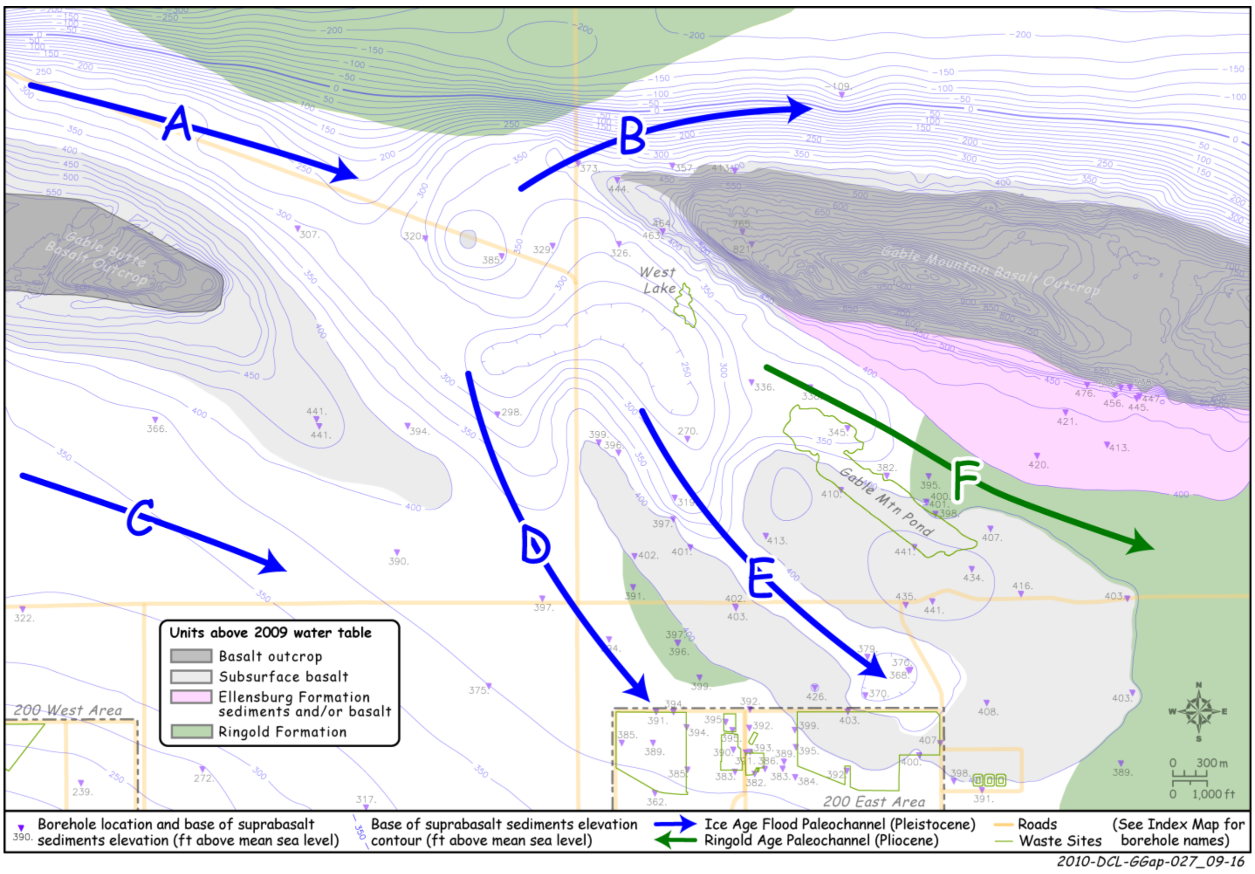


Figure 6.3. Buried paleochannels within the Gable Gap area. Most of the channels were carved out during Pleistocene Ice Age floods, except for Channel F, which was created prior to backfilling with deposits of the Pliocene Ringold Formation.

Figure 6.4. Example of highly irregular topography eroded by Ice Age floods, Lower Grand Coulee, Channeled Scabland. View looking north. Blue block arrows show general movement of floodwaters, which scoured and overtopped the crest of the basalt ridge along left side of image. Notice the numerous circular potholes in basalt bedrock, plucked out by violently swirling and turbulent floodwaters.

Paleochannel A was carved by floodwaters flowing east through the Pasco Basin. Upon colliding with Gable Mountain, the floodwaters divided (as shown in Figure 5.2) with some of the floodwater diverted north of Gable Mountain (Paleochannel B) and the remainder flowing south through Gable Gap via Paleochannels D, E, and F. Paleochannel C formed from Ice Age floodwaters that flowed east between Gable Butte and Cold Creek Bar (see Figure 3.3).

Paleochannel D, identified by Ault (1981) using a combination of geophysical techniques (i.e., gravity, magnetics, and seismic reflection), formed when floodwaters from Paleochannel A divided, sending vigorous streams of floodwater south through Gable Gap. Paleochannel D may have preferentially developed here along the structural axis of a buried syncline (see Figure 5.1). Just to the east, Paleochannel E appears to have incised into an anticline in basalt subparallel to Paleochannel D. This paleochannel is poorly defined via borehole data but suggested based on the seismic-reflection data (see Figure 2.5). At the southeast end of Paleochannel E lies a large pothole eroded into the Elephant Mountain Member basalt (defined by wells 699-48-48, 699-48-50, and 699-47-50) near the northeast corner of the 200 East Area (Figures 6.3 and D.1).

7.0 Hydrology

The hydrologic system of Gable Gap includes the 1) vadose zone, mostly composed of the Hanford formation; 2) the suprabasalt unconfined aquifer; and 3) multiple confined aquifers within and between flows of volcanic Columbia River basalt. Within the vadose zone, movement of moisture and liquid effluent from the 200 East Area is strongly influenced by anisotropic sedimentary layering within the Hanford formation and the underlying Cold Creek unit (Serne et al. 2010). This includes a sizable, elongated, and streamlined mound of CCUz, up to 55 ft (17 m) thick, ½ mile (0.8 km) wide, and up to 2 mi (3.2 km) long that extends northwestward into Gable Gap from the northern 200 East Area (see Figures 4.7, B.5, and C.6). Additional anisotropic features exist in the layered flood deposits of the Hanford formation, which drape across the Cold Creek flood bar (see Figures 1.1 and 3.3). Hanford formation strata appear to dip north and east off the north side of the bar into Gable Gap—the expected direction for lateral movement of moisture and effluents within the vadose zone (Serne et al. 2010).

A large window occurs in central Gable Gap where the uppermost Saddle Mountains Basalt members (Elephant Mountain, Pomona, Asotin, and Esquatzel Members) were locally eroded away by the ancestral Columbia River as well as cataclysmic megafloods (Figure 7.1). This is an area for potential comingling of groundwater from unconfined and confined aquifers. The potential for aquifer intercommunication within this erosional window has long been recognized (Strait and Moore 1982; Graham et al. 1984; Jensen 1987; Spane and Webber 1995). However, vertical head differences measured between the confined and unconfined aquifers suggests that any local groundwater contamination will not travel far within interbeds of the Ellensburg Formation. While groundwater may be locally driven into the upper-basalt confined aquifer system due to previous water-table mounding conditions within the Gable Gap area, this groundwater will likely discharge back into the overlying unconfined aquifer due to the reversal in vertical hydraulic head conditions (Graham et al. 1984; Jensen 1987; Spane and Webber 1995).

Figure 7.2 shows the elevation of the water table in the study area; also shown is the stratigraphic unit in contact with the top of the unconfined aquifer. Groundwater, following the regional gradient, enters the study area from the west. The steep gradient just east of the 200 West Area is the result of groundwater flow being restricted to the lower-hydraulic-conductivity Ringold Formation sediments. However, the hydraulic gradient flattens rapidly to the east where the Ringold Formation is eroded below the water table. Here, the unconfined aquifer lies mostly within higher hydraulic conductivity sediments of the Cold Creek unit and Hanford formation. The flow of groundwater appears to divide in the 200 East Area, with some of the flow going north through Gable Gap and the remainder continuing east to southeast through the central and southern portions of the 200 East Area (beyond the southern boundary of Figure 7.2). Because of the extremely low hydraulic gradient conditions in this area, the exact location of the groundwater divide is difficult to delineate; however, based on currently available data, the general divide appears to lie near the northwest corner of the 200 East Area.

As mentioned, the extremely flat gradient in the vicinity of Gable Gap is a reflection of the relatively high hydraulic conductivity for the Hanford formation and Cold Creek unit gravel-dominated facies in this area. In general, the Hanford formation has a hydraulic conductivity that is frequently an order of magnitude (or more) greater than the Ringold Formation (Bjornstad 1990; Thorne et al. 2006). The Cold Creek unit gravel-dominated facies (CCUg) are of an intermediate hydraulic conductivity. Thus, the ability to transmit groundwater is greatest in the relatively young, coarse-grained Hanford formation, followed by the CCUg subunit, in contrast with the low-K Ringold and Ellensburg Formations.

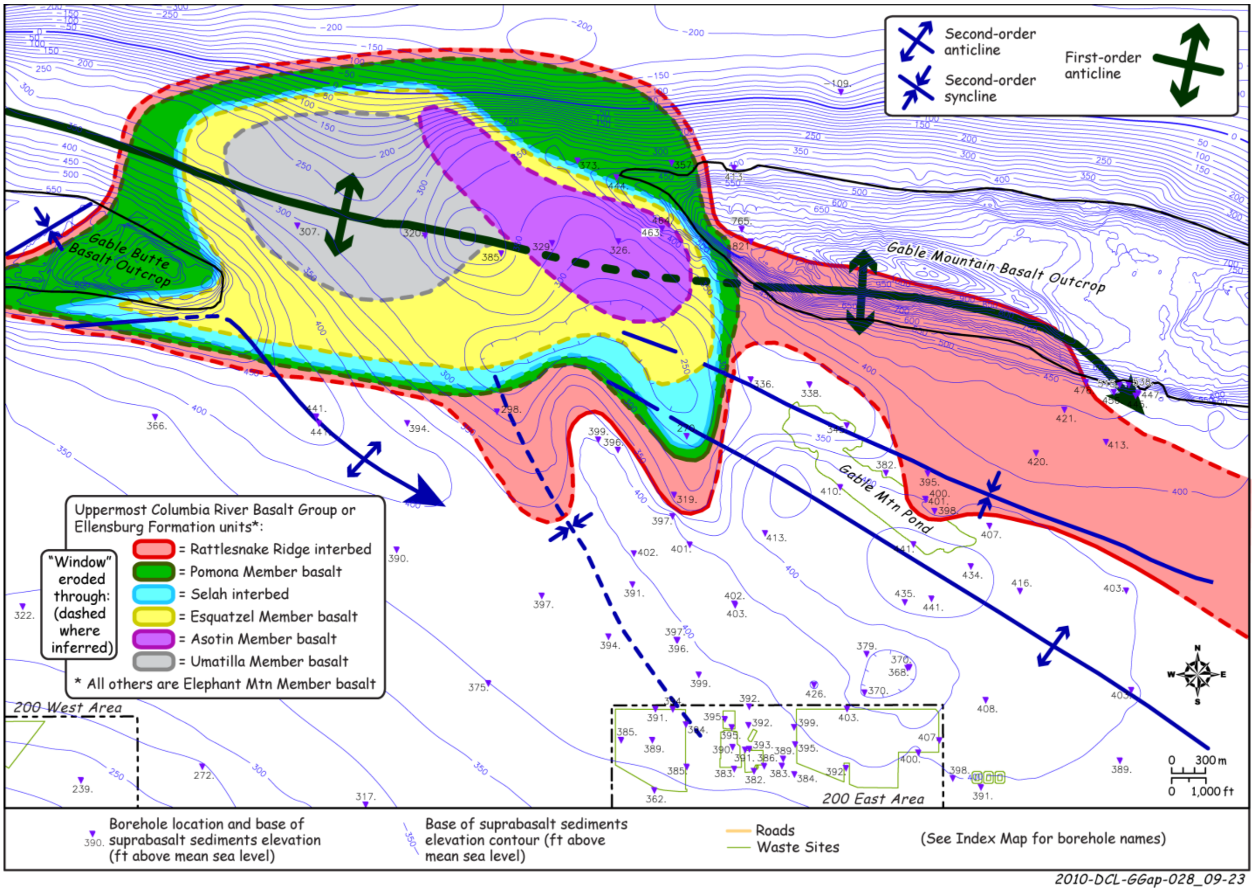


Figure 7.1. Location of window eroded through the upper flows of Columbia River Basalt Group within Gable Gap

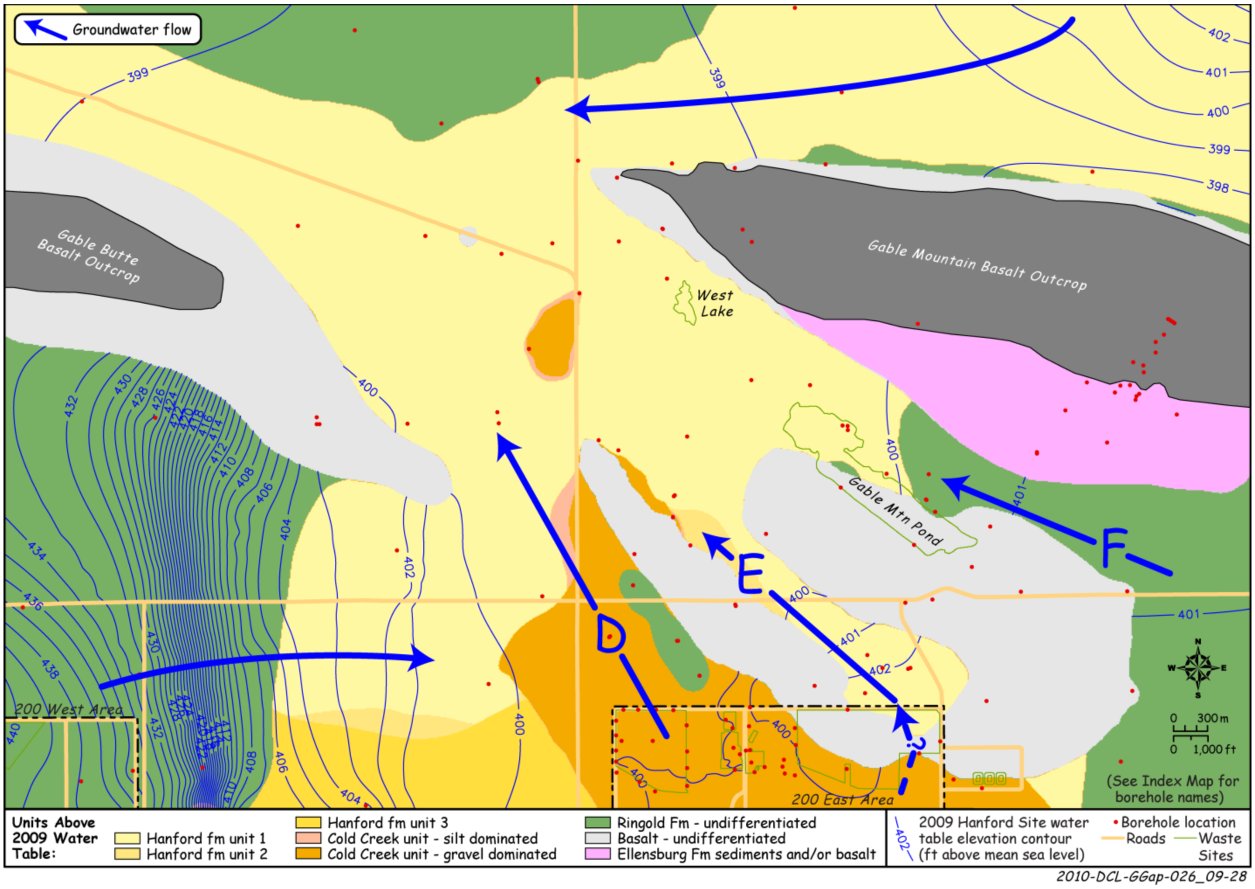


Figure 7.2. Distribution of stratigraphic units encountered at the 2009 water table. Arrows indicate flow of groundwater in the unconfined aquifer under the present flow regime. Flow occurs along buried Paleochannels D, E, and F shown in Figure 6.3.

The thickness of the unconfined aquifer is highly variable across Gable Gap (Figure 7.3). This is due to the irregular, tectonically deformed and eroded surface at the top of basalt (see Figure 2.5). The unconfined aquifer is relatively thick in the northwestern portion of the study area where erosion was most extreme. However, the amount of erosion decreases to the south and therefore so does the aquifer thickness. The thickness of unconfined aquifer thins to only a few feet or less, including the less-eroded high points along Paleochannels D, E, and F (Figure 6.3) discussed previously in Section 6.2. Because of a limited number of wells in the area of question, considerable uncertainty exists on the configuration of the paleochannels and top of basalt. Thus, there could be areas across the basalt divide that are incised deeper into the basalt, resulting in a localized conduits for the preferential flow of groundwater.

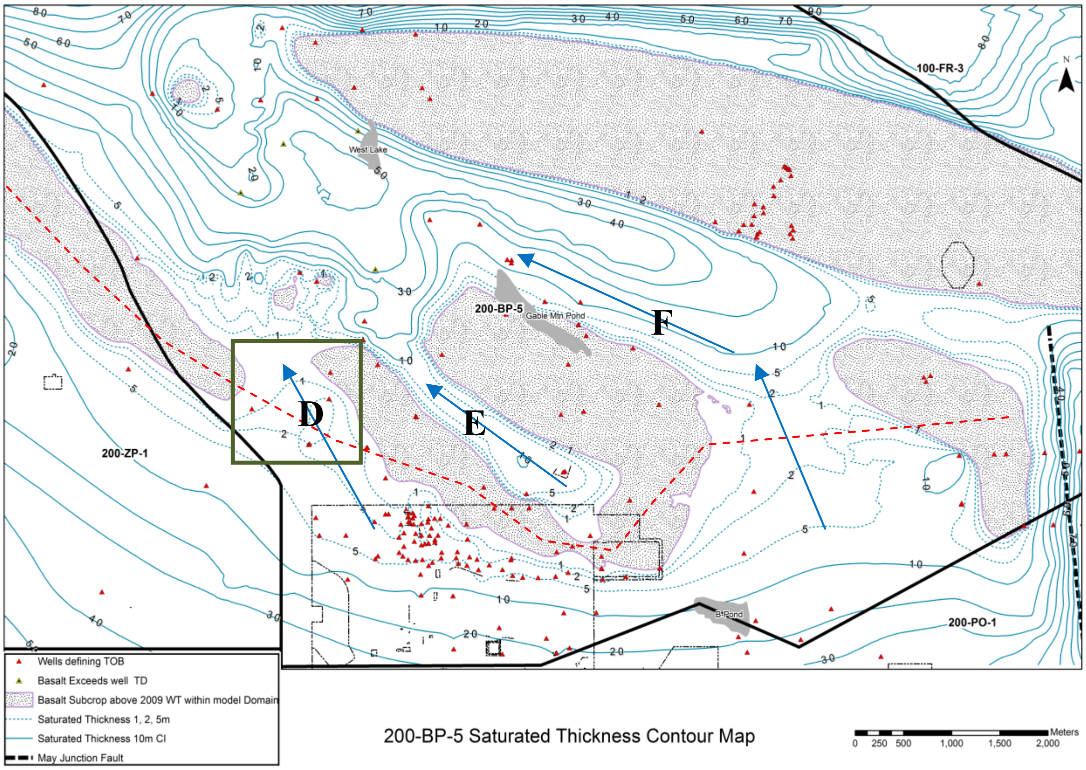


Figure 7.3. Aquifer thickness (in meters) map in the vicinity of Gable Gap. Thickness is based on the difference between the 2009 site-wide groundwater table and estimated top of basalt map shown in Figure 2.5. Blue arrows show possible groundwater flow paths across Gable Gap along buried paleochannels. Dashed red line marks the high basalt divide that separates the Wahluke and Cold Creek synclinal structural basins. Green rectangle marks critical area of uncertainty for the future of contaminated groundwater moving through Gable Gap.

Note that the thickness of the unconfined aquifer, represented in Figure 7.3, includes all strata down to the top of basalt, which includes the uppermost sedimentary interbed of the Ellensburg Formation in the area of the erosional window shown in Figure 7.1. Because of its impermeable, fine-grained, and semi-lithified nature, the Ellensburg Formation may behave more like an aquitard than an aquifer. If so, then the true unconfined aquifer thickness would be something less than that represented in Figure 7.3 in the area of the erosional window.

Groundwater appears to flow northward through Gable Gap via one or more paleochannels eroded into basalt (Figure 7.3). At least three paleochannels (D, E, and F) transect Gable Gap (see Figure 6.3). In some places, these channels are many tens of feet deep (e.g., see hydrogeologic cross sections B-B' and C-C' in Appendix A). Elsewhere, along the lengths of the paleochannels, the top of basalt rises toward the water table. Significant thinning of the aquifer along these paleochannels occurs at the basalt divide well south of Gable Gap (red dashed line in Figure 7.3). The thinning of the unconfined aquifer near this divide is apparent along the west side of the hydrogeologic cross section D-D' (Figure A.5).

Among the paleochannels that transect Gable Gap, Paleochannel E is interpreted here to be completely cut off from the flow of groundwater under the present hydrologic regime, although some investigators believe the northern of two Tc-99 plumes in Figure 2.5 is evidence for contaminated groundwater flowing through this paleochannel. However, Paleochannel D definitely appears to be transferring groundwater across Gable Gap to the northwest. This is based on historical contaminant flow associated with tritium, and more recently with detection of Tc-99 and I-129 (DOE/RL 2010). The southern of two Tc-99 plumes (Figure 2.5) is believed coincident with Paleochannel D.

Groundwater may also be moving northwestward through Gable Gap along Paleochannel F as well. However, the rate of groundwater flow may be significantly reduced in comparison to Paleochannel D considering the flow of groundwater is through low-K Ringold Formation sediments. Furthermore, if groundwater flows through Paleochannel F it does not appear to be impacted by any Hanford waste-management activities.

Groundwater levels in Gable Gap wells have fluctuated considerably since artificial recharge at the Hanford Site began around 1944 (Figure 7.4). These reflect changes in discharges to ground in the vicinity of the 200 East Area (Figure 7.5). Groundwater levels increased dramatically and steadily from 1954 to 1963, reaching a maximum between 1968-1969. This spike in water levels was the result of groundwater mounding associated with discharges to Gable Mountain pond. Maximum water levels were followed by a temporary low between 1978-1979 when artificial recharge was significantly reduced (Serne et al. 2010). Another rise in the water table occurred in 1986-1987 associated with increased discharge to the B Pond system, just east of the 200 East Area (see Figure 7.3 for location). Hanford Site well-water levels have been steadily declining since 1990, when wastewater discharges to the ground were terminated. Water levels have dropped an average rate of ~0.5 ft/y (0.14 m/y) in the northern portion of the 200 East Area since the cessation of these disposal practices (Horton 2007). The rate of decline can be expected to diminish as the water table continues to drop to pre-Hanford levels. As the water table approaches pre-Hanford levels, groundwater flow northwestward through Gable Gap may be more restricted to the incised portion of Paleochannel D. Eventually, the flow of groundwater may be diverted away from Gable Gap altogether if water levels continue to decline across the basalt divide within Gable Gap. However, because of a limited number of wells in the area of question, considerable uncertainty exists on the configuration of the Paleochannel D and the top of basalt (represented by a green rectangle in Figure 7.3). Therefore, the possibility exists there could be localized areas along the basalt divide that are incised deeper and therefore might transport groundwater indefinitely. Significant relief is known to exist in other eroded areas exposed by cataclysmic Ice Age floods (e.g., see Figure 6.4).

As groundwater levels continue to decline in the region, most groundwater flow may eventually be diverted from flowing through Gable Gap. However, localized flow may continue indefinitely in the vicinity of Paleochannel D if there are any as-yet undetected, locally deeper channels across the basalt divide shown in Figure 7.3.

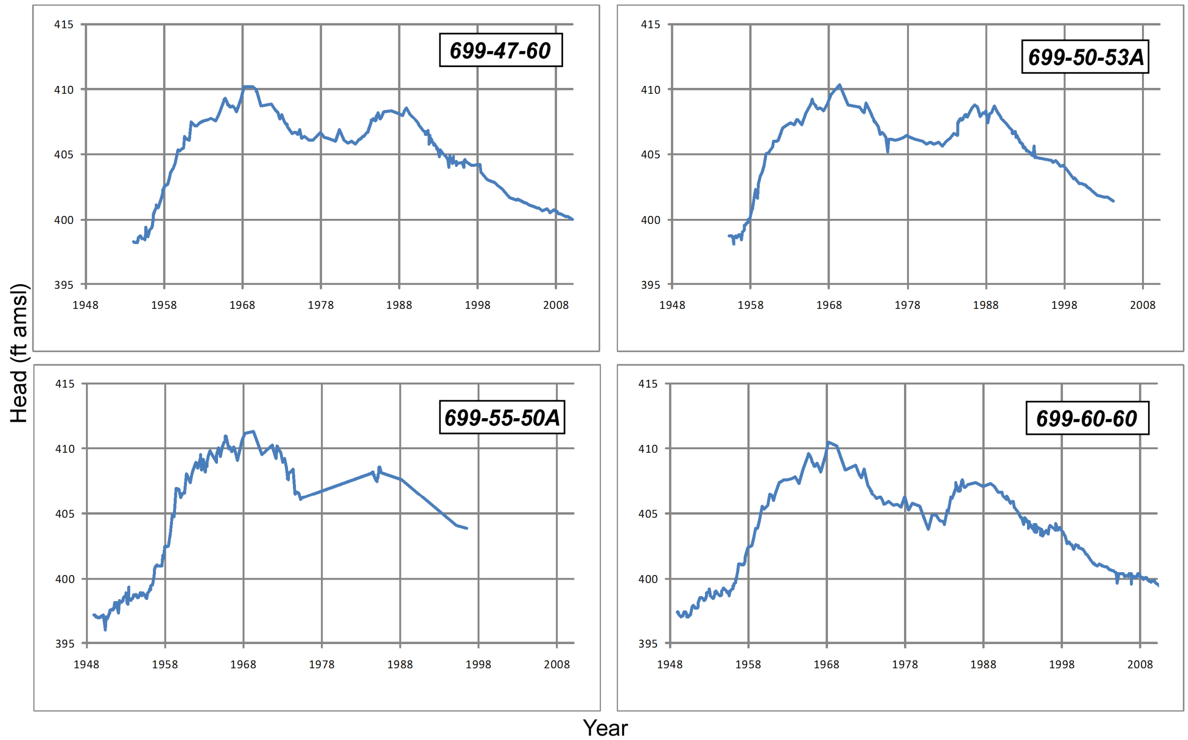


Figure 7.4. Selected hydrographs of Gable Gap wells open to the unconfined aquifer (Hanford formation). Present water levels appear to be a few feet (1 m) above pre-Hanford Site (1944) conditions, after once being almost 15 ft (4.6 m) above the pre-Hanford Site water level.

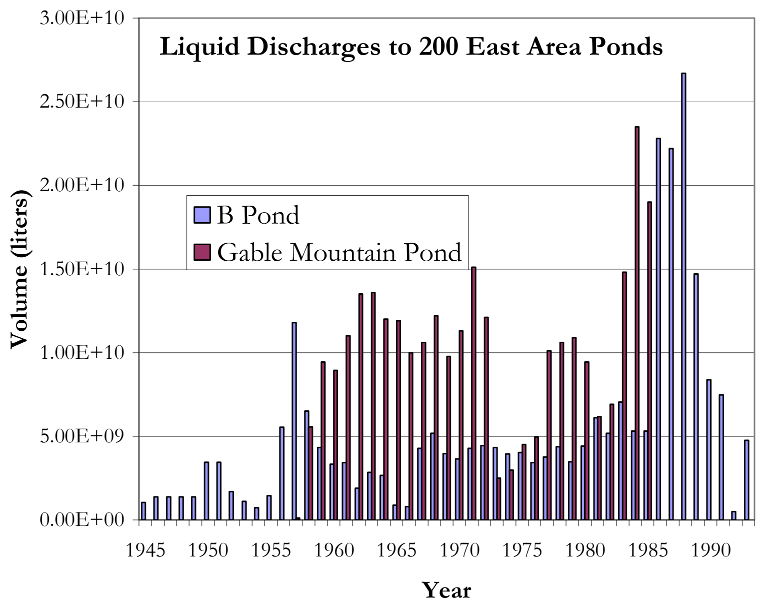


Figure 7.5. Discharge history for the B Pond and the Gable Mountain Pond systems. Source: Horton (2008).

8.0 Conclusions

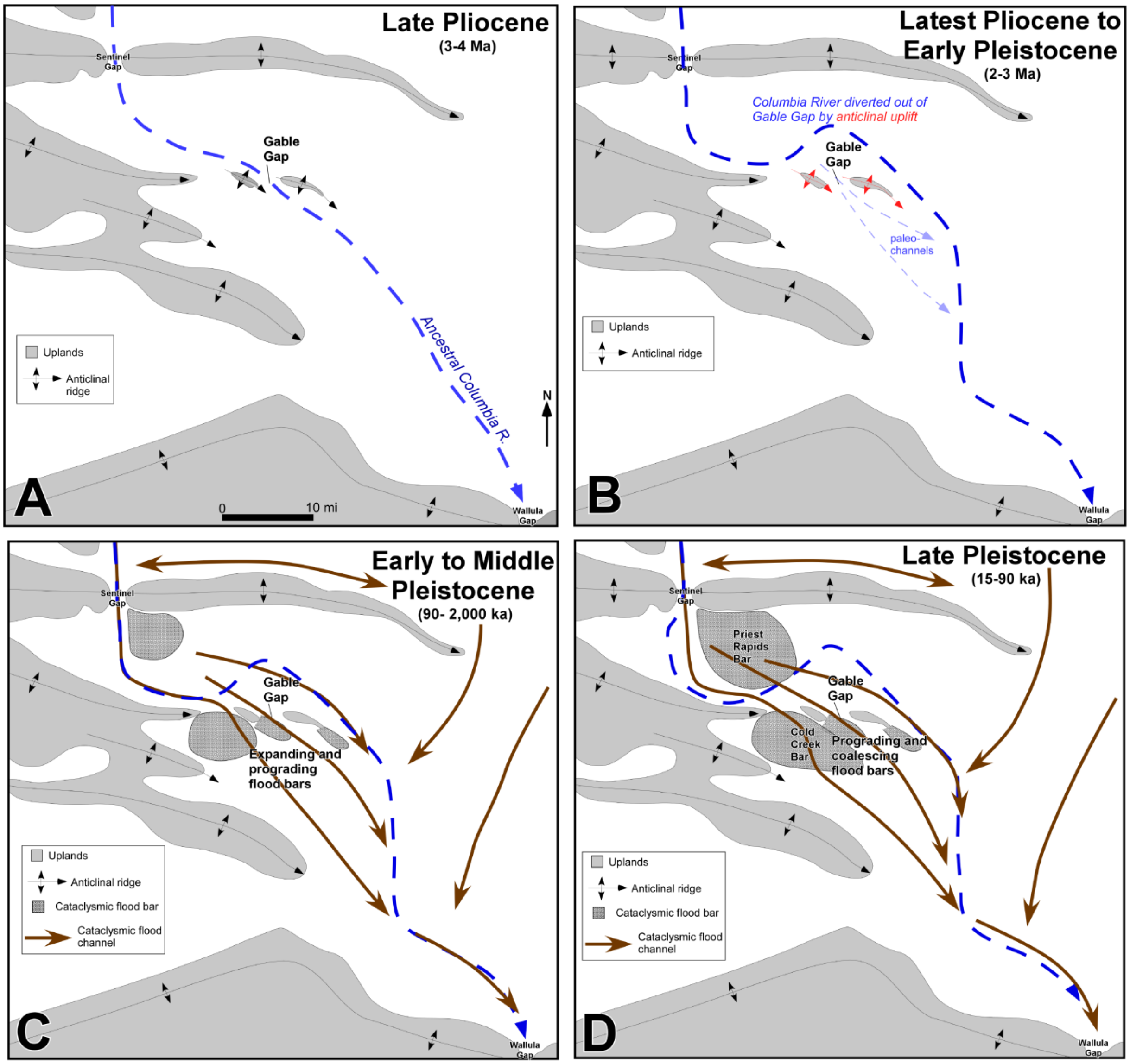
Gable Gap has a complex geologic history based on the long record of tectonism, erosion, and deposition located in an ancient water gap of the Columbia River. The following provides a synopsis of Gable Gap's geologic history.

Gable Gap's origins go back to the Miocene Epoch when lava flows of Columbia River basalt blanketed the area. Simultaneous with emplacement of the lava flows was north-south tectonic compression, which resulted in the growth of the YFB including the Umtanum Ridge-Gable Mountain anticline. This central anticline bisects the Pasco Basin and includes the second-order, en echelon folds of Gable Mountain and Gable Butte, which slowly uplifted between lava eruptions. This is indicated by the thickness of the lava flows and sedimentary interbeds of the Ellensburg Formation, which thin over the anticlinal ridges. More and more time separated basalt eruptions, so that towards the end of Columbia River basalt time, hundreds of thousands to millions of years separated basalt flows until the last flow covered the gap about 10.5 million years ago. Following basalt volcanism, the Umtanum Ridge-Gable Mountain uplift continued its long-term average slow growth.

The ancestral Columbia River continued to slowly fill the subsiding synclinal basins north and south of Gable Mountain/Gable Butte with sediments of the Ringold Formation (Fecht et al. 1987; DOE 1988; Lindsey 1995). During much of the Ringold time period, the Columbia River maintained a channel southeastward through the central Pasco Basin including Gable Gap (Fecht et al. 1987; Lindsey 1996). Aggradation of the Ringold Formation continued for another 7 million years, slowly filling in the Pasco Basin with fluvial and lacustrine sediments. During some of the Ringold time period, it appears the antecedent Columbia River may have flowed over bedrock to expose the Columbia River basalt across the axis of the Umtanum Ridge-Gable Mountain anticline within Gable Gap. Several of the upper basalt layers, along with intercalated sedimentary interbeds of the Ellensburg Formation, were locally removed along the crest of the tightly folded and fractured anticline during this time (Figure 8.1, Stage A). Infilling of the ancestral Columbia River channels with Ringold-age deposits suggest the earliest channels developed during the Ringold time interval.

Suddenly (with respect to geologic time) about 3 million years ago, infilling of the synclinal basins ceased and the Columbia River began to erode and incise back down into the Ringold Formation, removing much of the sediment previously deposited from the center of the basin. (The area known as White Bluffs is an erosional remnant of the former Ringold surface.) The cause for the incision is believed to be the result of regional tectonic uplift and Cascade volcanism associated with the ancestral Cascade Range, or perhaps the downstream breaching of a volcanic dam in the Columbia River Gorge (Fecht et al. 1987). Within a relatively short time, the Columbia River found a new base level that was ~500 ft (150 m) lower than at the end of the Ringold time period.

The ancestral post-Ringold Columbia River continued to flow through Gable Gap into early Cold Creek time (Figure 8.1, Stage A). Along the new channel, the Columbia River partially backfilled low areas with additional fluvial-channel deposits, creating the Cold Creek unit. A train of Cold Creek gravels spreads out southeast of Gable Gap, marking the former path of the Columbia River through the central Hanford Site. The transition from gravel-dominated to silt-dominated sediments of the Cold Creek unit marks the shift of the ancestral Columbia River out of Gable Gap and into the Wahluke syncline north of Gable Mountain (Figure 8.1, Stage B). The cause for this dramatic, permanent shift in the river channel may have been due to tectonic uplift along the Umtanum Ridge-Gable Mountain structure. With the river channel out of the gap, fluvial overbank deposits (CCUz) would have begun to accumulate within the abandoned Gable Gap.



gg.chron.comp.jpg

Figure 8.1. Late-Cenozoic history and evolution of paleodrainage in the vicinity of Gable Gap

During the Ice Age (Pleistocene Epoch), massive cataclysmic floods repeatedly occurred. Erosion and deposition by Ice Age floods had a profound effect on the Pasco Basin and overwhelmed all other geologic processes occurring during or since the Pleistocene. The exact age of the earliest Ice Age floods to pass through the Pasco Basin is unknown. The oldest documented floods were at least 780,000 years ago (Bjornstad et al. 2001; Pluhar et al. 2006), although the first floods may have occurred closer to the beginning of the Ice Age around 2.6 million years ago. Evidence for the earliest floods has since either been eroded away by a hundred or more younger floods, or lies buried beneath the cover of younger flood deposits. The Ice Age was not a single climatic event—instead, glacial periods were cyclic, occurring about every 100,000 years over at least the last million years (Figure 8.2). Ice Age floods may be associated with each major glacial advance. In between glacial cycles were several tens of thousands of years of interglacial conditions similar to those of today. It is possible the earliest cycles going back to the beginning of the Pleistocene Epoch were not as regular or well behaved as the last cycles shown in Figure 8.2.

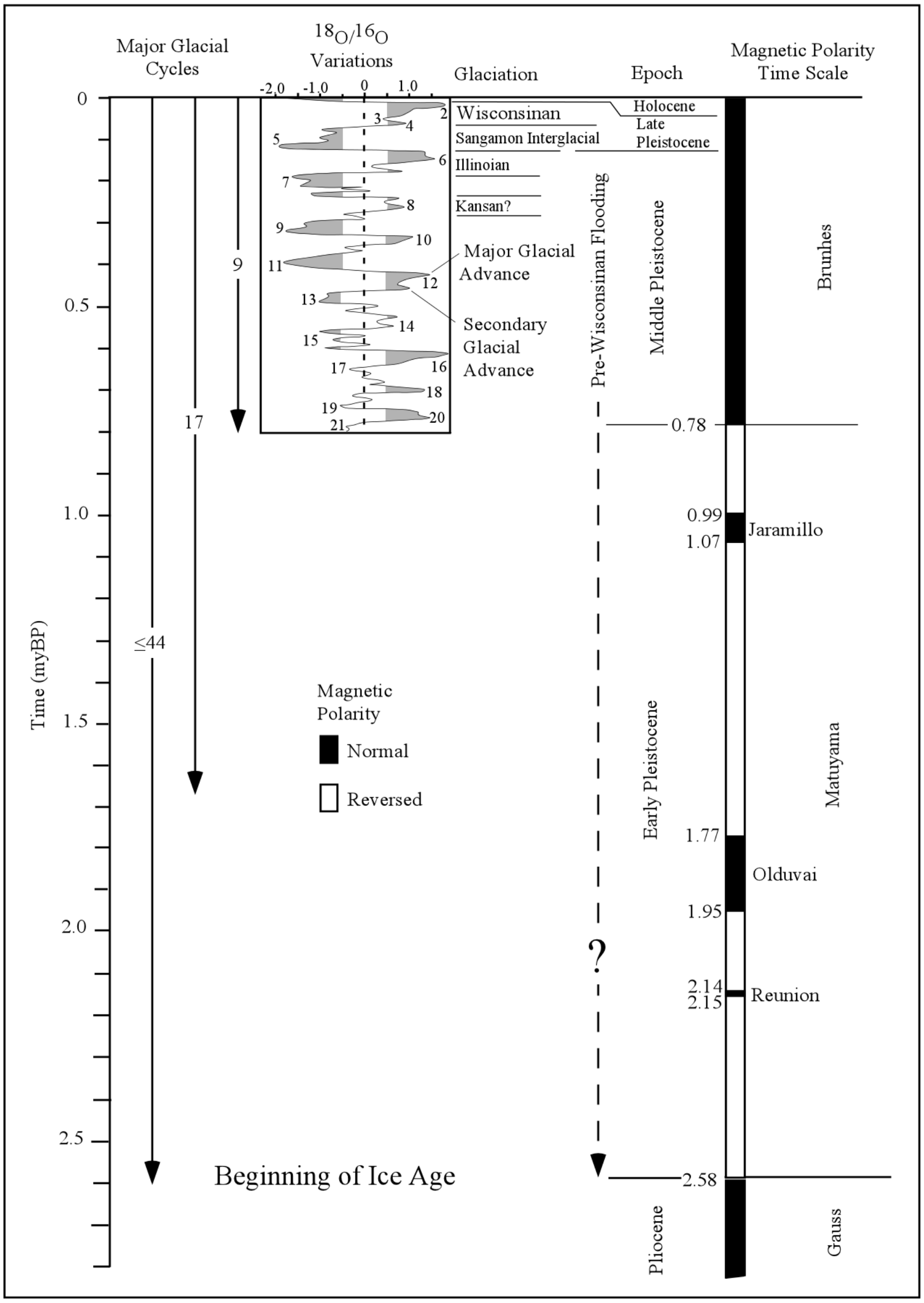


Figure 8.2. Ice Age floods in geologic time. The Ice Age, equivalent to the Pleistocene Epoch, lasted from 2.6 million years ago until about 15,000 years ago. Source: Bjornstad (2006).

Intense erosion occurred with the earliest Ice Age floods as they squeezed through the narrowed hydraulic constriction at Gable Gap. Locally, the floods scoured out deep rock basins and potholes in the uppermost basalt flows and interbeds (e.g., wells 6-55-60 and 6-55-55 in cross section C-C' [Figure A.4]). This resulted in the local removal of all pre-existing suprabasalt sediments along the narrowest section of the gap. In the south part of Gable Gap, the floods shaped a cohesive, flood-resistant sequence of CCUz into an elongated mound, reminiscent of those eroded by Missoula floods within the Channeled Scabland (see Figure 4.8). The streamlined island, capped with a thick cover of cohesive silt, effectively protected an underlying Cold Creek unit gravel sequence and Ringold Formation sediments from flood erosion at the core of the islands (see Figures 2.2, 4.7, A.2, and A.5). Seismic-reflection data also support the presence of remnant, pre-Hanford-formation mounds in the subsurface (Repasky et al. 2009).

Several huge flood bars, including the Cold Creek, Priest Rapids, and Gable Mountain bars, probably began developing with the first floods early in the Pleistocene age (see Figure 8.1, Stage C). Erosional flood channels and streamlined islands capped with CCUz in Gable Gap were eventually buried as each flood deposited more sediment and the flood bars expanded and prograded east from Umtanum Ridge (see Figure 3.3). Eventually the bars expanded across Gable Gap, covering the older flood channels and streamlined hills with younger flood-bar deposits (Figure 8.1, Stage D). Even though the Columbia River had permanently shifted north, subsequent Ice Age floods continued to periodically flow through Gable Gap, reworking and carving shallow channels into the flood deposits. The configuration of the flood bars and channels from the last Ice Age flood about 15,000 years ago is as it appears today (see Figure 6.2). Since the end of the Ice Age, only minor changes to Gable Gap have been those caused by localized wind deposition or by humans.

Today, basalt extends above the water table and groundwater from the Central Plateau moves through Gable Gap within one or more paleochannels eroded into the basalt (Figure 8.3). If groundwater levels continue to decline, groundwater flow to the northwest of the 200 East Area through Gable Gap may become more restricted or cut off as water levels drop across the buried basalt divide. However, other as-yet unidentified deeper channels across the basalt divide may allow for flow of groundwater to continue indefinitely.

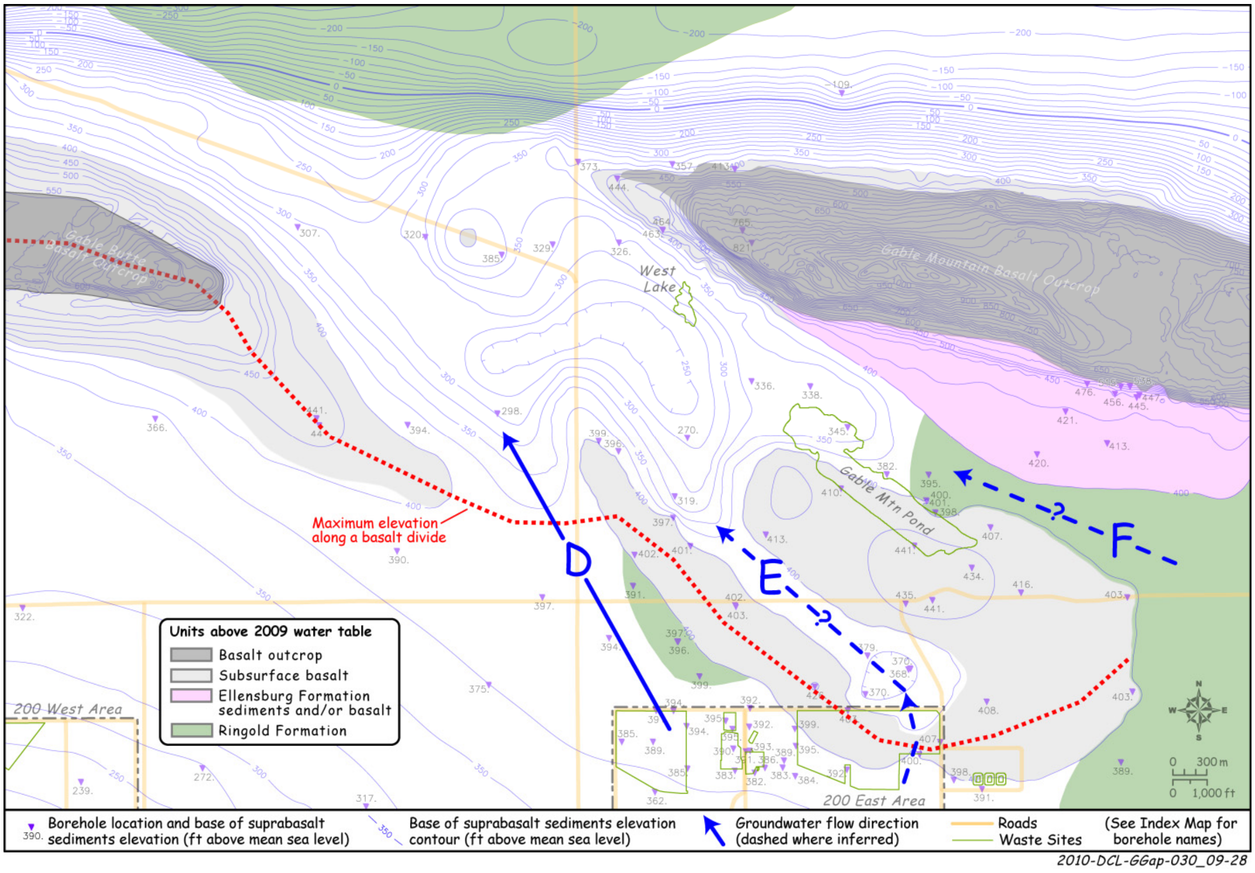


Figure 8.3. Areas of suspected groundwater flow through Gable Gap from the Central Plateau. Flow appears to be occurring along deeply buried paleochannels within the Gap (Paleochannels D, E, and F in Figure 6.3). Flow continues via a Paleochannel D from the northwest corner of the 200 East Area. Flow through Paleochannels E and F may also be moving through Gable Gap. Red dotted line marks maximum elevation along a basalt divide.

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Appendix A

Hydrogeologic Cross Sections

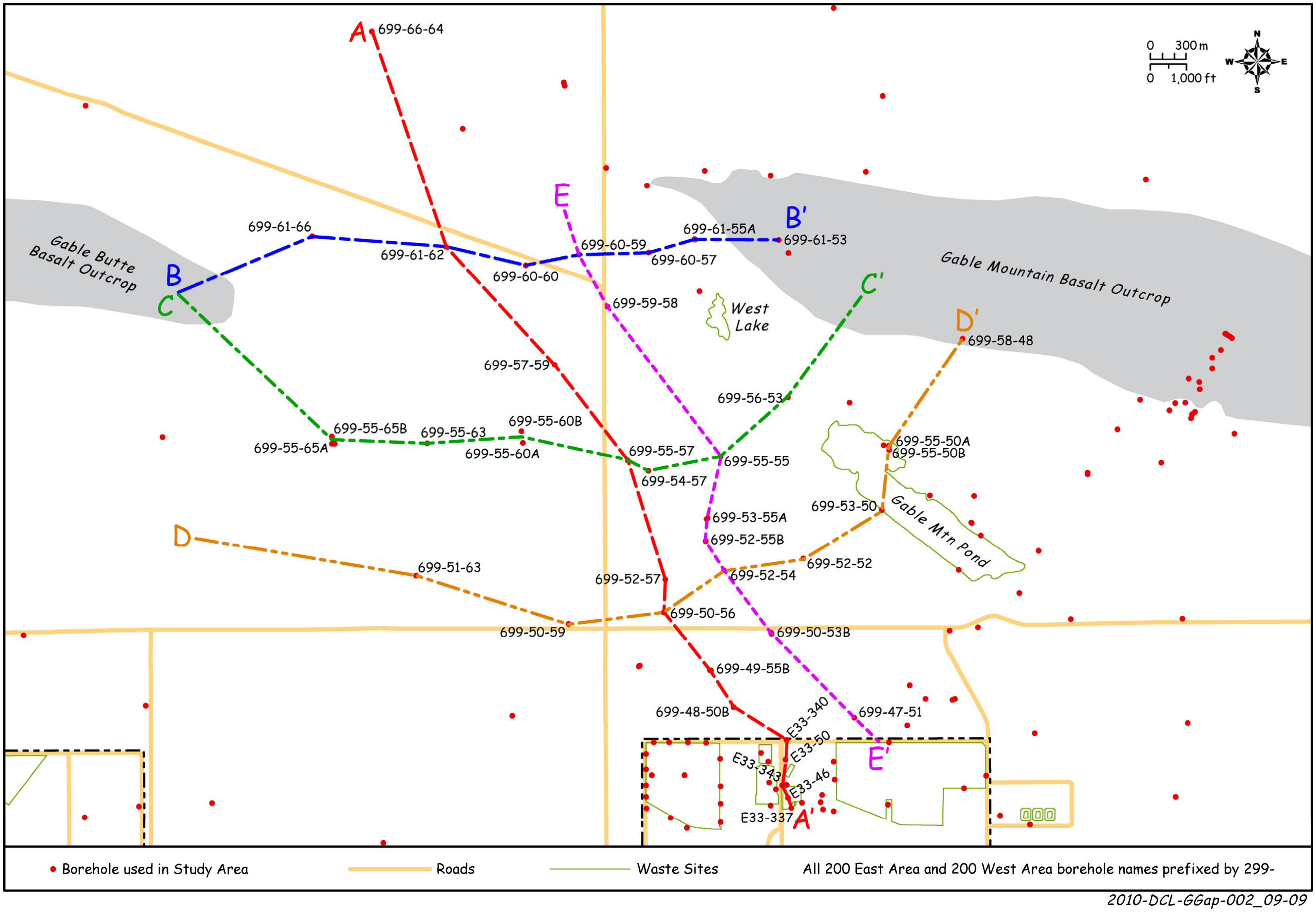

Figure A.1. Cross-section location map

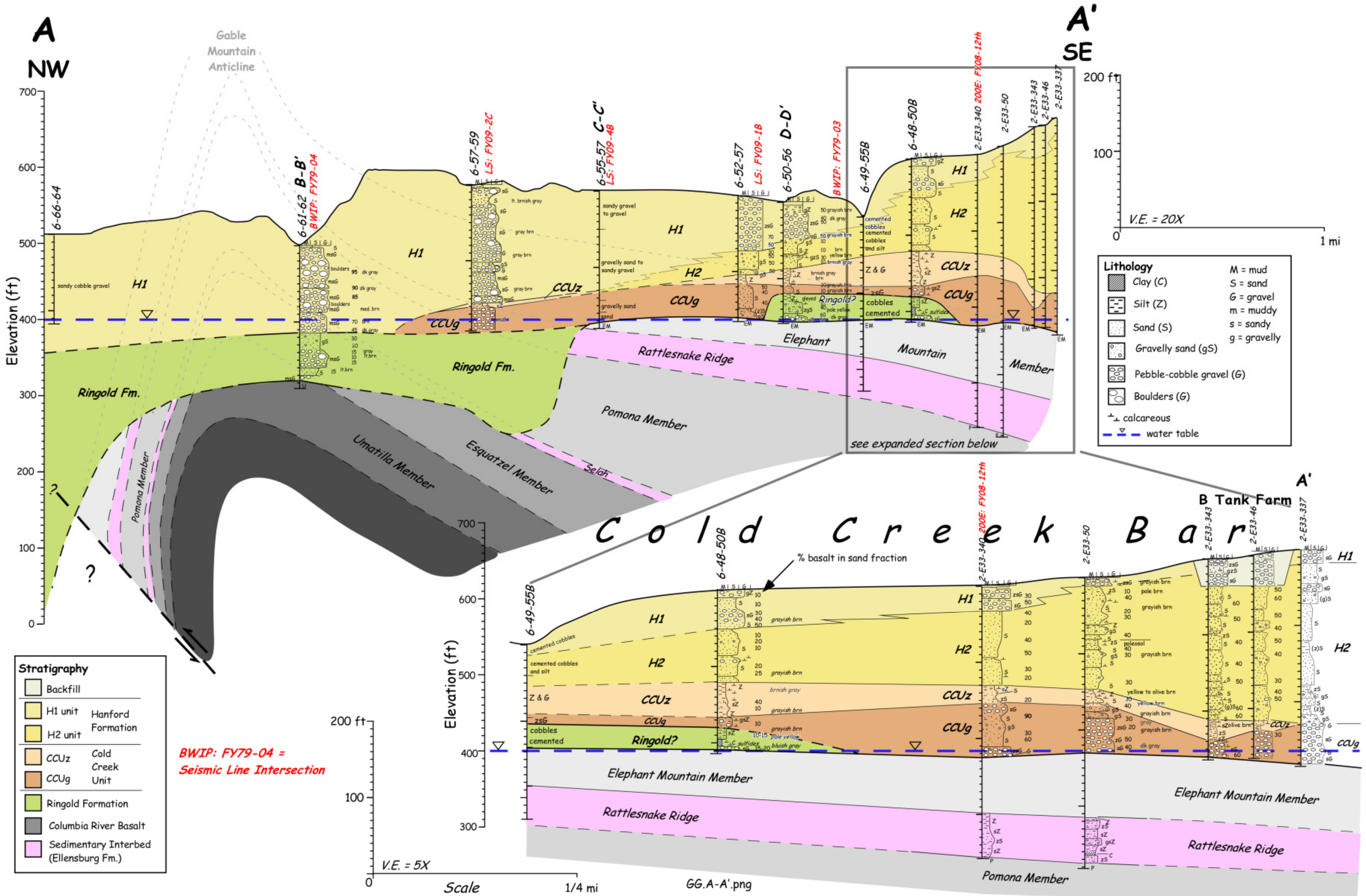

Figure A.2. Hydrogeologic cross section A-A'

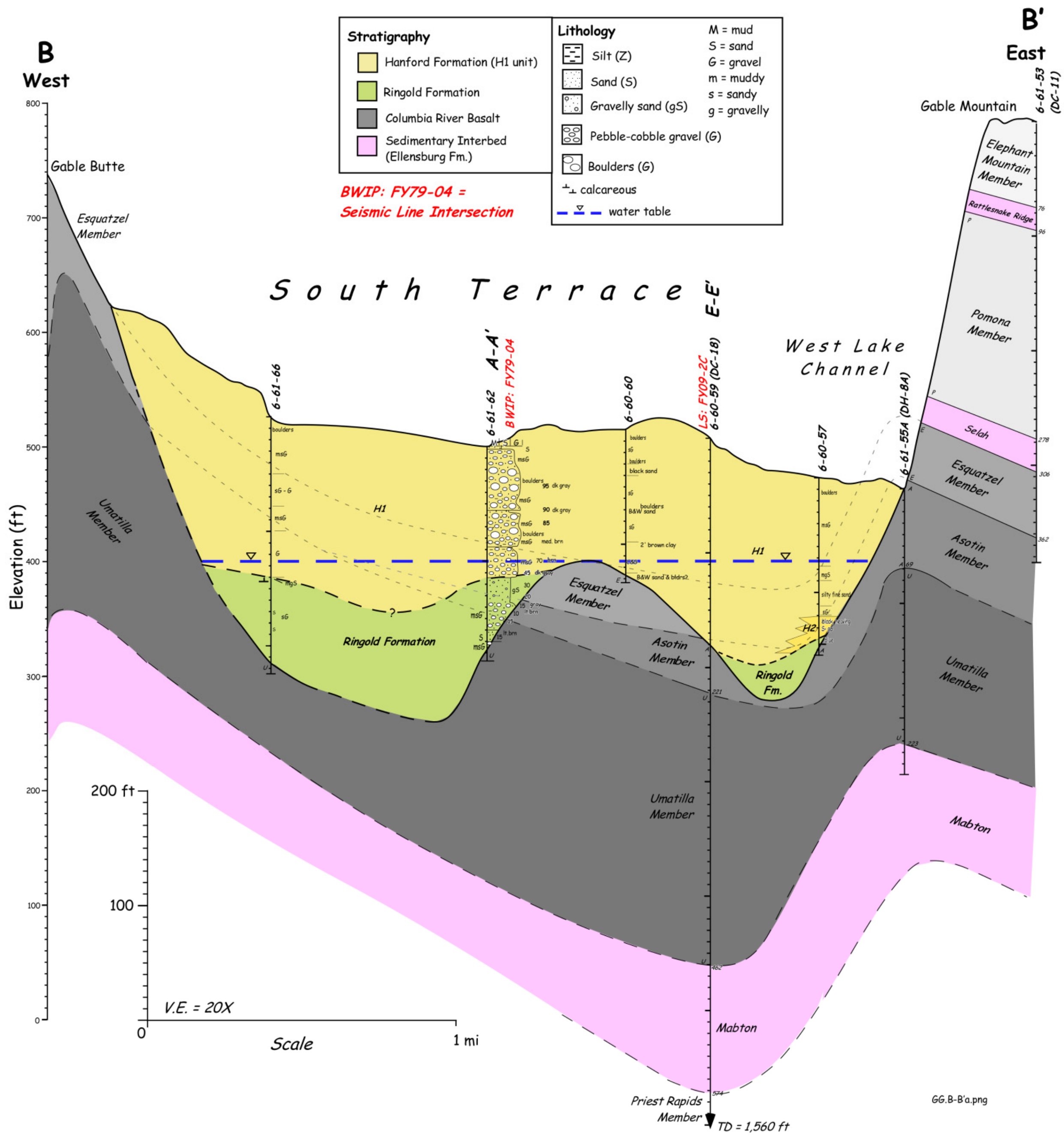

Figure A.3. Hydrogeologic cross section B-B’

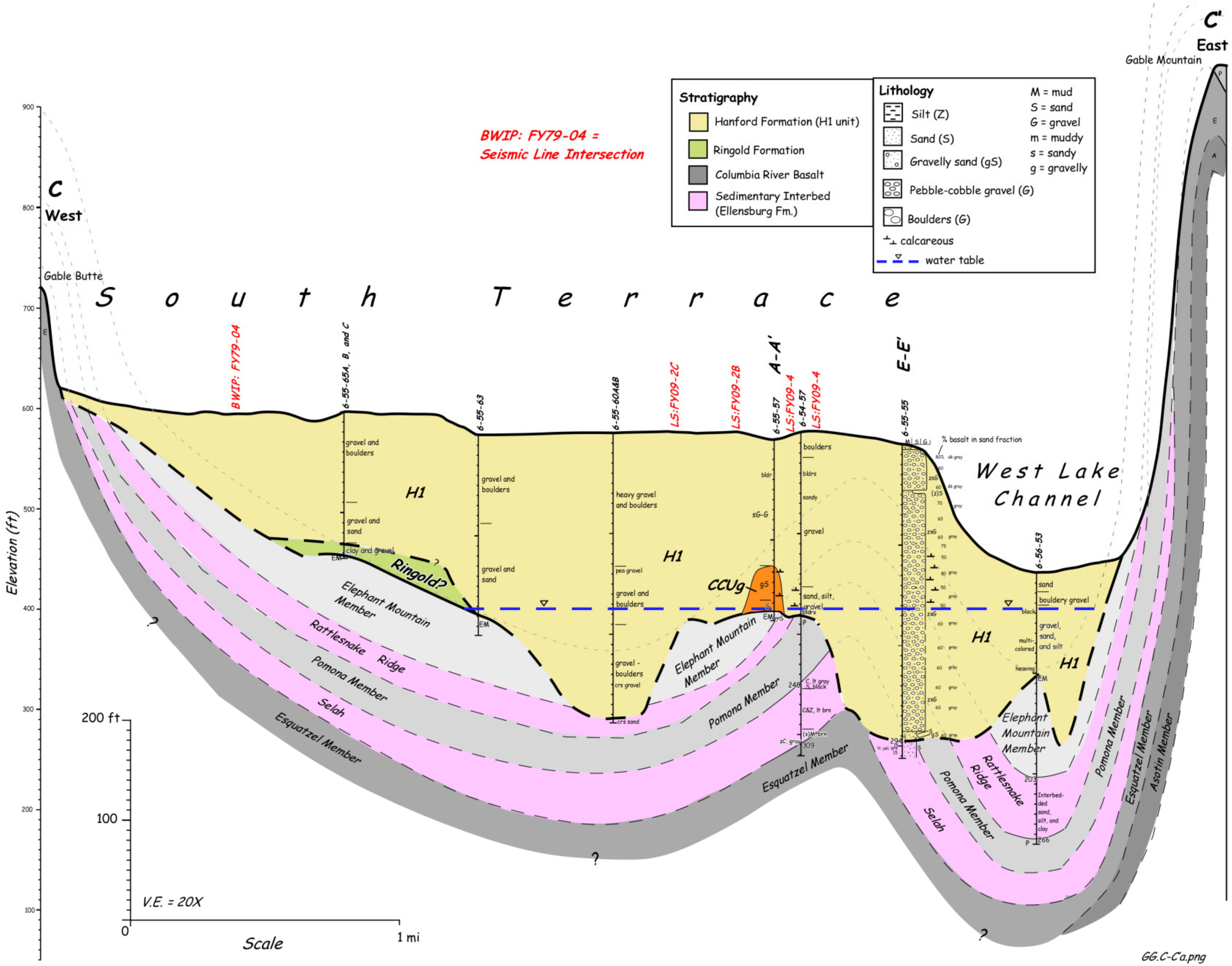

Figure A.4. Hydrogeologic cross section C-C’

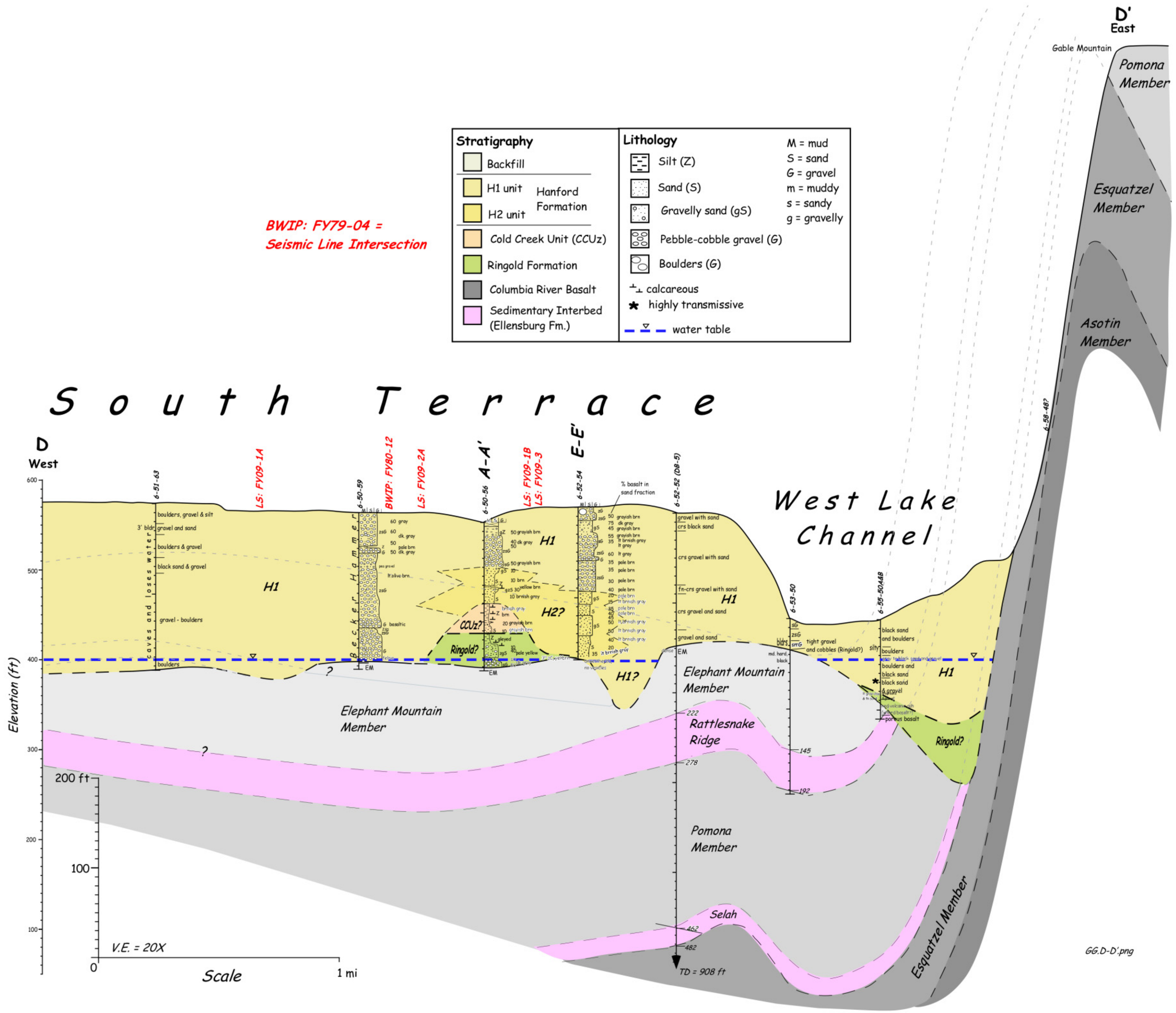

Figure A.5. Hydrogeologic cross section D-D'

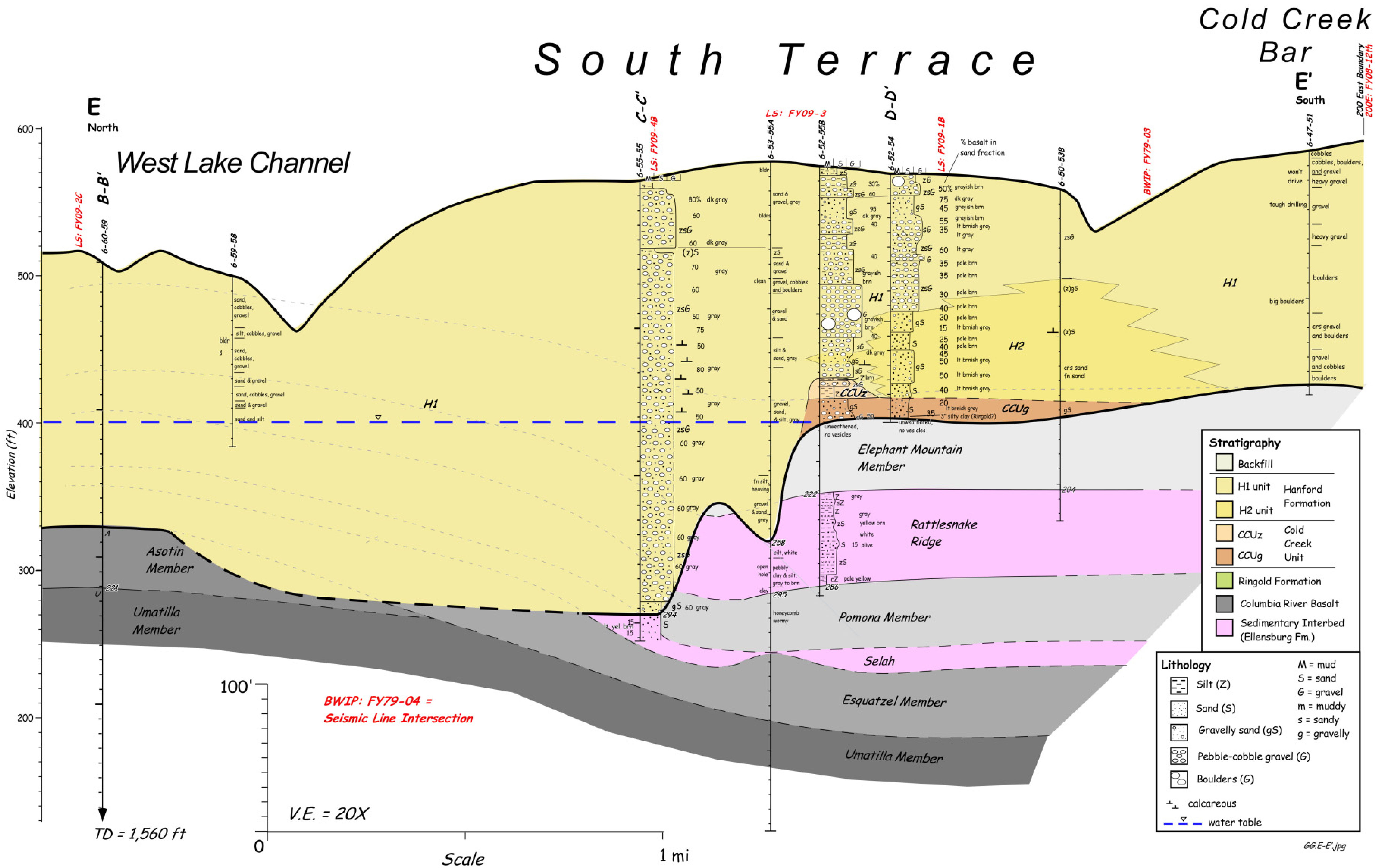

Figure A.6. Hydrogeologic cross section E-E'

Appendix B

Structure-Contour Maps Based on EarthVision® Model

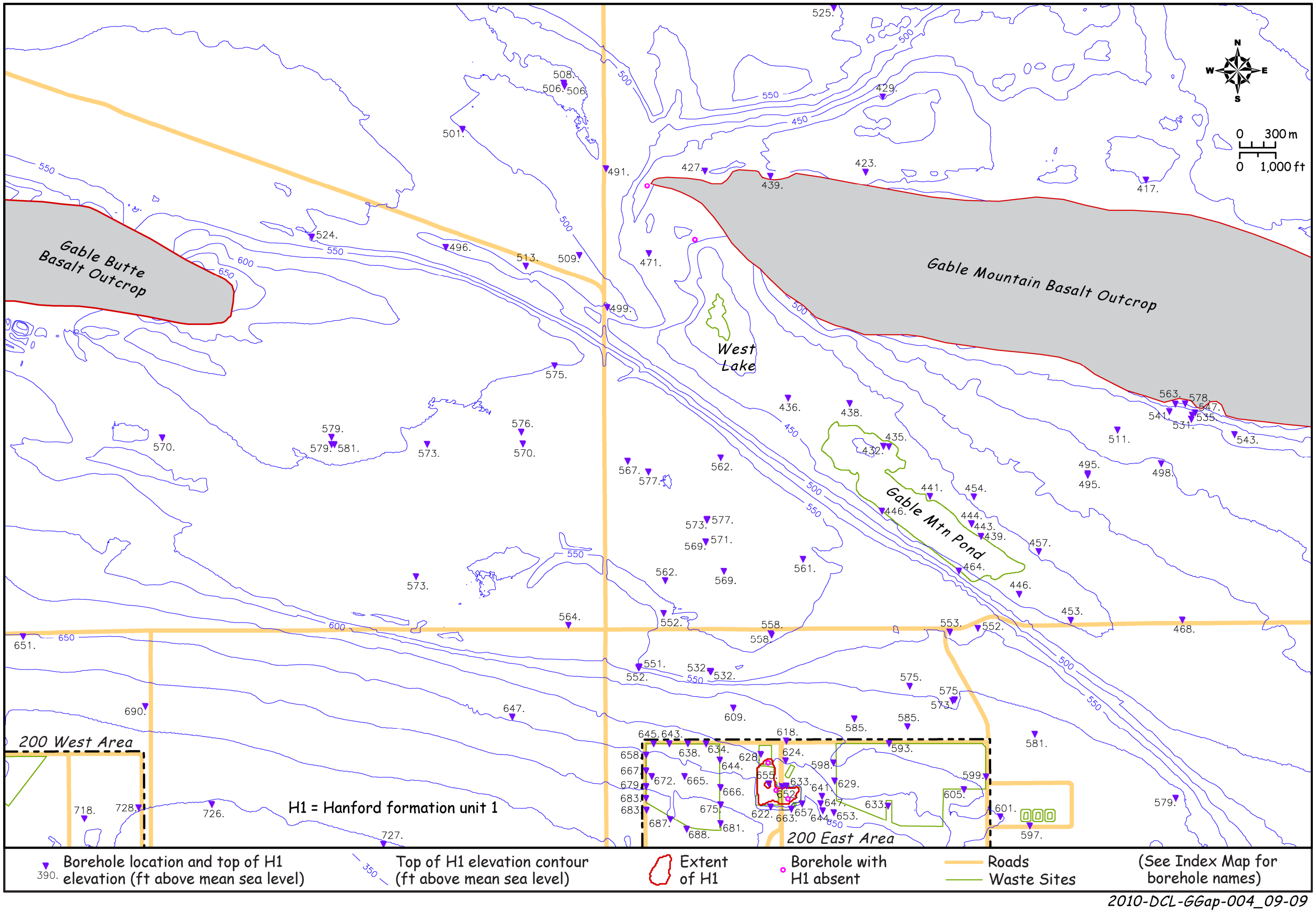

Figure B.1. Top of the Hanford formation H1 (upper gravel-dominated) unit. Contour interval = 25 ft (7.6 m)

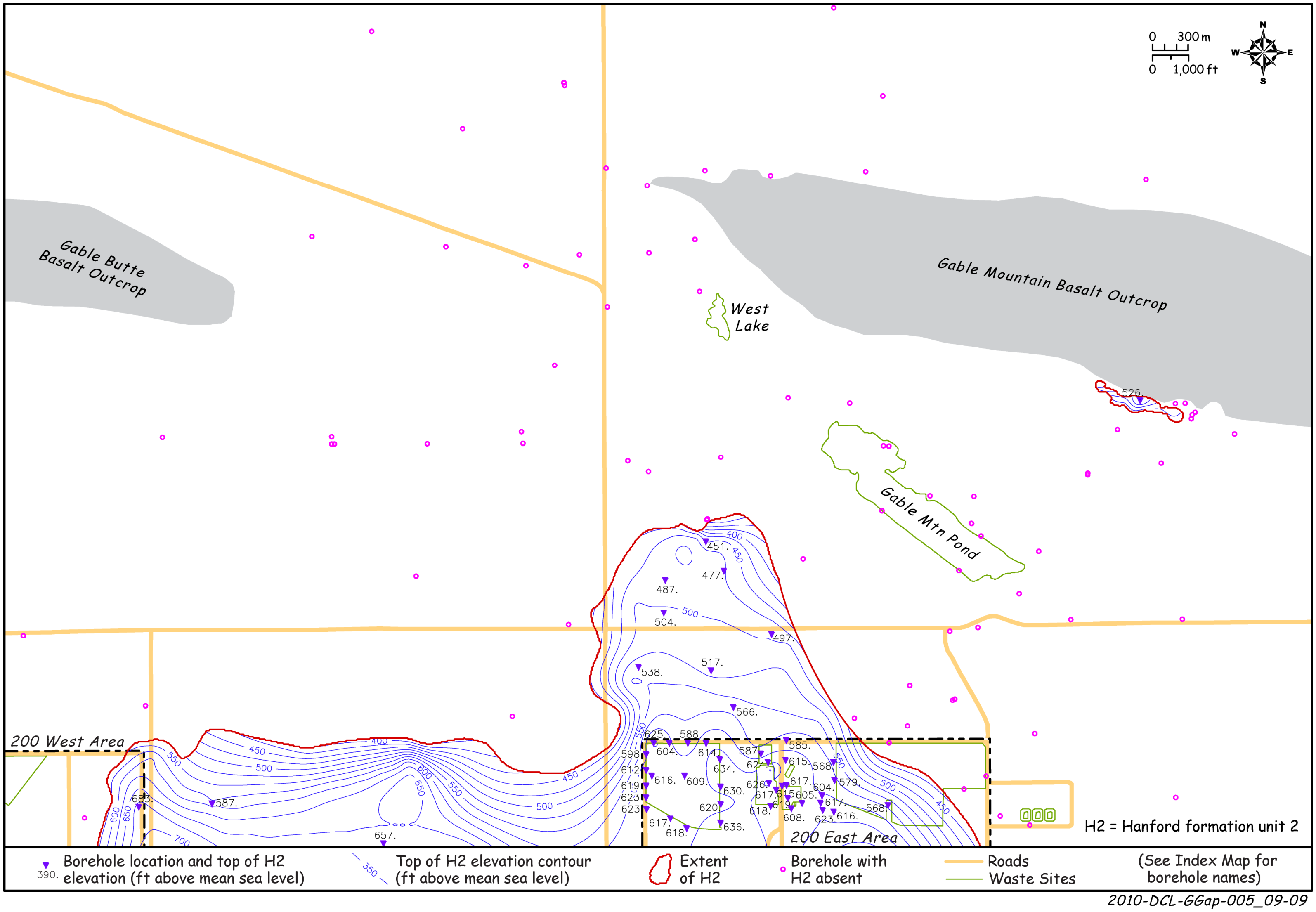

Figure B.2. Top of the Hanford formation H2 (sand-dominated) unit. Contour interval = 25 ft (7.6 m)

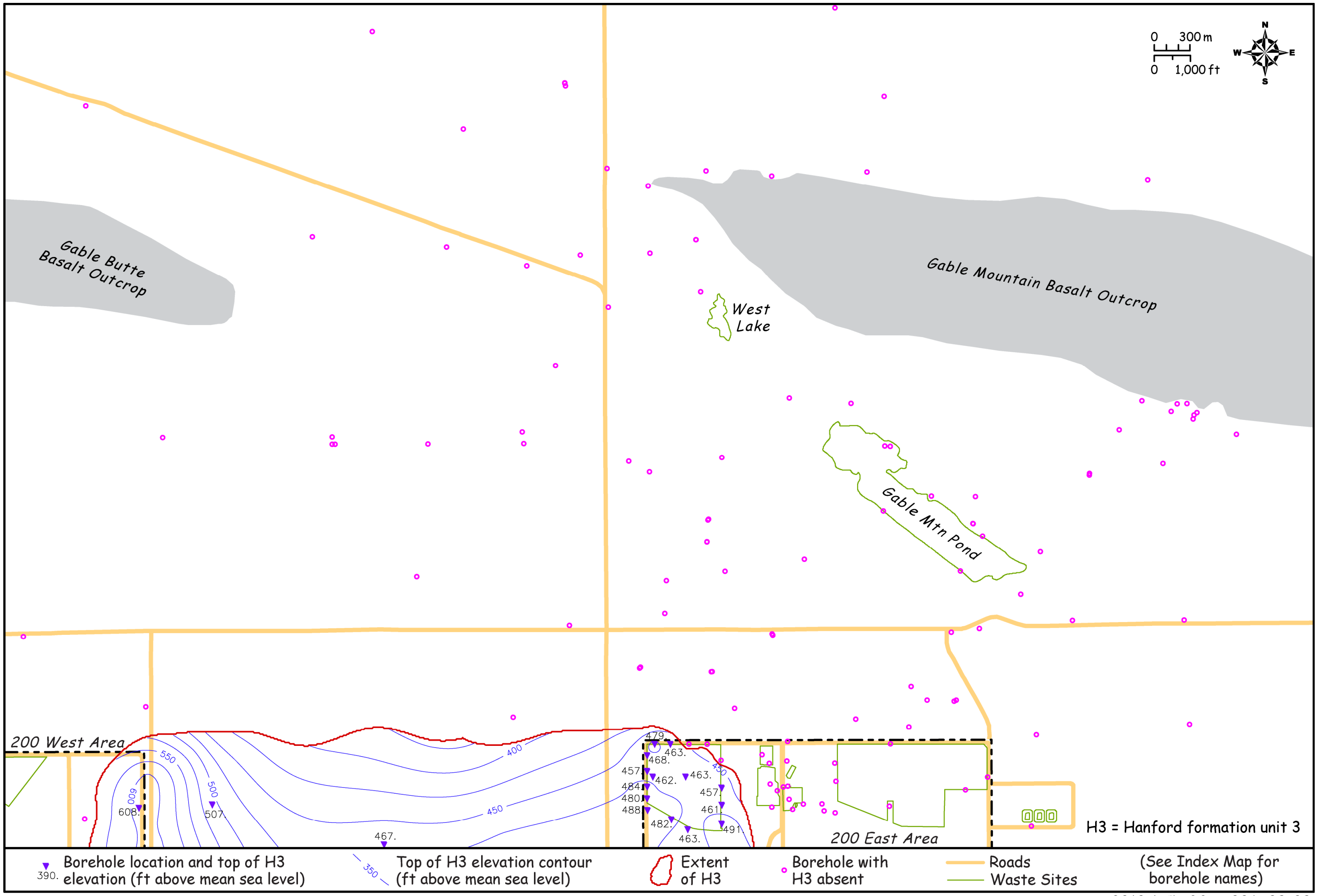

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Figure B.3. Top of the Hanford formation H3 (lower gravel-dominated) unit. Contour interval = 25 ft (7.6 m).

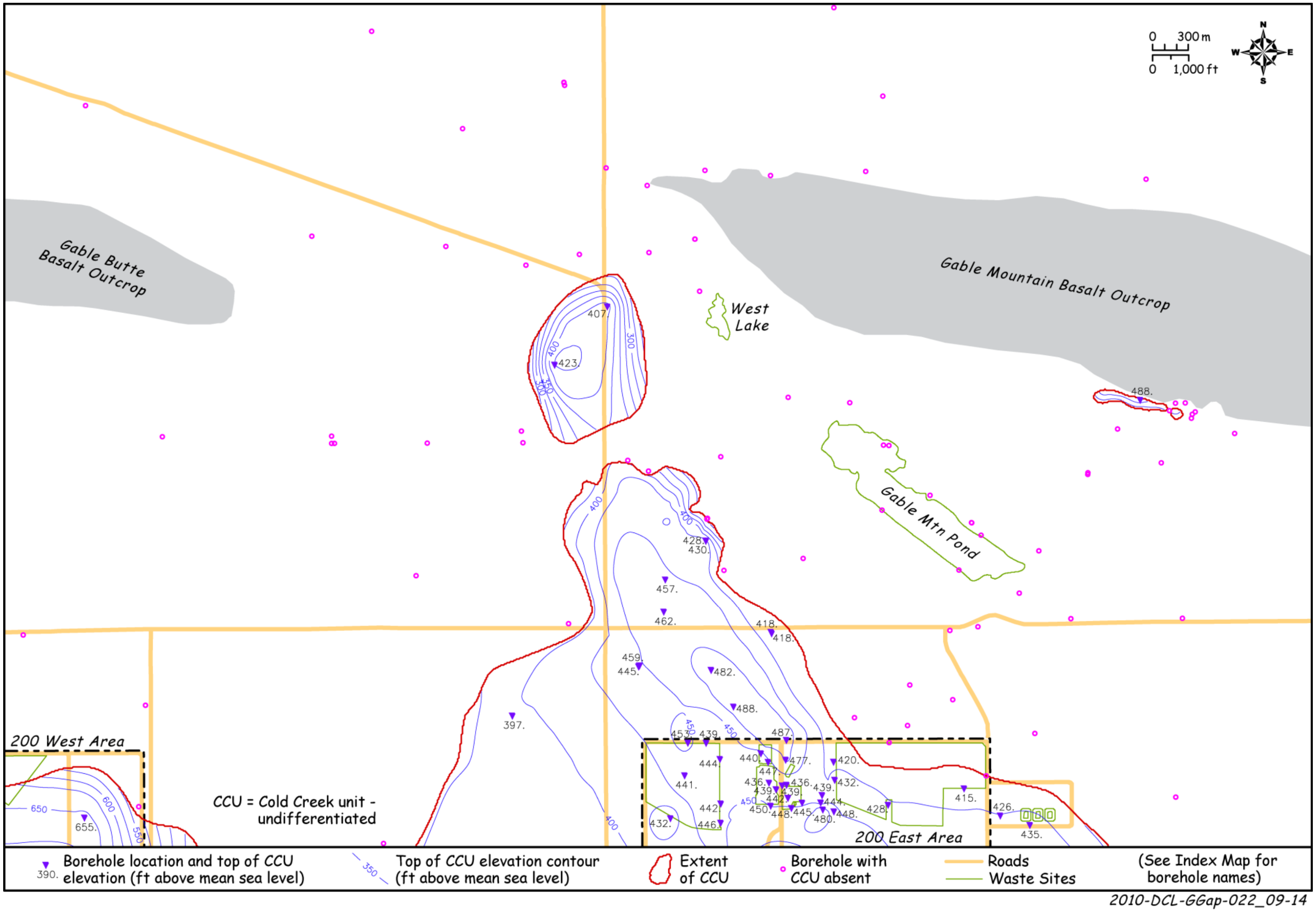

Figure B.4. Top of the Cold Creek unit (undifferentiated). Contour interval = 25 ft (7.6 m).

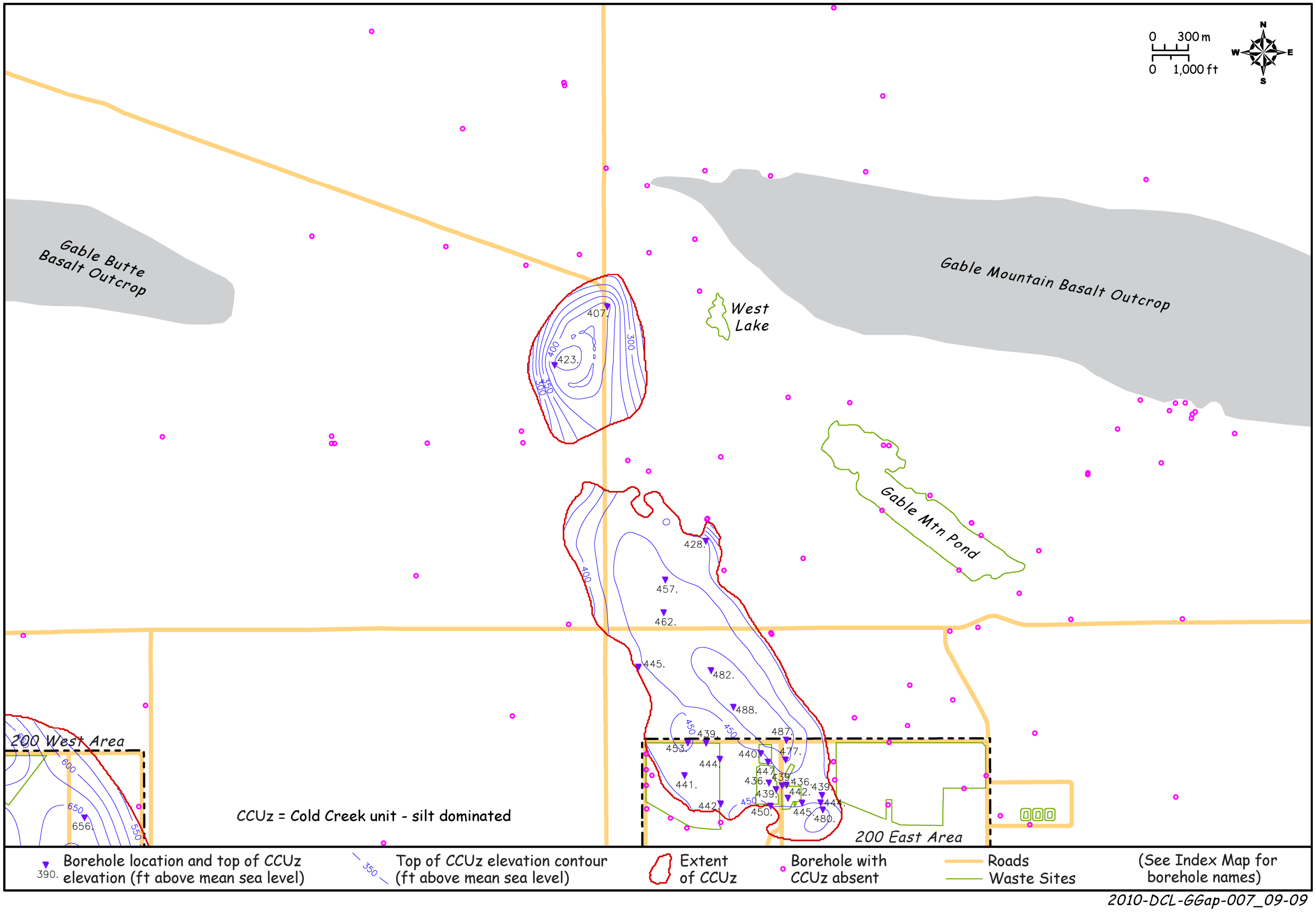

Figure B.5. Top of the Cold Creek silt (CCUz) subunit. Contour interval = 25 ft (7.6 m).

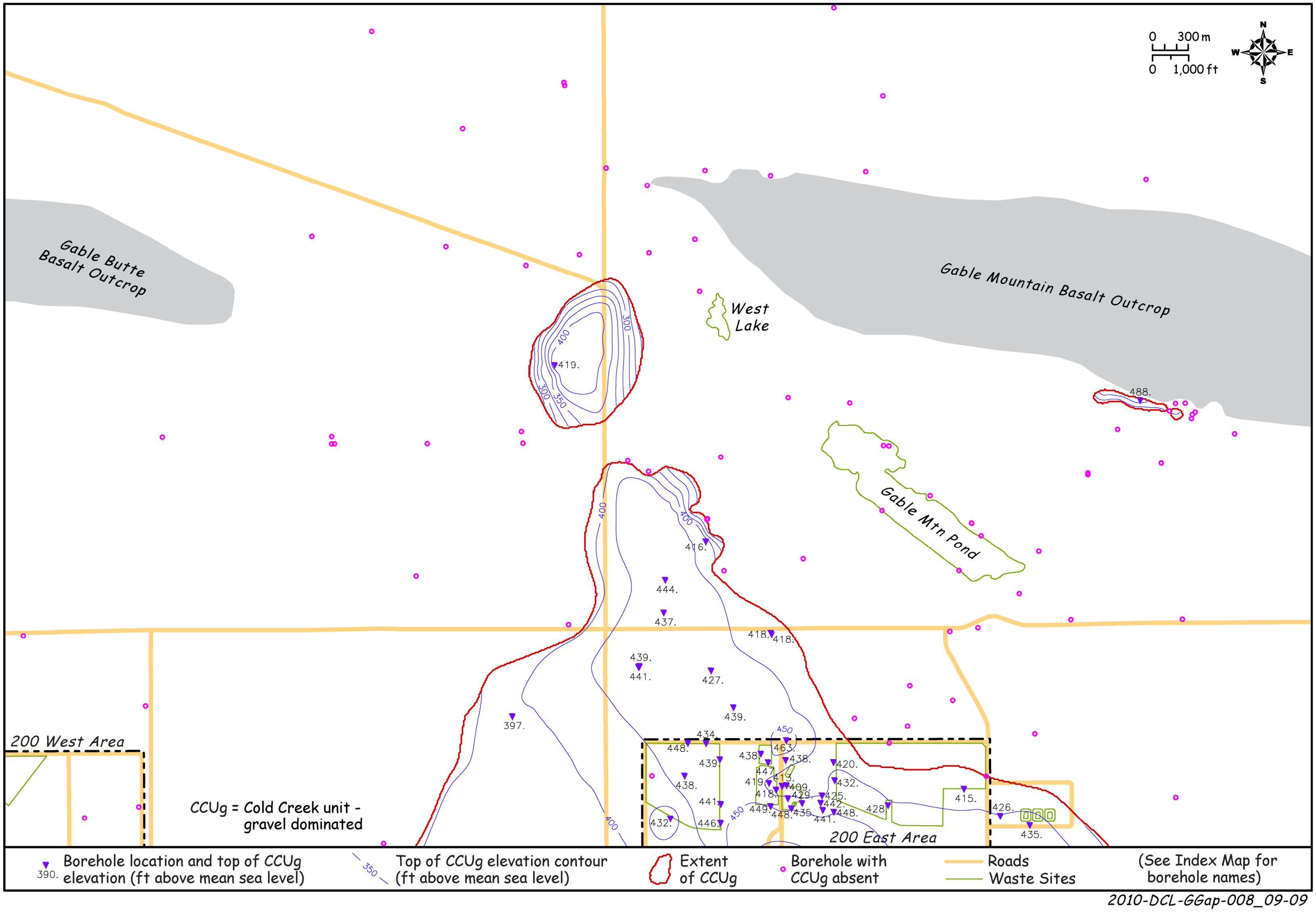

Figure B.6. Top of the Cold Creek gravel (CCUg) subunit. Contour interval = 25 ft (7.6 m).

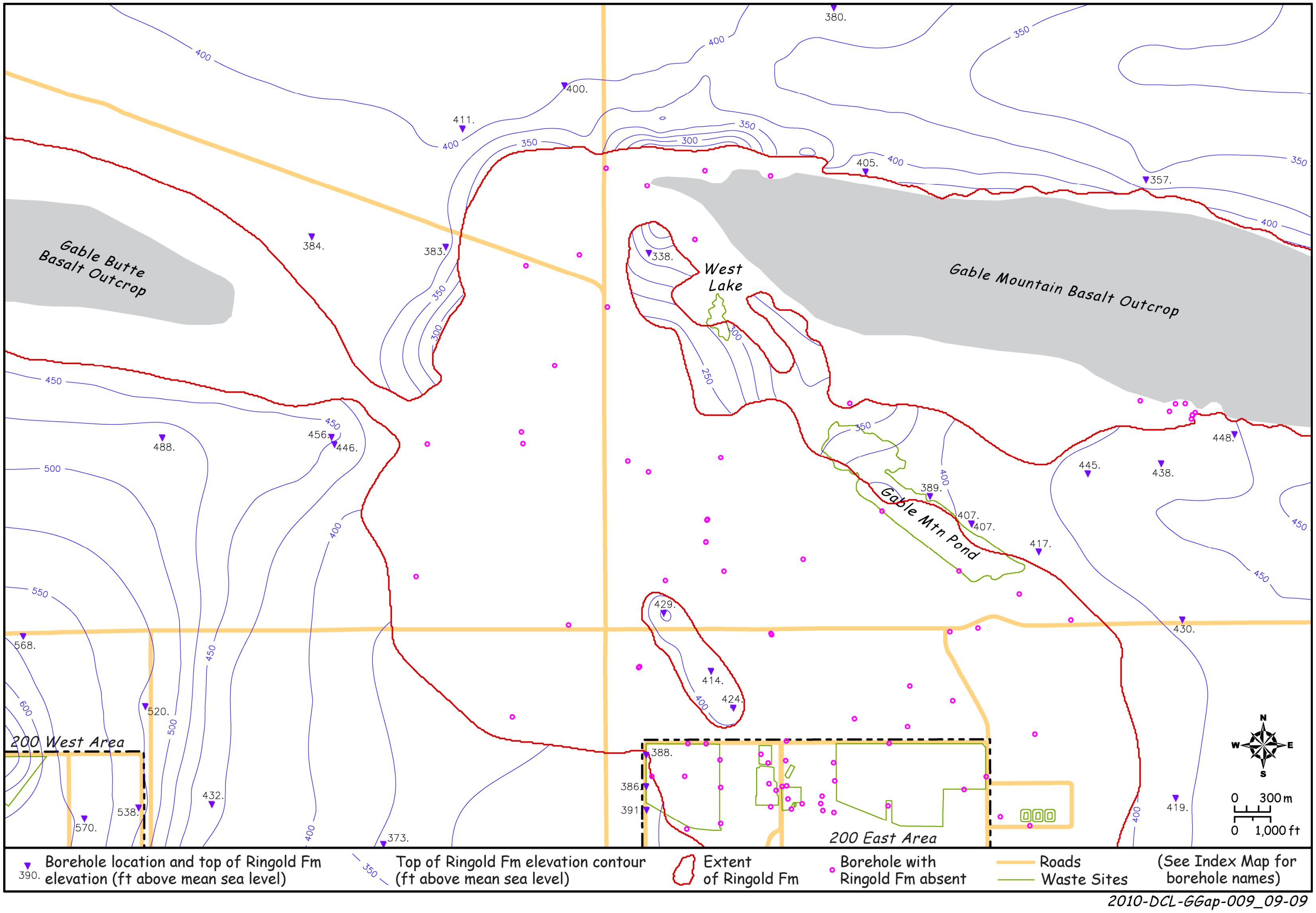

Figure B.7. Top of the Ringold Formation (undifferentiated). Contour interval = 25 ft (7.6 m).

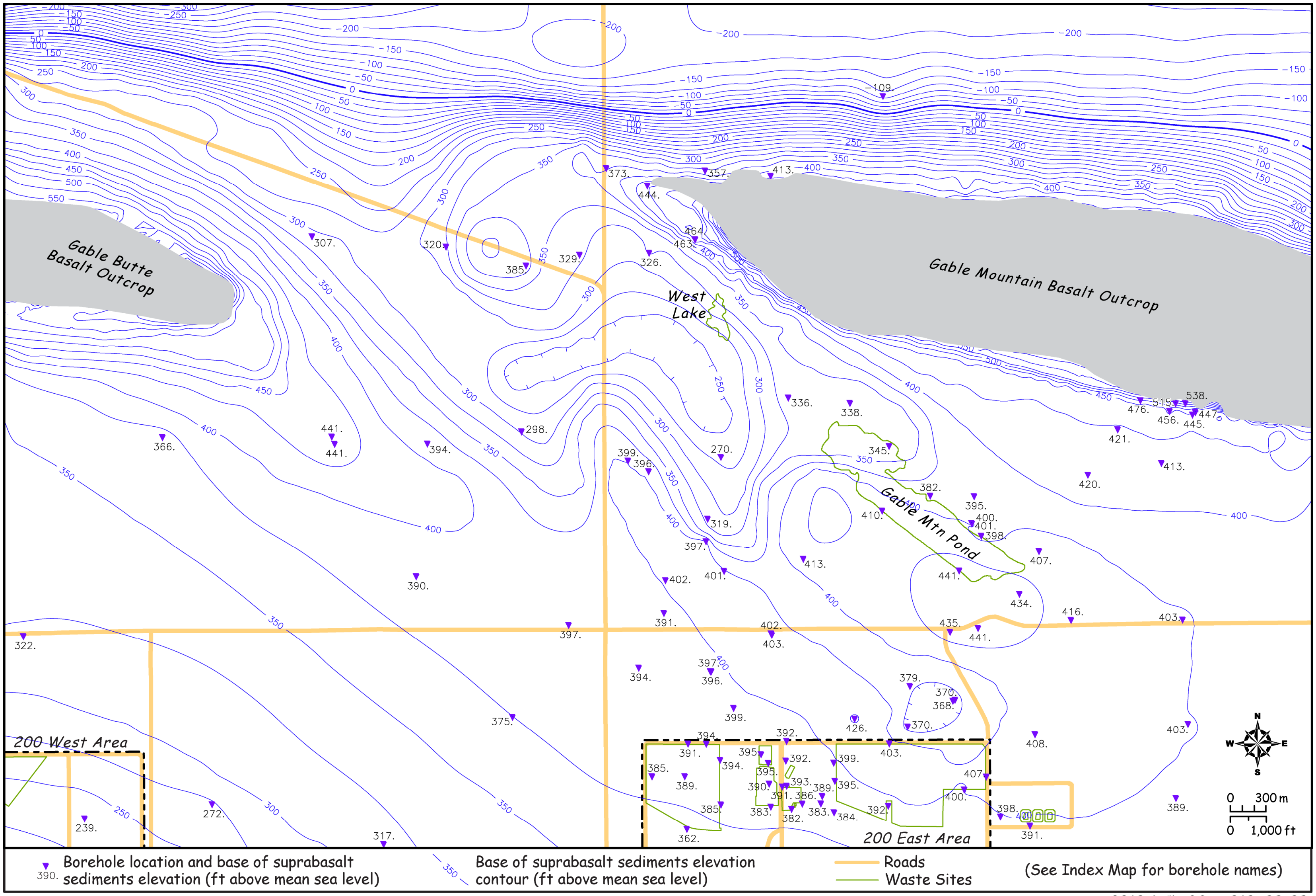

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Figure B.8. Base of the suprabasalt sediments (top of the Columbia River Basalt Group and Ellensburg Formation – undifferentiated). Contour interval = 25 ft (7.6 m).

Appendix C

Isopach Maps Based on EarthVision® Model

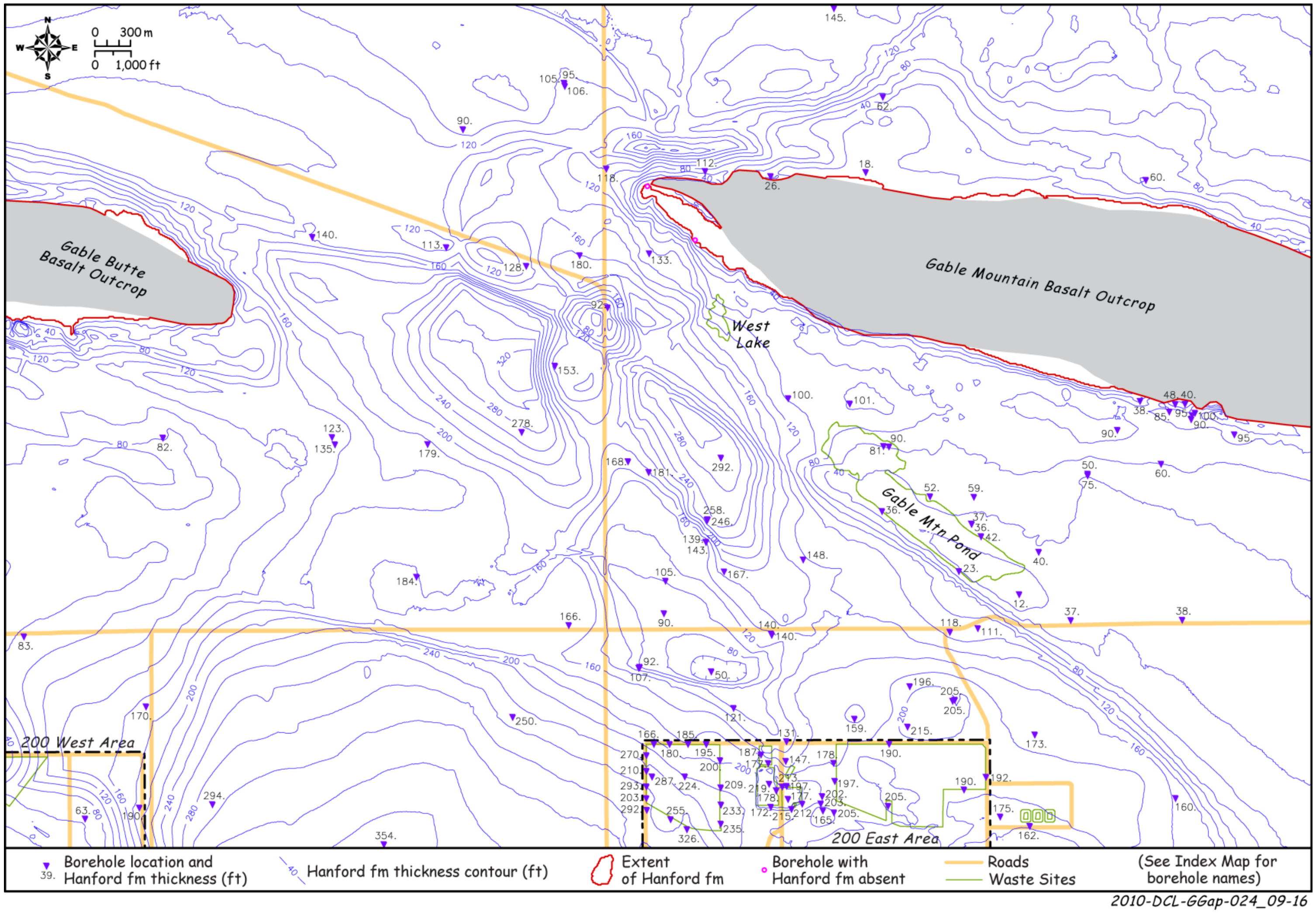

Figure C.1. Total thickness of the Hanford formation (undifferentiated). Contour interval = 20 ft (6.1 m).

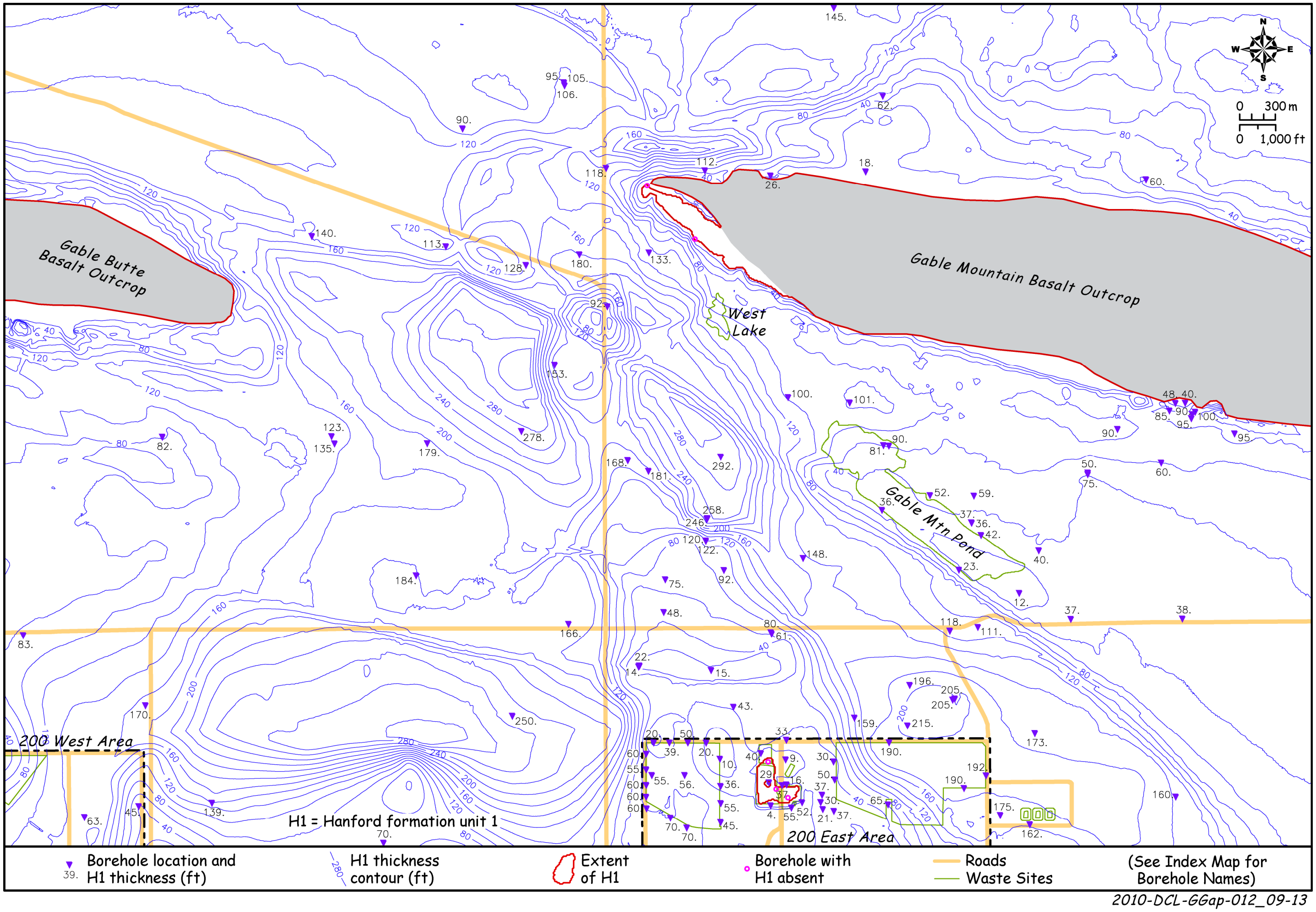

Figure C.2. Thickness of the Hanford formation H1 (upper gravel-dominated) unit. Contour interval = 20 ft (6.1 m).

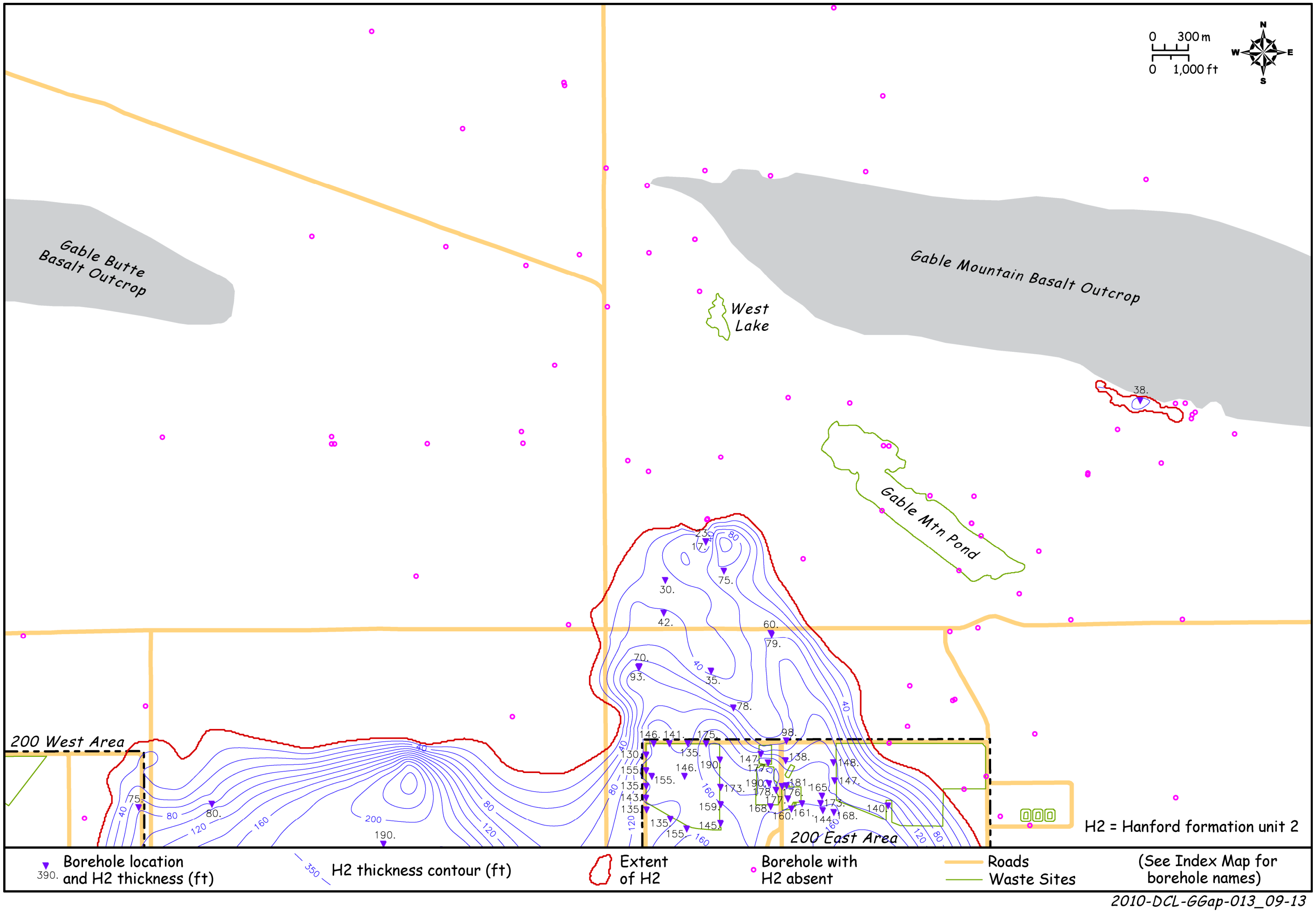

Figure C.3. Thickness of the Hanford formation H2 (sand-dominated) unit. Contour interval = 20 ft (6.1 m).

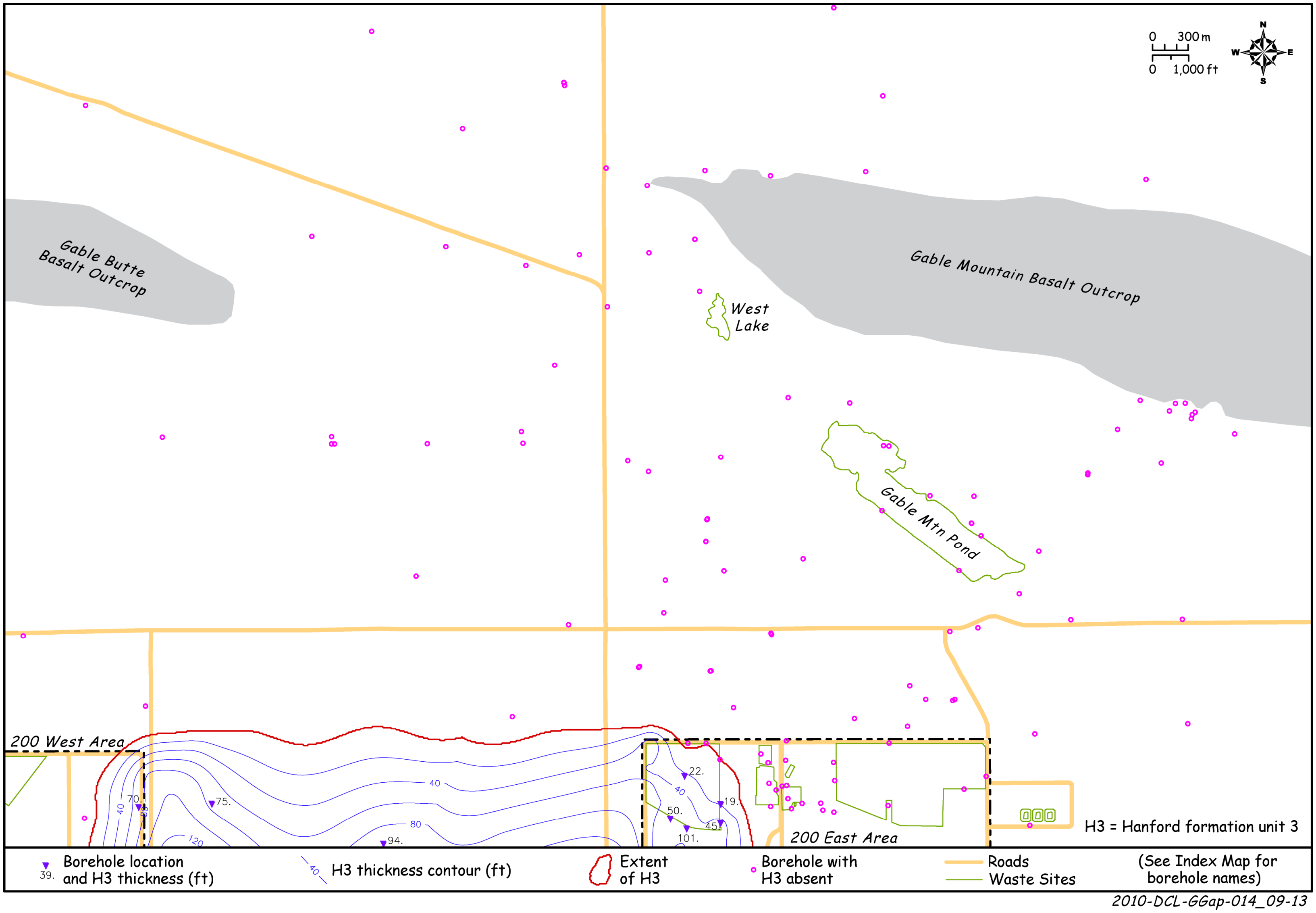

Figure C.4. Thickness of the Hanford formation H3 (lower gravel-dominated) unit. Contour interval = 20 ft (6.1 m).

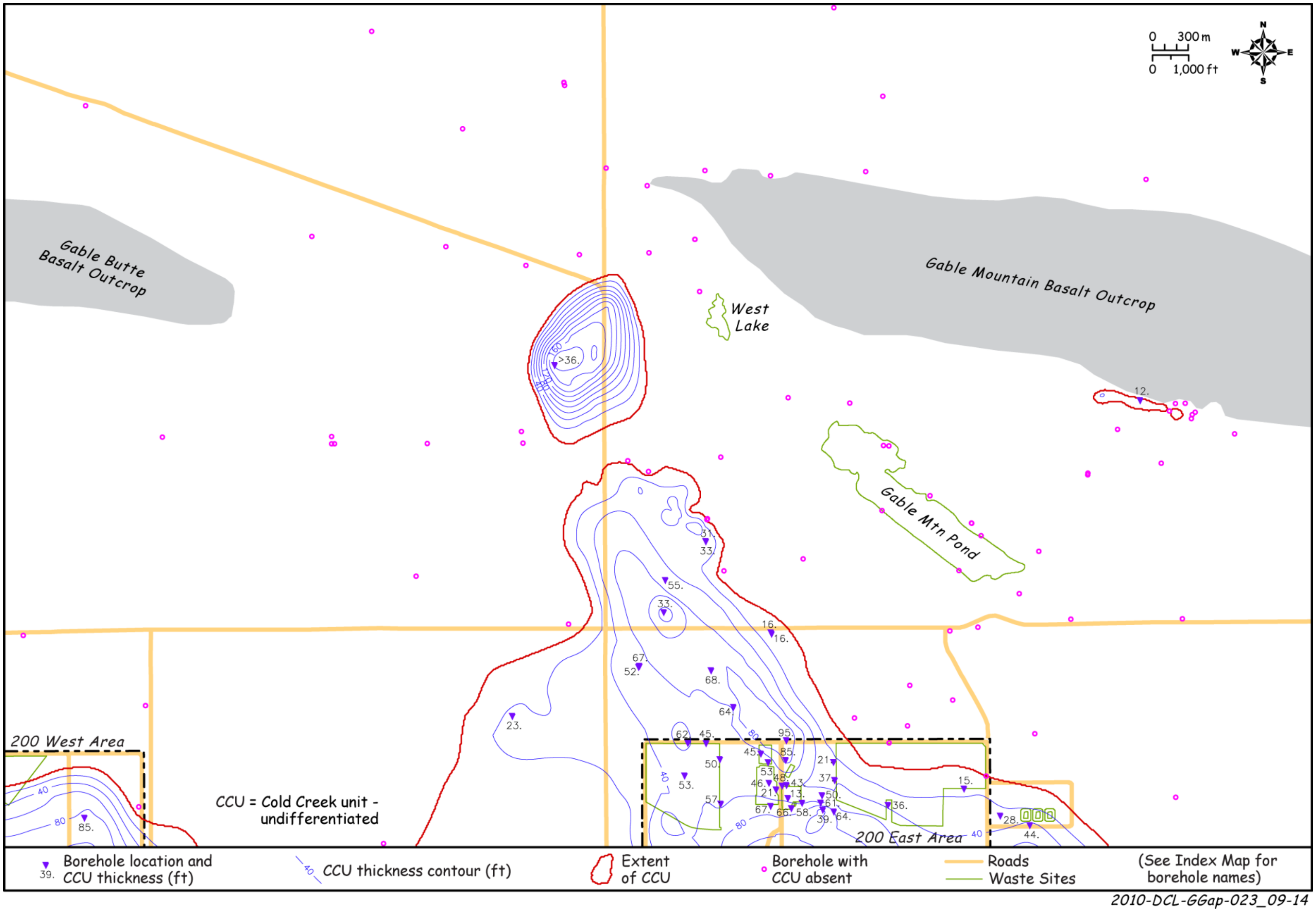

Figure C.5. Total thickness of the Cold Creek unit (undifferentiated). Contour interval = 20 ft (6.1 m).

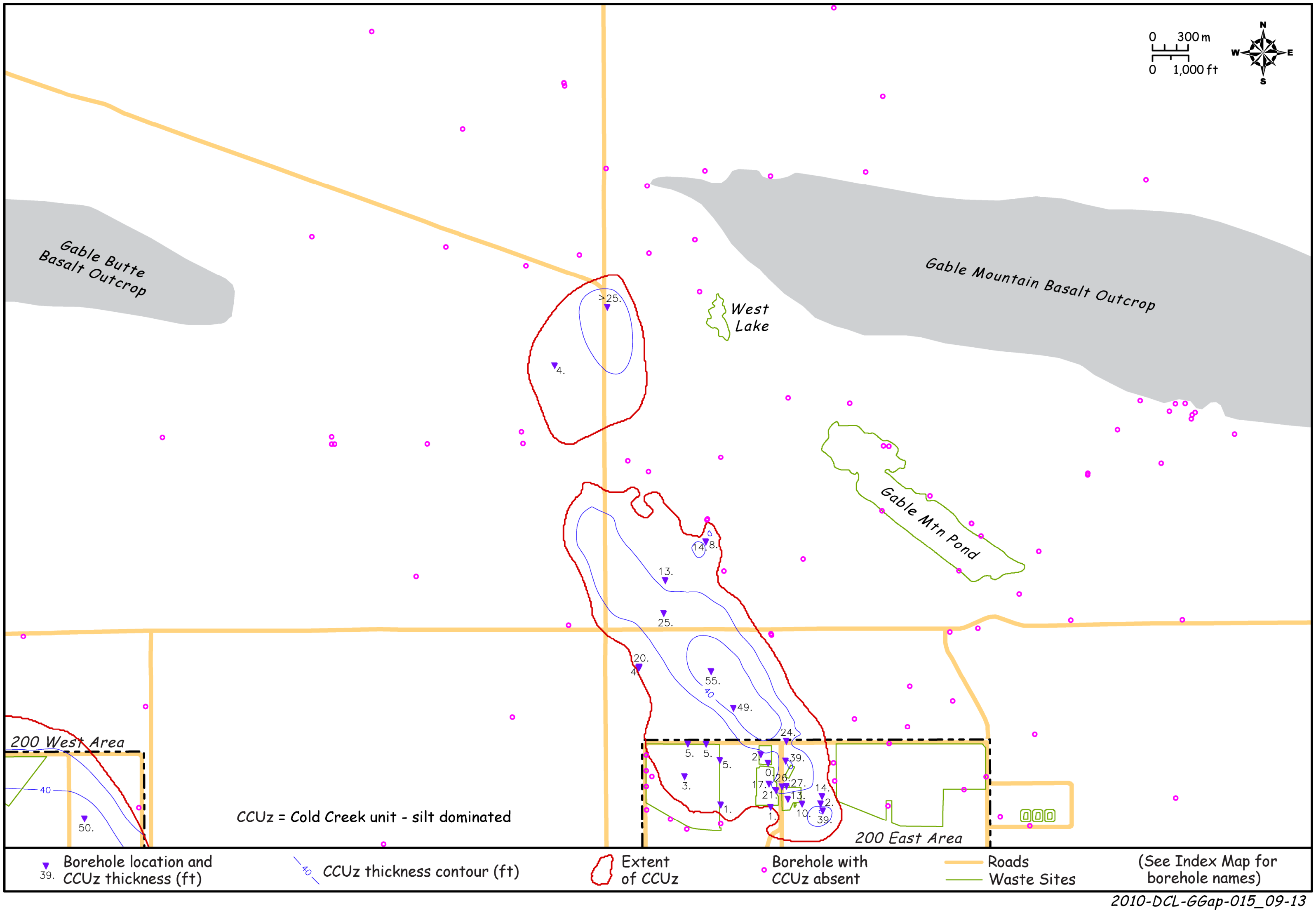

Figure C.6. Thickness of the Cold Creek silt (CCUz) subunit. Contour interval = 20 ft (6.1 m).

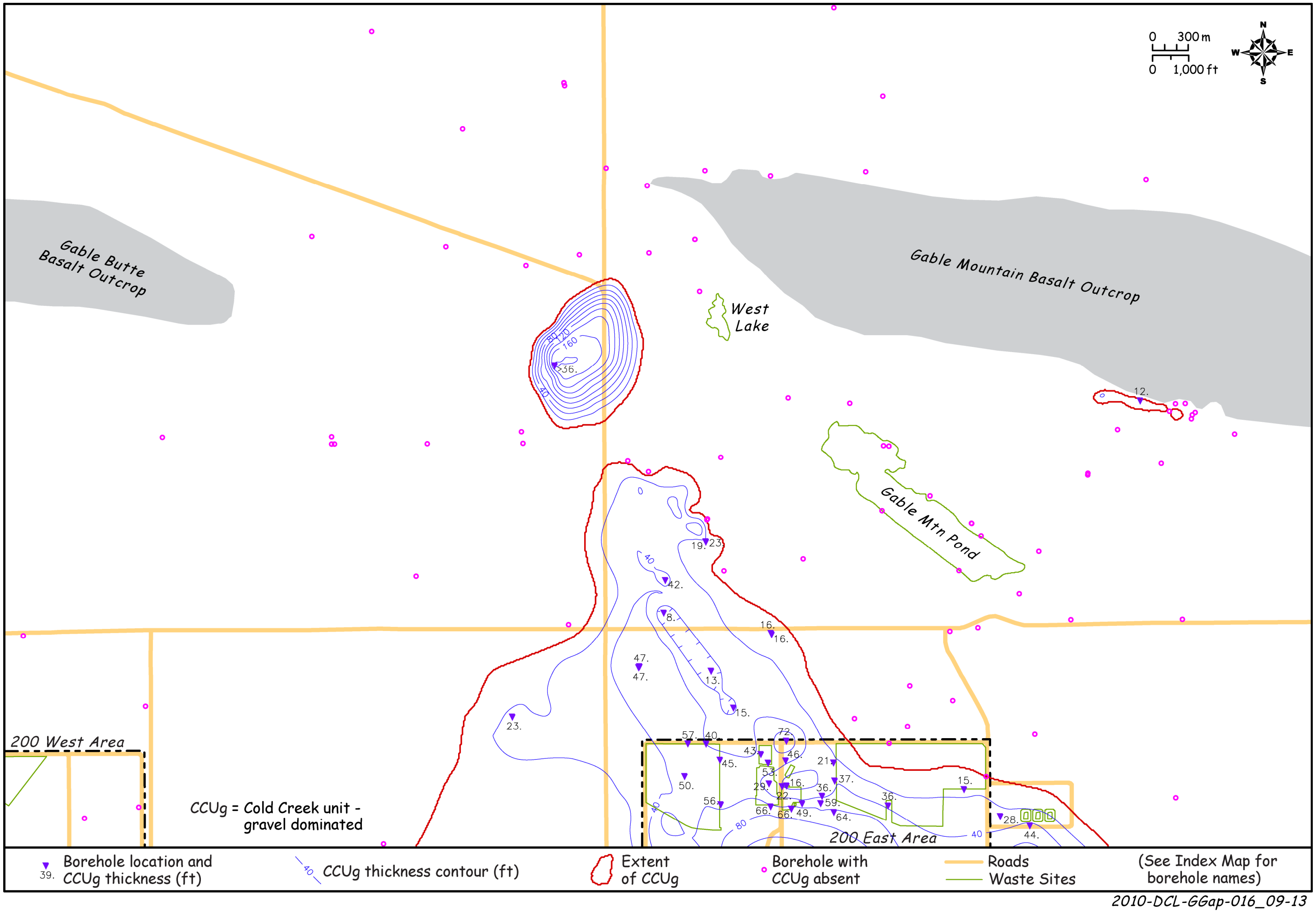

Figure C.7. Thickness of the Cold Creek gravel (CCUg) subunit. Contour interval = 20 ft (6.1 m).

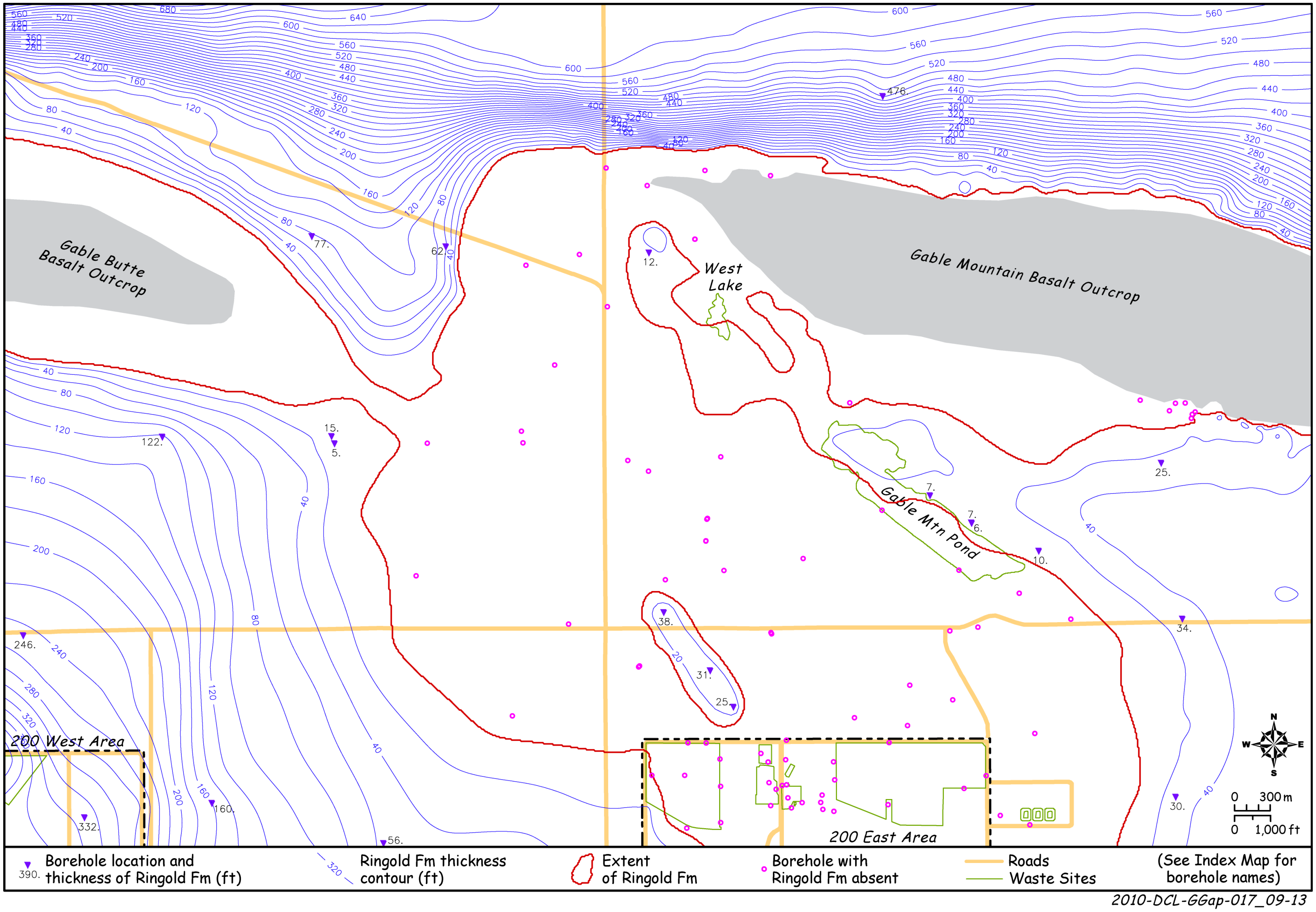

Figure C.8. Total thickness of the Ringold Formation (undifferentiated). Contour interval = 20 ft (6.1 m).

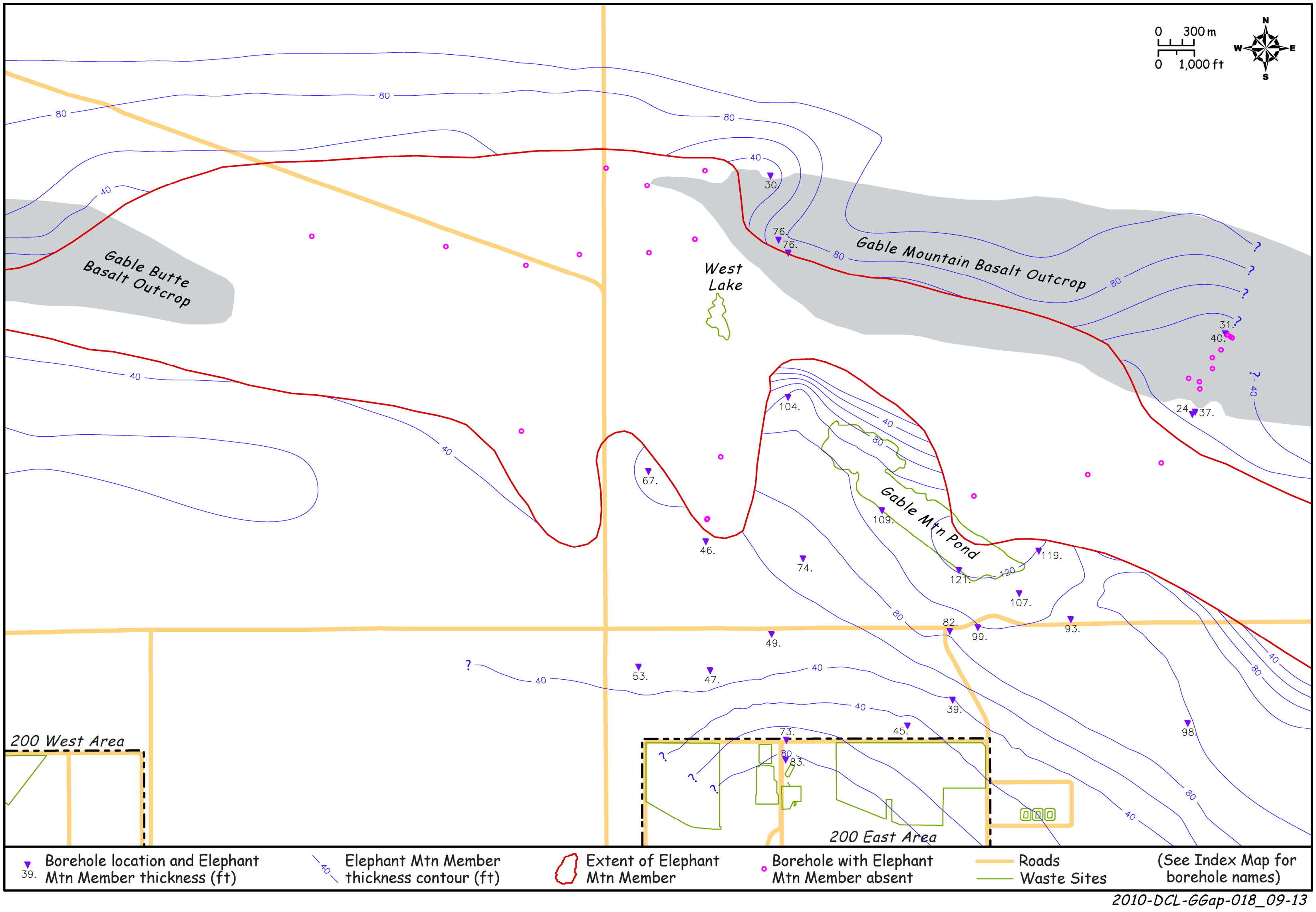

Figure C.9. Thickness of the Elephant Mountain Member basalt. Contour interval = 20 ft (6.1 m).

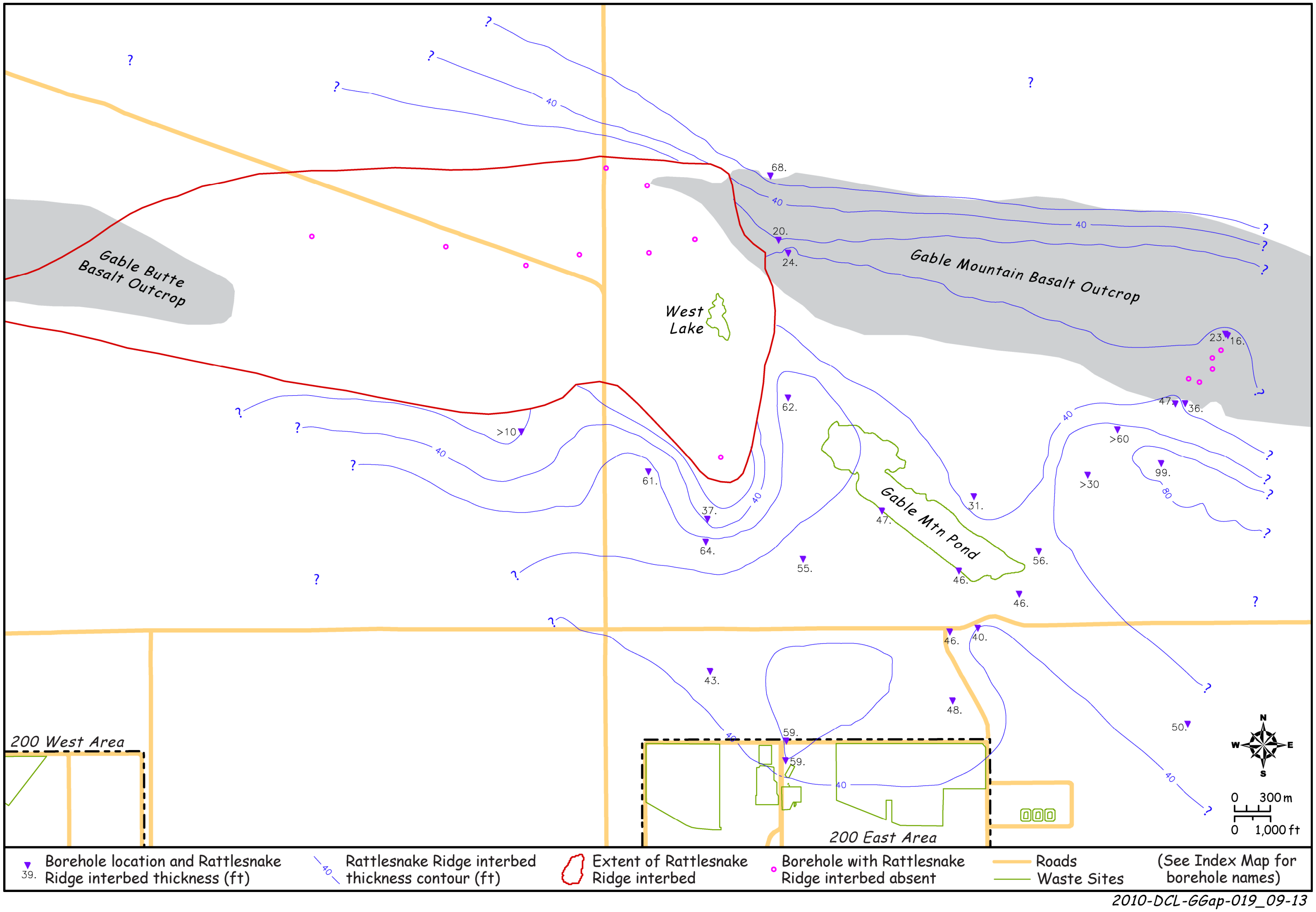

Figure C.10. Thickness of the Rattlesnake Ridge interbed (uppermost Ellensburg Formation). Contour interval = 20 ft (6.1 m).

Appendix D

Three-dimensional EarthVision® Model

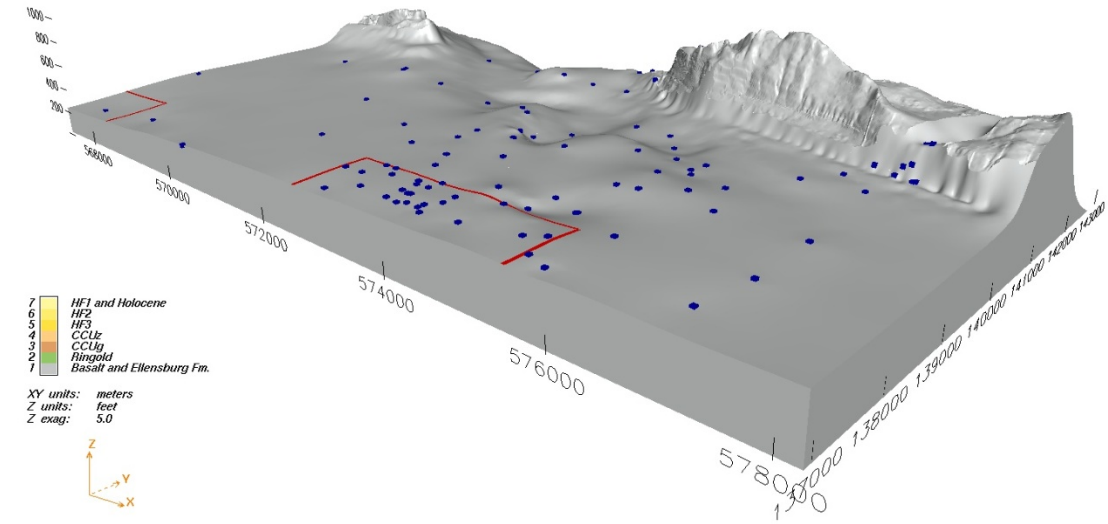

Figure D.1. Base of the suprabasalt sediments (top of Columbia River Basalt Group and Ellensburg Formation - undifferentiated). Oblique view looking northwest. Vertical exaggeration = 5X.

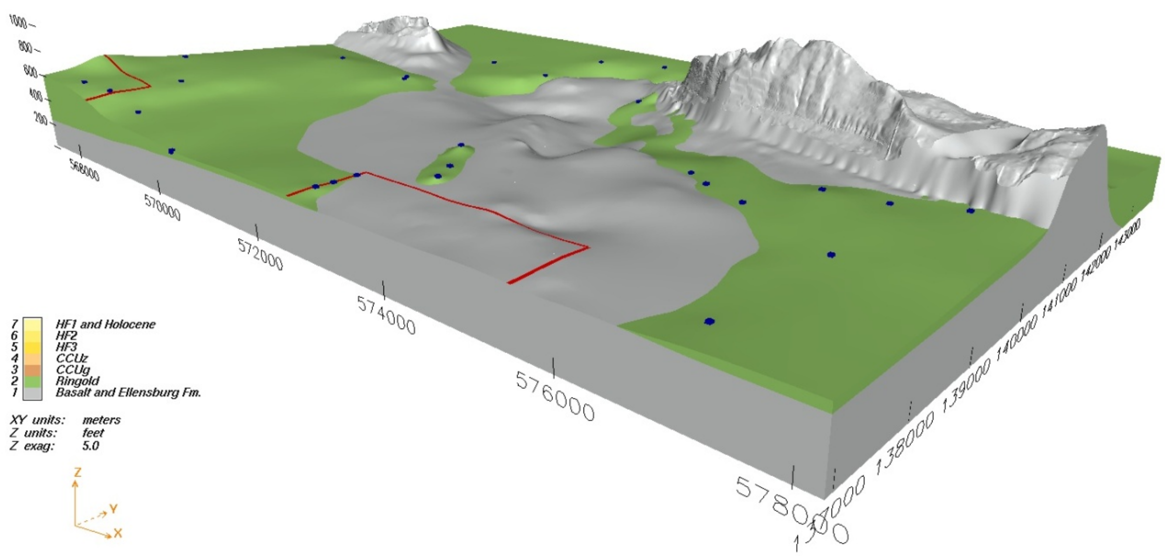

Figure D.2. Distribution of the Ringold Formation (undifferentiated). Oblique view looking northwest. Vertical exaggeration = 5X.

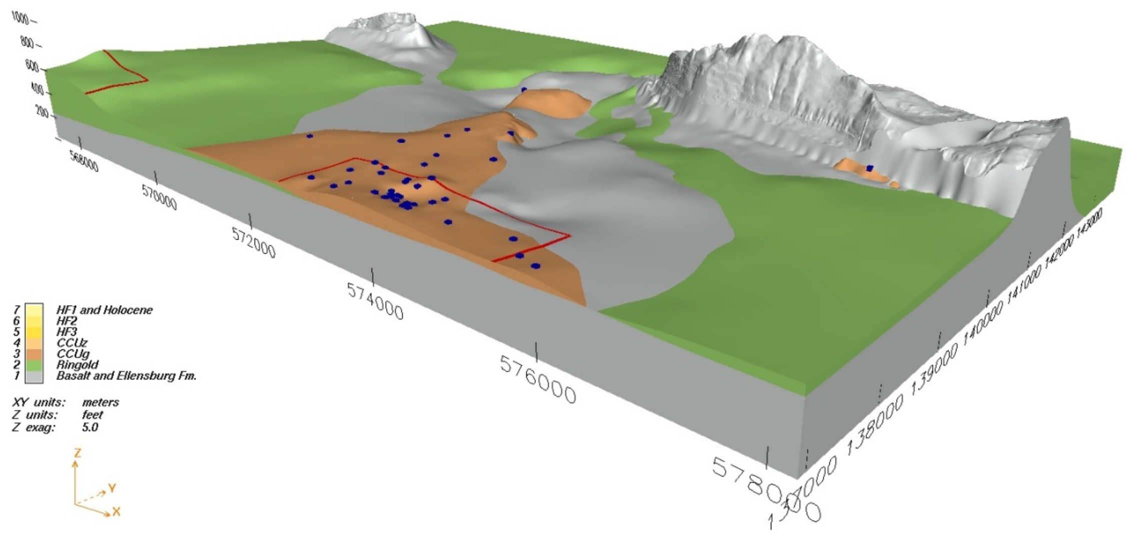

Figure D.3. Distribution of the Cold Creek gravel (CCUg) subunit. Oblique view looking northwest. Vertical exaggeration = 5X.

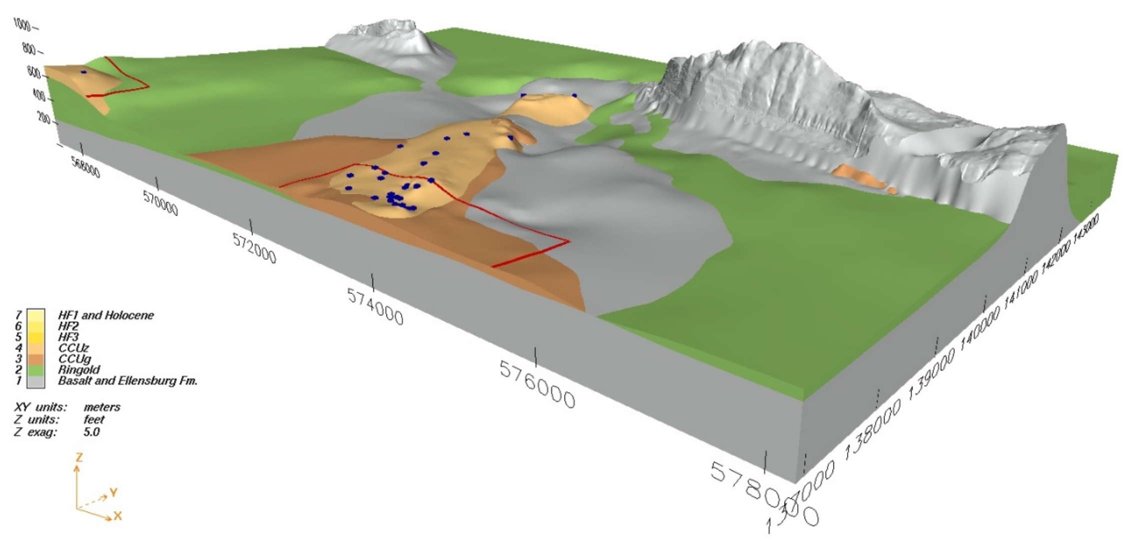

Figure D.4. Distribution of the Cold Creek silt (CCUz) subunit. Oblique view looking northwest. Vertical exaggeration = 5X.

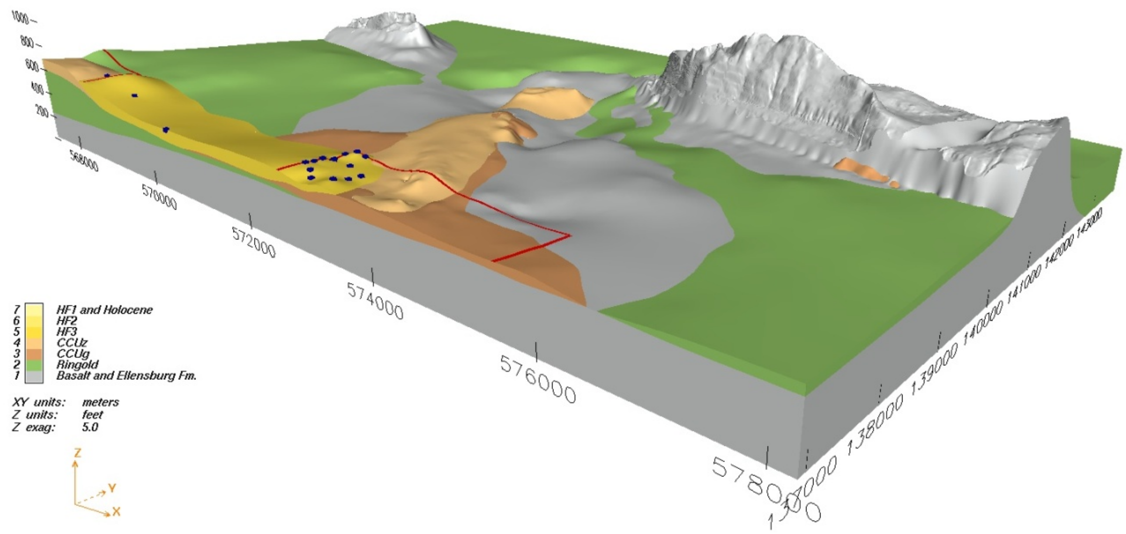

Figure D.5. Distribution of the Hanford formation H3 (lower gravel-dominated) unit. Oblique view looking northwest. Vertical exaggeration = 5X.

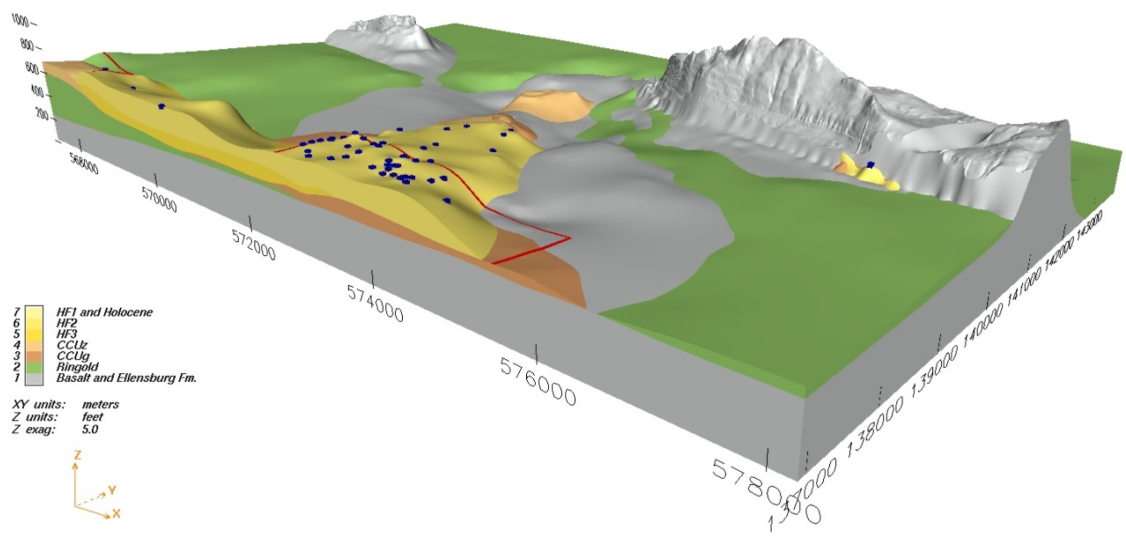

Figure D.6. Distribution of the Hanford formation H2 (sand-dominated) unit. Oblique view looking northwest. Vertical exaggeration = 5X.

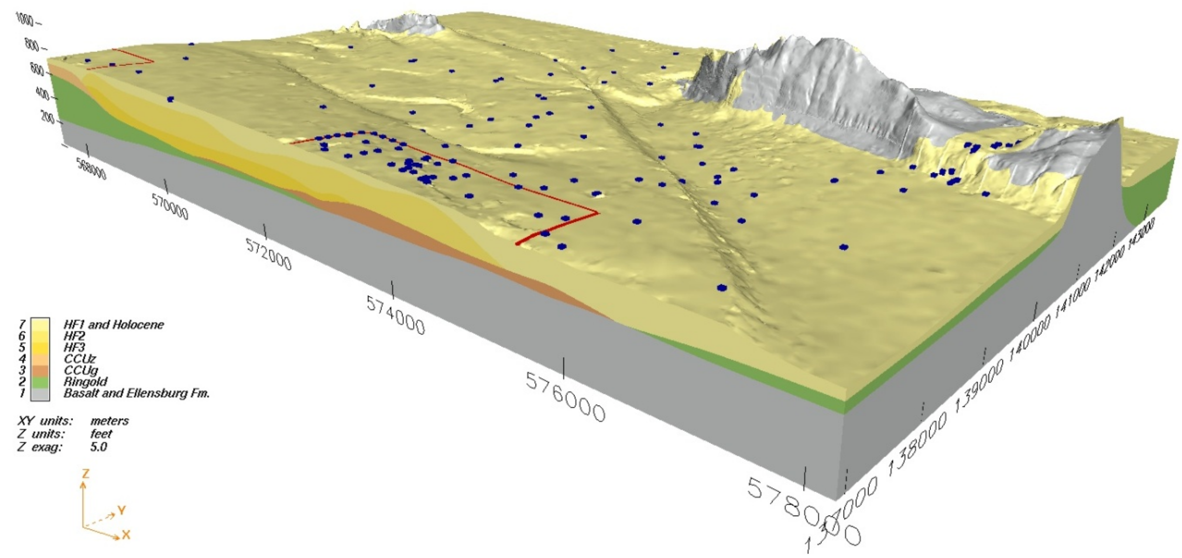

Figure D.7. Distribution of the combined Hanford formation H1 (upper gravel-dominated) unit and overlying Holocene deposits. Oblique view looking northwest. Vertical exaggeration = 5X.

Appendix E

Borehole Information and Tops of Stratigraphic Unit Contacts

Table E.1. All Gable Gap Boreholes

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
299-E26-77		C6455	224.8	DB	2008	200.8-225.6	CCUg?/EM	No		No	Yes	No	No	Yes	Yes		1	603.2	137129.97	575579.26
299-E26-79		C6826	224.8	DB	2008	195.2-220.2	CCUg/EM	No		No	Yes	No	No	Yes	Yes		1	598.3	137027.55	575836.95
299-E27-16		A4814	269	DB/HT	1990	239-260	CCUg	Yes			No	No	Yes	No	No		3	652.8	137164.856	574179.237
299-E28-26		A4822	328.5	DB/HT	1987	279-299	CCUg	Yes		Yes	Yes	Yes	Yes	No	No		2	688.4	137024.016	572941.553
299-E28-27		A4823	301.5	HT/DB	1987	270-290	CCUg	Yes		Yes	Yes (incomp)	Yes	Yes	No	No		3	681.4	137070.063	573226.784
299-E28-28		A4824	296	DB/HT	1990	275-295	CCUg	Yes		No	Yes	No	Yes	No	No		3	687.3	137108.259	572804.351
299-E32-2		A4830	289.2	DB/HT	1987	258-289	CCUg	Yes		Yes	Yes	Yes	Yes	No	No		2	671.5	137467.509	572648.02
299-E32-3		A4831	304	HT/DB	1987	266-301	CCUg/Ringold A	Yes		No	Yes	Yes	Yes	No	No		2	678.9	137383.996	572600.614
299-E32-4		A4832	311	DB/HT	1987	278-308	CCUg/Ringold	Yes		Yes	Yes	Yes	Yes	No	No		2	688.3	137187.218	572603.743
299-E32-5		A4833	293.6	DB/HT	1989	271-292	CCUg	Yes		Yes	Yes	Yes	Yes	No	No		2	682.7	137285.125	572599.697
299-E32-6		A4834	278.8	DB/HT	1991	254.5-275.5	H3	Yes		No	Yes	No	Yes	No	No		3	667.3	137515.1	572600.4
299-E32-7		A4835	273.8	DB	1991	246-266	H3	Yes		No	Yes	No	Yes	No	No		2	658.2	137647.05	572600.38
299-E32-8		A4836	256.7	DB	1991	235-255	H3?	Yes		No	Yes	No	Yes	No	No		2	645.5	137741.47	572663.39
299-E32-9		A4837	254.6	DB/HT	1991	231-251	H3	Yes	Yes	No	Yes	Yes	Yes	No	No		2	643.1	137741.69	572795.11
299-E32-10		A5432	245.8	DB	1992	225-245	H3	Yes	Yes	No	Yes	Yes	Yes	No	No		2	638.2	137741.69	572951.13
299-E33-28		A4852	278.3	HT/DB	1987	256-276	H3	Yes		Yes	Yes	Yes	Yes	No	No		3	666.2	137375.019	573226.365
299-E33-29		A4853	290	DB/HT	1987	263-290	CCUg*	Yes		Yes	Yes	Yes	Yes	No	No		2	675.0	137231.193	573227.858
299-E33-30		A4855	280.1	DB/HT	1987	267-277	CCUg	Yes		Yes	Yes	Yes	Yes	No	No		2	665.5	137467.779	572923.796
299-E33-33		A4858	252	DB/HT	1989	227-247	CCUg	No		No	Yes	No	Yes	No	No		2	640.7	137301.934	574080.137
299-E33-34		A4859	240	DB/HT	1990	219-239	CCUg	Yes	Yes	No	Yes	Yes	Yes	No	No		2	634.0	137740.427	573104.458
299-E33-35		A4860	250	DB/HT	1990	228-249	CCUg	Yes		No	Yes	Yes	Yes	No	No		3	643.6	137605.098	573220.798
299-E33-36		A4861	264	DB/HT	1990	234-255	CCUg	Yes		No	Yes	No	Yes	No	No		2	647.2	137239.981	574068.54
299-E33-45		C3269	261	DB/SS	2001	N/A		Yes	Yes	No	Yes	No	No	Yes	Yes	Core logs, photos	1	656.8	137347	573683
299-E33-46		C3360	264.4	DB/SS	2001	N/A										Core logs, photos	1	657.3	137278.365	573792.553
299-E33-49		C4261	288.8	DB	2004	263.5-283.5	CCUg	No		No	Yes	No	No	Yes	Yes		1	666.8	137212.8	573647.48
299-E33-50		C5195	381	DB/SS	2006	316-331	RRI	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	625.8	137599.3	573773.61
299-E33-205	"C" well	C5989	270.6	DB	2008	257.5-267.5	CCUg	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	657.2	137406.22	573633.38
299-E33-333		B8079	254	DB/SS	1998	None	N/A	No		No	Yes	No	No	?	?		2	653.4	137181.278	574086.41
299-E33-337		C3390	286	AR	2001	255-280	CCUg	No		No	Yes	No	No	Yes	Yes		2	662.7	137193.87	573821.8
299-E33-338		C3391	275.8	SS/DB	2001	251-271	CCUg	No		No	Yes	No	No	Yes	Yes	Core photos, paleomag	1	657.0	137238.24	573912.07

Table E.1. (contd)

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
299-E33-340	"G" Well	C5853	325.7	CT/AR	2008	308.2-323.2	RRI	No	Yes	No	Yes	No		Yes	Yes	Lab char., hi-res photos	1	617.9	137766.194	573779.325
299-E33-341	"D" well	C5856	237	DB/SS	2008	223-233	CCUg	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	627.5	137652.5	573565.21
299-E33-342	"E" well	C5857	245.5	DB	2008	232.6-242.6	CCUg	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	636.9	137579.96	573625.68
299-E33-343	"A" well	C5858	263.8	DB	2008	250-260	CCUg	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	652.3	137382.25	573743.98
299-E33-345	"Br" well	C6226	263.8	DB	2008	249.7-259.7	CCUg	No		No	Yes	No	No	Yes	Yes	Photos, lab logs	1	653.2	137388.24	573780.87
299-E34-2		A4877	241.5	HT	1987	222-242	CCUg	No		No	Yes	Yes	Yes	No	No		2	632.6	137220.694	574634.81
299-E34-5		A4880	190.5	HT	1987	170-190	CCUg	Yes		No	Yes	Yes	Yes	No	No		2	592.6	137743.332	574643.809
299-E34-7		A4882	205.5	HT/DB	1989	194-204	CCUg?	Yes		Yes	Yes	No	Yes	No	No		3	604.7	137357.745	575274.184
299-E34-9		A4884	234.5	BH/DB	1991	212-232	CCUg?	Yes		No	Yes	No	Yes	No	No	$CaCo_3$, moisture	2	629.3	137429.82	574186.02
299-E34-11		A4876	219.3	DB	1991	207.5-2117.5	CCUg	Yes		No	Yes	No	Yes	No	No	$CaCo_3$, moisture	2	618.1	137581.78	574176.16
299-E35-1		A4885	193.8	DB/HT	1989	181-192	H1	Yes		Yes	Yes	0-80'	Yes	No	No		2	598.8	137464.956	575459.729
299-W11-88		C5572	490.2	Sonic/rotary	2008	445-485		No		No	Yes	No	No	Yes	No		1	725.5	137113.09	567874.67
299-W12-1		A4912	314	CT	1956	274-309 (P)		Yes		Yes	No	Yes	No	No	No		4	727.6	137206.116	568331.248
699-44-64		A5188	452	DB/HT	1960	316-360 (P)		Yes		Yes	No	Yes	No	No	No		3	726.7	136897.43	570390.65
699-45-42	699-46-43	A5195	195	CT	1948	158-180	?	Yes		Yes	No	No	No	No	No		4	579.2	137286.372	577055.094
699-45-69C		C5574	455	Rotary/sonic	2007	367-382	Ringold	No		No	Yes	No	No	Yes	No		2	727.3	137233.81	568947.12
699-47-42	BWIP DB-15	A8749	1971	CT/MR	1979	None	N/A	Yes		No	Not for post-basalt sediments	No					5	470.9	137909.026	577156.481
699-47-46A		A5200	207	CT	1961	168-181	Hanford fm and basalt		Yes	Yes	No	10-200'	No	No	No		3	581.7	137820.739	575869.826
699-47-50		A5201	295	CT	1980	260-295	RRI	No		Yes	No	265-295'	No	No	No		4	585.1	137887.166	574798.717
699-47-51		A8752	167	CT	1959	None	N/A	No		Yes	No	0-160'	Yes				4	585.0	137953.171	574352.297
699-47-60		A5202	287	CT	1948	250-287	Hanford/CCUg/CRB	Yes	Yes	Yes	No	5-250'	No	No	No		3	652.3	137968.732	571474.38
699-48-48A	ARH-DC-1	A8768	5661	MR	1972	None	N/A		No	No	No	No		No	No		5	575.0	138112.7	575196.576
699-48-48B	BWIP DC-2	A8769	3374	CT	1977	None	N/A		No	Yes	Yes	No		No	No		4	573.1	138104.005	575179.031
699-48-49		A8770	?	?	?	?	?	No	No	No	No	No	No	No	No		5	572.5	138113.13	574951.895
699-48-50		A5212	197	DB/HT	1990	160-180	Hanford	No	No	No	Yes	No	Yes	No	No		2	574.6	138227.088	574817.584
699-48-50B		C5196	215.2	DB	2006	204.2-214.5	Ringold/CRB	No	Yes	No	Yes	No	No	Yes	Yes	138056.941	1	608.8	138044.28	573334.48
699-48-71		A5214	305	CT	1956	239-302	Ringold	Yes		Yes	No	Yes	No	No	No		4	690.3	138056.941	568387.914
699-49-55A		A5217	149	HT/DB	1961	124-139	Ringold/CRB	Yes		Yes	No	No	No	No	No		4	531.8	138351.781	573146.301

Table E.1. (contd)

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
699-49-55B		A5218	227	CT/AR	1982	175-226	CRB/RRI	Yes	Yes	Yes	No	No	No	No	No		4	531.8	138350.879	573138.718
699-49-57A		A5219	168	HT/AR	1956	144-161 (P)	CCUg	Yes		Yes	No	5-168'		No	No		3	554.3	138389.24	572544.276
699-49-57B		A5220	230.4	DB/HT	1990	220-230	RRI	No	Yes	No	Yes		Yes	No	No		2	556.5	138381.034	572536.452
699-49-71		A9918	30	DB	1993	None	N/A	No		Yes	No			No	No		5		138223	568580
699-50-42		A5224	125	CT	1955	53-64 (P); 110-115'	Ringold;CRB	Yes		Yes	No	5-65'	No	No	No		3	468.4	138786.691	577111.013
699-50-45		A5225	178	CT/AR	1980	133-178	RRI	Yes		Yes	No	135-175' (RRI)	No	No	No		3	452.6	138783.367	576172.755
699-50-48A	BWIP DDH-1	A8812	1,165	CT/RC	1955/1969	None	N/A	Yes	Yes	Yes	No	5-170'	No	No	No		3	553.4	138684.761	575154.969
699-50-48B		A5226	250	CT/AR	1980	210-250	RRI	Yes		Yes	No	225-250' (RRI)	No	No	No		3	552.0	138715.913	575390.732
699-50-53A		A5227	185	CT	1955	142-159	Hanford	Yes		Yes	No	5-185'	No	No	No		3	558.3	138670.477	573649.666
699-50-53B		A5228	225	DB/SS	1990	215-225	RRI	No		No	Yes		Yes	No	No		2	558.4	138659.519	573655.45
699-50-56		C5197	164.1	DB	2006	151-161	Ringold	No	Yes	No	Yes	No	No	Yes	Yes	Photos, core log	1	551.8	138841.55	572748.21
699-50-59		C4882	173.2	BH	2005	163-168	Hanford	No	Yes	No	Yes	No	No	No	No	Core log	2	564.6	138741.72	571946.9
699-50-74		C4697	338.8	BH	2005	?	?	No		No	Yes	No	No	Yes	No		2	658.3	138646.73	567359.52
699-51-46	699-51-47	A5230	168	AR/HT	1980	113-163	RRI	Yes		Yes	No	125-165' (RRI)	No	No	No		4	446.0	139001.588	575738.496
699-51-63		A5231	184.5	CT	1956	157-183	Hanford	Yes		Yes	No	5-185	No	No	No		3	573.4	139148.408	570664.4
699-52-46A		A5234	225	CT/AR	1980	175-225	RRI	Yes	Yes	Yes	No	175-225' (RRI)	No	No	No		3	457.2	139358.005	575903.296
699-52-46B		A8841	44	CT	1980	39-44	Hanford?	Yes		Yes	No	No	No	No	No		4	?	139395	575952.5
699-52-48		A5235	197	CT/AR	1980	153-195	RRI	Yes		Yes	No	155-190' (RRI)	No	No	No		3	468.6	139195.665	575231.474
699-52-52	BWIP DB-5	A8842	903	AR/RC	1974	None	N/A	Yes		Yes	Yes	5-145'	No	No	No		3	560.8	139293.862	573920.523
699-52-54		A5236	168.6	DB/HT/SS	1990	156-166	Hanford	No		No	Yes	No	Yes	No	No		2	568.9	139193.172	573254.242
699-52-55	699-52-55A; "N" well	C5861	183.3	DB	2007	170-180	CCUg	No	Yes	No	Yes	No	No	Yes	yes	Photos	1	574	139443.2	573102.44
699-52-55B	"H" well	C5862	292	DB	2008	228.5-243.5	RRI	No	Yes	No	Yes	No	No	Yes	Yes	Core log (RRI)	1	573.7	139440.66	573102.17
699-52-57	699-51-56	A5237	165.5	DB/SS/HT	1991	149-159	CCUg	Yes	Yes	No	Yes	No	Yes	No	No		2	561.7	139115.316	572761.346
699-53-47A		A5239	41.5	DB/HT	1966	22-33	Hanford	Yes		Yes	No	No	No	No	No		4	439.2	139489.296	575417.545
699-53-48A		A5241	53	DB/HT	1984	None	N/A	Yes		Yes	No	No	No	No	No		4	443.4	139593.885	575338.712
699-53-48B		A5242	44	CT	1984	24-44	Hanford/CCUz	Yes		Yes	No	No	No	No	No		4	443.6	139595.705	575336.306
699-53-50		A5243	194	HT/AR	1980	144-194	RRI	Yes		Yes	No	160-190' (RRI)	Yes	No	No		3	445.8	139700.592	574584.129
699-53-55A		A5244	455	CT	1961	165-280 (P)	Hanford/RRI	Yes		Yes	No	No	No	No	No		4	577.3	139631.884	573115.859

Table E.1. (contd)

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
699-53-55B		A5245	252	AR	1975	232-252 (P)	Hanford	Yes		Yes	No	No	No	No	No		4	577.6	139624.964	573110.622
699-54-42		A5250	210	CT	1948	100-145 (P), 180-200 (P)	RRI	Yes		Yes	No	85-210'	No	No	No		4	513.4	140099.176	576933.16
699-54-45A		A5251	105	CT	1971	95-105	Hanford	Yes		Yes	No	5-105	No	No	No		3	494.7	140001.429	576314.759
699-54-45B		A8862	314	HT/AR	1980	299-314	Ellensburg/CRB	Yes	Yes	Yes	No	No	No	No	No		4	495.3	140015.663	576316.062
699-54-48		A5252	101	CT	1984	42-62		Yes		Yes	No	No	No	No	No		4	458.1	139821.176	575357.767
699-54-49		A8863	62	HT	1984	32-52	Hanford	Yes		Yes	Yes	No	No	No	No		3	441.2	139825.684	574988.009
699-54-57		A5253	321	HT/AR	1955, 1982	159-180 (P), 236-321	Hanford/CRB/Selah Interbed	Yes	Yes	Yes	No	5-199	Yes	No	No		3	577	140029.626	572619.411
699-55-40		A5255	145	CT	1971	135-145	Ringold	Yes		Yes	No	5-145	No	No	No		4	543.3	140346.524	577550.24
699-55-44		A5256	160	DB/HT	1971	140-150	Ringold or RRI	Yes		Yes	No	No	No	No	No		4	520.9	140384.107	576565.593
699-55-50A		A8865	110	CT	1948	40-100 (P)	Hanford	Yes		Yes	No	5-110'	No	No	No		3	444.9	140245.044	574642.279
699-55-50D		A8867	100	CT	1956	33-90 (P)	Hanford	Yes		Yes	No	No	Yes	No	No		3	442.2	140248.355	574596.5
699-55-55		A5258	312	DB/SS/HT	1990	148-169	Hanford	No	Yes	No	Yes	No	Yes	No	No		2	563.8	140150.538	573227.561
699-55-57		A5259	180	AR	1975	139-169 (P)	CCUg	Yes	Yes	Yes	No	0-175'	Yes	No	No		3	569	140119.853	572445.432
699-55-60A		A8868	233	HT	1943	190-230	Hanford	Yes		No	No	No	No	No	No		4	574.2	140268.28	571563.5
699-55-60B		A8869	288	HT	1944	230-285	Hanford	Yes	Yes	No	No	No	Yes	No	No		4	576.0	140366.395	571550.483
699-55-63		A8871	198	CT	1944	None	N/A	Yes	Yes	No	No	No	No	No	No		4	573.0	140265.131	570758.372
699-55-65A		A8872	136	CT	1944	None	N/A	Yes		No	No	No	No	No	No		4	581.0	140262.888	569953.789
699-55-65B		A8873	146	CT	1944	None	N/A	Yes	Yes	No	No	No	No	No	No		4	581.0	140323.845	569953.617
699-55-65C		A8874	146	CT	1944	?	?	No		No	No	No	No	No	No		5	581.0	140262.956	569978.17
699-55-70		A5260	205	CT	1948	136-202 (P)	Ringold	Yes		Yes	No	5-205'	No	No	No		3	571.0	140318.965	568529.958
699-56-42A	Golder #GH-7	A8885	245	AR/RC	1981	None	N/A	No		No	Yes	No	No	No	No		2	535.3		
699-56-42B	Golder #GH-9	A8886	250	AR/RC	1981	None	N/A	No		No	Yes	No	No	No	No		2	546.8		
699-56-42C	Golder #GH-11	A8887	354	AR/RC	1981	None	N/A	No		No	Yes	No	No	No	No		2	530.8	140474.664	577186.675
699-56-42D	Golder #GH-18	A8888	670	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	562.6		
699-56-42E	Golder #GH-19	A8889	700	AR/MR	1981	None	N/A	No		No	Yes	No	No	No	No		3	541.1		
699-56-42F	Golder #GH-21	A8890	520	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	578.1		
699-56-43		A5264	155	DB/HT	1971	145-155	CRB/Ellensburg	Yes	Yes	Yes	No	5-150'	Yes	No	No		3	540.9	140627.536	576756.291
699-56-51	699-56-50	A8891	105	HT	1984	55-105	Hanford	Yes		Yes	No	No	No	No	No		3	440.5	140605.596	574312.679
699-56-53	699-57-53	A5265	270	HT/AR	1982	190-270	EM/RRI	Yes	Yes	Yes	No	No	No	No	No		3	435.9	140650.663	573794.188
699-57-41A	Golder #GH-14	A8896	512	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	707.0		

Table E.1. (contd)

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
699-57-41B	Golder #GH-15	A8897	461	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	710.6		
699-57-41C	Golder #GH-16	A8898	430	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	709.3		
699-57-41E	Golder #GH-22	A8900	554	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	698.4		
699-57-41F	Golder #GH-23	A8901	608	AR/RC	1981	None	N/A	No		No	Yes	No	No	No	No		2	707.6	140986.334	577362.842
699-57-59		A5269	190.5	DB	1980	166-186	CCUg or Ringold	No	Yes	Yes	Yes	0-188'	Yes	No	No		2	576.6	140923.719	571830.216
699-58-41A	Golder #GH-1	A8908	274	AR/RC	1980	None	N/A	No		No	Yes	No	No	No	No		2	709.9		
699-58-41B	Golder #GH-2	A8909	225	AR/RC	1980	None	N/A	No		No	Yes	No	No	No	No		2	704.0		
699-58-41C	Golder #GH-3	A8910	130	AR	1980	None	N/A	No		No	Yes	No	No	No	No		3	702.9		
699-58-41D	Golder #GH-4	A8911	79	AR/RC	1980	None	N/A	No		No	Yes	No	No	No	No		2	701.8		
699-58-41E	Golder #GH-13	A8912	390	AR	1981	None	N/A	No		No	Yes	No	No	No	No		3	700.4	141188.31	577473.22
699-58-41F	Golder #GH-20	A8913	600	AR/MR	1981	None	N/A	No		No	Yes	No	No	No	No		3	699.5	141051.482	577435.757
699-58-48		A8914	?	?	?	?	?	No		No	No	No	No	No	No		5	?	141153.4	575262.6
699-59-55	BWIP DH-10	A8918	145	AR	1976	None	N/A	Yes		No	No	No	No	No	No		5	432.2	141544.108	573049.268
699-59-58	GBM-8	A5277	117	CT	1972	85-105	Hanford	Yes	Yes	Yes	No	60-110'	Yes	No	No		3	498.8	141414.963	572273.618
699-60-53B	CH-2	A8922	160	RC	1980	None	N/A	Yes		No	No	No	No	No	No		5	?	141766.917	573722.707
699-60-53C	CH-3	A8923	150	RC	1980	None	N/A	Yes		No	No	No	No	No	No		5	?		
699-60-53F	CH-6	A8926	290	RC	1980	None	N/A	Yes		No	No	No	No	No	No		5	821.0		
699-60-57		A5280	155	HT	1972	60-70, 127-147	Hanford, Hanford/Ringold	Yes	Yes	Yes	No	40-143'	Yes	No	No		3	470.6	141870.325	572623.495
699-60-59	BWIP DC-18	A5281	1561	CT/RC	1986	None	N/A	Yes		Yes	Yes	No	Yes	No	No		2	509.2	141854.447	572038.132
699-60-60		A5282	133	CT	1948	100-127 (P)	Hanford	Yes	Yes	Yes	No	No	No	No	No		4	513	141763.907	571588.581
699-61-53	BWIP DC-11	A8932	385	RC	1978	None	N/A	Yes		No	Yes	No	No	No	No		3	764.8	141978.102	573714.117
699-61-55A	BWIP DH-8A	A8933	249	RC	1976	None	N/A	Yes		No	Yes	No	No	No	No		3	463.0	141983.739	573009.153
699-61-55B	BWIP DH-8B	A8934	327	AR/CT	1976	None	N/A	No		No	No	No	No	No	No		5	464.1		
699-61-57	BWIP DB-9	A8935	589	RC	1977	490-589	Mabton	Yes		No	Yes	No	No	No	No		3	444	142435.066	572608.219
699-61-62	GBM-1	A5285	188	DB/HT	1972	86-100 (P)	Hanford	Yes	Yes	Yes	Yes	No	Yes	No	No		2	497.9	141921.659	570914.859
699-61-66		A5286	225	CT	1955	105-160	Hanford/Ringold	Yes	Yes	Yes	No	5-225'	Yes	No	No		3	523.9	142007.963	569787.591
699-62-43B		A8940	68	CT	1959	3-50 (P)	Hanford	Yes		Yes	No	No	Yes	No	No		3	422.4	142488.248	576805.215
699-62-53	BWIP DC-10	A8953	456	RC	1977	None	N/A	No		No	Yes	No	No	No	No		3	439.4	142518.932	573646.175
699-63-51	GM-17	A5290	36	CT	1971	18-31 (P)	Hanford/Ringold	Yes		Yes	No	5-35'	No	No	No		3	425.4	142553.674	574446.762
699-63-55		A5291	121	DB/HT	1972	23-65 (P)	Hanford	Yes		Yes	No	Yes	No	No	No		3	427.1	142562.319	573094.386

Table E.1. (contd)

Well Name	Available Data																	Survey Data		
													Geophysical Logs							
	Other ID	Well ID	Total Depth (ft)	Drill Method*	Completed	Screen Interval (depth in ft)[1]	Open Formation	As-Built Diagram	PNNL Logplot	Driller's Log	Geologist Log	ROCSAN (sieve)	PNNL Log	SGLS log	NMLS log	Other	Data Quality Ranking^	Ground Surf. Elev. (ft)	Northing	Easting
699-63-58		A5292	133	DB/HT	1972	80-120	Hanford	Yes	Yes	Yes	No	55-118'	No	No	No		3	493.3	142583.069	572262.686
699-64-62	GBM-2	A5296	116	DB/HT	1972	90.5-110.5	Ringold?	Yes	Yes	Yes	No	5-116	Yes	No	No		3	500.6	142913.859	571055.768
699-65-50		A5300	585	CT	1955	55-85 (P)	Hanford/Ringold	Yes		Yes	No	5-585'	No	No	No		3	468.9	143187.852	574590.787
699-65-59A		A5301	200	CT	1958	170-190 (P)	Ringold?	Yes		Yes	No	5-200'	Yes	No	No		4	508.5	143278.674	571913.723
699-65-59B		A8960	200	AR	1976	100-190 (P)	Ringold?	Yes		Yes	No	No	Yes	No	No		3	507.6		
699-65-59C		A8961	140	AR	1976	100-140 (P)	Ringold?	Yes		Yes	No	No	Yes	No	No		3	506.1		
699-65-72		A5302	216	CT	?	137-157 (P)	Hanford?	Yes		No	No	No	No	No	No		5	541.1	143107.924	567883.669
699-66-64	GBM-3	A5310	118	CT	1972	96-116	Hanford?	Yes	Yes	Yes	No	5-116'	No	No	No		4	506.7	143734.119	570290.742
699-67-51		A5312	250	CT	1961	184-194^, 230-235^		Yes		Yes	No	No	No	No	No		4	525.0	143933.215	574178.927
699-69-45		A8967	300	DB/HT	1961	97-117, 152-178, 210-235, 255-277^	Ringold	Yes		Yes	No	0-300'	No	No	No		3	487.8	144556.307	576157.407
699-70-68		A5319	149	CT	1954	126-147 (P)	Ringold	Yes		Yes	No	5-145'	No	No	No		3	527.0	144845.401	569021.847
699-71-52		A5321	210	CT	1954	120-160	Ringold	Yes		Yes	No	Yes	No	No	No		3	524.7	145214.843	573907.901
699-72-73		A5323	200	DB/HT	1961	60-176 (P)	Hanford/Ringold	Yes		Yes	No	No	No	No	No		4	483.5	145418.782	567551.544
699-73-61	699-74-60	A5327	150	CT	1962	107-146 (P)	Hanford/Ringold	Yes		Yes	No	No	No	No	No		3	533.1	145781.525	571420.823

*AR = air rotary
BH = Becker hammer
CT = cable tool
DB = drive barrel
HT = hard tool
MR = mud rotary
RC = rotary core
SS = split spoon

(P) perforated
^ piezometer

^1 = best
5 = worst

Surface Elev.
Brass Cap Survey
Ground Surface Survey
Disc_Z
TOC - Recorded Stickup
TOC – Assumed 2.5 ft stickup

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
299-E26-77	0	3	NP		178?	NP	178?	NP	205.5			603	600	NP		425?	NP	425?	NP	397.7	3	175?	175?	NP	NP	27	0	27	NP			Geophys. Anomaly from 178-183 = top of CCUg?
299-E26-79	0	1	NP	NP	163	NP	163	NP	207			597	597	NP		435?	NP	435?	NP	391	1	162	162	NP	NP	44?	0	44?	NP			
299-E27-16	NP	0	37	NP	205	NP	205	NP	269			NP	653	616	NP	448	NP	448	NP	383.8	0	205	37	168	NP	64	NP	64	NP			
299-E28-26	NP	0	70	225	?	NP	?	NP	326			NP	688	618	463	?	NP	?	NP	362.4	0	?	70	155	?	?	NP	?	NP			
299-E28-27	NP	0	45	190?	235?	NP	235?	NP	ETD			NP	681	636	491?	446?	NP	446?	NP	ETD	0	235?	45	145?	45?	>66	NP	>66	NP			150 m/day constant rate aquifer test
299-E28-28	NP	0	70	205	255?	NP	255?	?	ETD			NP	687	617	482	432?	NP	432?	?	ETD	0	255?	70	135	50?	>41	NP	>41	?			
299-E32-2	NP	0	55	210	NP			NP	287			NP	672	617	466	?	NP	?	NP	384.5	0	?	55	150	?	?	NP	?	NP			
299-E32-3	NP	0	60	195	?	NP	?	293	ETD			NP	679	619	484	?	NP	?	386	ETD	0	?	60	135	?	?	NP	?	>11			
299-E32-4	0	5	65	200	?	NP	?	297	ETD			688	683	623	488	?	NP	?	391	ETD	5	?	60	135	?	?	NP	?	>14			>264 m/day constant rate aquifer test
299-E32-5	NP	0	60	203	?			?	ETD			NP	683	623	480	?		?	?	ETD	0	?	60	143	?	?		?	?			175 m/day slug test
299-E32-6	NP	0	55	210	?	NP	?	?	ETD			NP	667	612	457	?	NP	?	?	ETD	0	?	55	155	?	?	NP	?	?			
299-E32-7	NP	0	60	190	?	NP	?	270	ETD			NP	658	598	468	?	NP	?	388	ETD	0	>274	60	130	?	?	NP	?	?			
299-E32-8	NP	0	20	166	?		?	?	ETD			NP	645	625	479	?		?	?	ETD	0	?	20	146	?	?		?	?			
299-E32-9	NP	0	39	180	?	NP	?	?	ETD			NP	643	604	463	?	NP	?	?	ETD	0	?	39	141	?	?	NP	?	?			
299-E32-10	NP	0	50	NP	185	185	190	NP	247			NP	638	588	NP	448	448	443	NP	391.2	0	190	50	140	NP	57	5	52	NP			
299-E33-28	NP	0	36	209	?	NP	?	NP	ETD			NP	666	630	457	?	NP	?	NP	ETD	0	?	36	173	?	?	NP	?	NP			
299-E33-29	NP	0	55	214	233	233	234		290			NP	675	620	461	442	442	441	NP	385.0	0	233	55	159	19	57	1	56	NP			*>1400 m/d constant-rate aquifer test = discrepancy
299-E33-30	NP	0	56	202	224	224	227	NP	277			NP	666	610	463	441.5	441.5	438.5	NP	388.5	0	225	56	147	21	53	3	50	NP			
299-E33-33	NP	0	37		202	202	216	NP	252			NP	641	604		439	439	425	NP	389	0	202	37	165	NP	50	14	36	NP			
299-E33-34	NP	0	20	NP	195	195	200	NP	240			NP	634	614	NP	439	439	434	NP	394	0	195	20	175	NP	45	5	40	0			
299-E33-35	NP	0	10	NP	200	200	205	NP	250			NP	644	634	NP	444	444	439	NP	394	0	200	10	190	NP	50	5	45	0			
299-E33-36	NP	0	30	NP	203	203	205	NP	263.8			NP	647	617	NP	444	444	442	NP	383.4	0	203	30	173	NP	61	2	59	NP			
299-E33-45	0	NP	40	NP	218	218	239	NP?	ETD			657	NP	617	NP	439	439	418	NP?	ETD	40	178	NP	178	NP	>43	20	>23	NP?			40' backfill at surface
299-E33-46	0	NP	38.5	NP	215	215	228	NP?	ETD			657	NP	619	NP	442	442	429	NP?	ETD	38.5	177	NP	177	NP	>49	13	>36	NP?			38 ft of backfill at surface
299-E33-49	0	45	49	NP	217	217	218	NP	283.5			667	622	618	NP	450	450	449	NP	383.5	45	172	4	168	NP	66.5	1	65.5	NP			Holocene = 45' backfill
299-E33-50	0	2	11	NP	149	149	187.5	NP	233.6	Elephant Mtn	RRI = 316.5, Pomona = 375.5	626	624	615	NP	477	477	438.5	NP	392	2	147	9	138	NP	85	38.5	46	NP	83	59	
299-E33-205	0	2	31	NP	221	221	238	NP	267	Elephant Mtn		657	655	626	NP	436	436	419	NP	390	2	219	29	190	NP	46	17	29	NP			
299-E33-333	0	9	30	NP	173.5	173.5	212	NP?	ETD			653	644	623	NP	480	480	441	NP?	ETD	9	164	21	143	NP	>80	38.5	>42	NP?	ETD		Holocene = 9' ditch fill; can't find Stoller logs
299-E33-337	NP	0	55	NP	215	NP?	215	NP	281			NP	663	608	NP	448	NP?	448	NP	382	0	215	55	160	NP	66	NP?	66	NP			
299-E33-338	NP	0	51.5	NP	212.5	212.5	222	NP	271			NP	657	605.5	NP	444.5	444.5	435	NP	386	0	212.5	51.5	161	NP	58.5	10	48.5	NP			

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
299-E33-340	NP	0	33	NP	131	131	154.5	NP	226	Elephant Mtn	RRI = 298.5', Pomona = 357.5'	NP	618	585	NP	487	487	463	NP	392	0	131	33	98	NP	95	23	72	NP	73	59	
299-E33-341	NP	0	40	NP	187	187	189	NP	232.5			NP	628	588	NP	441	441	439	NP	395	0	187	40	147	NP	46	2	44	NP			
299-E33-342	0	NP	13	NP	189.5	189.5	189.6	NP	242.4			637	NP	624	NP	447	447	446.9	NP	394.5	13	177	0	177	NP	53	0.1	52.9	NP			
299-E33-343	NP	0	37	NP	213	213	239	NP	260.9			NP	652	615	NP	439	439	413	NP	391	0	213	37	176	NP	48	26	22	NP			
299-E33-345	0	20	36	NP	217	217	244	NP	260.3			653	633	617	NP	436	436	409	NP	392.9	20	197	16	181	NP	43	27	16	NP			
299-E34-2	NP	0	65	NP	205	NP	205	NP	~241			NP	637	572	NP	432	NP	432	NP	396	0	205	65	140	NP	36	0	36	NP			
299-E34-5	NP	0	NP	NP	NP	NP	NP	NP	~190			NP	593	NP	NP	NP	NP	NP	NP	403	0	190	190	NP	NP	NP	0	NP	NP			
299-E34-7	NP	0	NP	NP	190?	NP	190?	NP	205			NP	605	NP	NP	415	NP	415	NP	400	0	190	190	NP	NP	15	NP	15	NP			
299-E34-9	NP	0	50	NP	197?	NP	197?	NP	234.5			NP	629	579	NP	432?	NP	432?	NP	394.8	0	197?	50	147?	NP	37.5	NP	37.5	NP			
299-E34-11	0	20	50	NP	198?	NP	198?	NP	219			618	598	568	NP	420?	NP	420?	NP	399	20	178?	30	148?	NP	21?	NP	21?	NP			
299-E35-1	NP	0	NP	NP	NP			NP	192	Elephant Mtn		NP	599	NP	NP	NP			NP	406.8	NP	192	192	NP	NP	NP			NP			
299-W11-88	0	7	NP	NP	70	70	NP*	155	487			726	719	NP	NP	656	656	NP	571	238.5	7	63	63	NP	NP	85	50	NP	332			CCUz = 70-120'; *CCUc =120-155', Rtf = 155-163', Re = 163-487'; Changed from sonic to rotary @460'
299-W12-1	NP	0	45	120	NP			190	ETD			NP	728	683	608	NP			538	ETD	NP	120	45	75	70	NP			>190			
699-44-64	NP	0	70	260?	NP?			354?	410			NP	727	657	467?	NP?			373?	317	0	260	70	190	94?	NP			56?			
699-45-42	NP	0	NP		NP			160?	190	Elephant Mtn?		NP	579	NP		NP	NP	NP	419?	389	0	160	160	NP		NP			30?			
699-45-69C	0	1	140	220?	?			295	455			727	726	587	507?	?			432	272	1	219	139	80	75	?			160			Almost 40' of Rlm starting @ 325'; Ra @ 364' depth. Changed from rotary to sonic ~20 ft above basalt
699-47-42	?	?	?	NP	?			?	68	Elephant Mtn	RRI = 166', Pomona = 216', Selah, 400', Esquatzel = 426, Cold Cr. Interbed = 518', Asotin = 612', Umatilla = 665', Mabton 745', Priest Rapids = 839'	?	?	?	NP	?			?	403	?	?	?	?	NP	?	?	?	?	98	50	Little or no information on post-basalt sediments
699-47-46A	0	1	NP	NP	NP?	NP	NP?	NP	174	Elephant Mtn		582	581	NP	NP	NP?	NP	NP?	NP	408	1	173	173	NP	NP	NP?	NP	NP?	NP			

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-47-50	NP	0	NP	NP	NP?	NP	NP?	NP	215	Elephant Mtn	RRI = 260'	NP	585	NP	NP	NP?	NP	NP?	NP	370	NP	215	215	NP	NP	NP?	NP	NP?	NP	45		Drillers log mislabeled as 699-48-50
699-47-51	NP	0	NP	NP	NP	NP	NP	NP	159			NP	585	NP	NP	NP	NP	NP	NP	426	NP	159	159	NP	NP	NP	NP	NP	NP			No water encountered during drilling
699-47-60	0	5	NP	NP	255	NP	255	NP	277.5	Elephant Mtn		652	647	NP	NP	397	NP	397	NP	375	5	250	250	NP	NP	22	NP	22	NP			TOB reported at 284' but casing stopped at 277.5 = prob. TOB
699-48-48A	NP	0	NP	NP	?			?	205	Elephant Mtn		NP	575	NP	NP	?			?	370	NP	?	?	NP	NP	?	?	?	?			
699-48-48B	NP	0	NP	NP	NP			NP	205	Elephant Mtn	RRI = 244', Pomona = 292', Selah = 484', Esquatzel = 504', Cold Cr Interbed = 602', Umatilla = 695', Mabton = 835', Priest Rapds = 933'	NP	573	NP	NP	NP			NP	368	NP	205	205	NP	NP	?	?	?	NP	39	48	Consolidated, open hole, brownish starting @140' = Ringold?
699-48-49	?	?	?	NP	?	?	?	?	?			?	?	?	NP	?	?	?	?	?	?	?	?	?	NP	?	?	?	?			
699-48-50	NP	0	NP	NP	NP			NP	195.6	Elephant Mtn		NP	575	NP	NP	NP			NP	379	NP	196	196	NP	NP	NP	NP	NP	NP			Change to hard tool @177'
699-48-50B	NP	0	43	NP	121	121	170?	185	209.5	Elephant Mtn		NP	609	599	NP	488	488	439?	424	399	NP	121	10	111	NP	64	49?	15?	25			
699-48-71	NP	0	NP	NP	NP			170?	ETD			NP	690	NP	NP	NP			520?	ETD	NP	170	170	NP	NP	NP			>135			
699-49-55A	NP	0	15	NP	50	50	99	118?	135	Elephant Mtn		NP	532	517	NP	482	482	433	?	397	NP	50	15	35	NP	68	49	6	?			>30 ' = DB, casing stopped driving @135' = TOB?
699-49-55B	NP	0	?	NP	?	?	?	105	136	Elephant Mtn	RRI = 183', Pomona = 226'	NP	532	?	NP	?	?	?	427	396	NP	?	?		NP	?	?	?	31	47	43	
699-49-57A	0	3	25	NP	95	95	115	NP	162	Elephant Mtn		554	551	529	NP	459	459	439	NP	392	3	42	22	20	NP	67	20	47	NP			
699-49-57B	0	4	18	NP	111	111	115	NP	162.5	Elephant Mtn	RRI = 215'	556.5	553	539	NP	446	446	442	NP	394	4	107	14	93	NP	52	4	48	NP	53		
699-49-71	0	3																														
699-50-42	NP	0	NP	NP	NP	NP	NP	38	65	Elephant Mtn		NP	468	NP	NP	NP	NP	NP	430	403	NP	38	38	NP	NP	NP	NP	NP	27			Calcareous fines from 35-45'
699-50-45	NP	0	NP	NP	NP			NP	37	Elephant Mtn	RRI = 130'	NP	453	NP	NP	NP			NP	416	NP	37	37	NP	NP	NP	NP	NP	NP	93		Air rotary through basalt from 41-134'

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-50-48A	NP	0	NP	NP	NP			NP	118	Elephant Mtn	RRI = 200', Pomona = 246', Selah = 442', Esquatzel = 460', Asotin = 608', Umatilla = 666', Mabton = 794', Priest Rapids = 904'	NP	553	NP	NP	NP			NP	435	NP	118?	118?	NP	NP	NP?	NP?	NP?	NP	82	46	CT to 173', deepened via RC in 1969
699-50-48B	NP	0	NP	NP	NP	NP	NP	NP	111	Elephant Mtn	RRI = 210', Pomona = 250'	NP	552	NP	NP	NP	NP	NP	NP	441	NP	111	111	NP	NP	NP	NP	NP	NP	99	40	AR from 119-213'; no bldrs, compacted starting at 45'
699-50-53A	NP	0	80	NP	140	NP	140	NP	156.5	Elephant Mtn		NP	558	478	NP	418	NP	418	NP	402	NP	140	80	60	NP	16	NP	16	NP			
699-50-53B	NP	0	61	NP	140	NP	140	NP	155.8	Elephant Mtn	RRI = 205'	NP	558	497	NP	418	NP	418	NP	403	NP	140	61	79	NP	15	NP	15	NP	49		Geologist log should be available but can't find anywhere
699-50-56	NP	0	48	NP	90	90	115	123	161	Elephant Mtn		NP	552	504	NP	462	462	437	429	391	NP	90	48	42	NP	33	25	8	38			
699-50-59	0	1	NP	NP	NP			NP	167	Elephant Mtn		565	564	NP	NP	NP			NP	397	1	167	167	NP	NP	NP	NP	NP	NP			
699-50-74	0	7	NP	NP	NP	NP	NP	90?	~336			658	651	NP	NP	NP	NP	NP	568?	~322	7	83?	83	NP	NP	NP	NP	NP	123?			
699-51-46	NP	0	NP	NP	NP			NP	12	Elephant Mtn	RRI = 119', Pomona = 165'	NP	446	NP	NP	NP			NP	434	NP	12	12	NP	NP	NP	NP	NP	NP	107	46	Drill log mislabeled 51-47, HT from 0-17' and 120-163'
699-51-63	NP	0	NP	NP	NP			NP	183.5?	Elephant Mtn		NP	573	NP	NP	NP			NP	390?	NP	184	183.5	NP	NP	NP	NP	NP	NP			TOB or boulder?
699-52-46A	NP	0	NP	NP	NP?			40	50	Elephant Mtn	RRI = 169', Pomona = 225'	NP	457	NP	NP	NP?			417	407	NP	40	40	NP	NP	NP?	NP?	NP?	10	119	56	Sticky clay @40'
699-52-46B	?	?	?	NP	?			?	44	Elephant Mtn		?	?	?	NP	?			?	?	?	?	?	?	NP	?	?	?	?			
699-52-48	0	5	NP	NP	NP			NP	28	Elephant Mtn	RRI = 149', Pomona = 195'	469	464	NP	NP	NP			NP	441	5	23	23	NP	NP	NP	NP	NP	NP	121	46	

Table E.1. (contd)

Well Name	Contact Depths (ft)										Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-52-52	NP	0	NP	NP	NP			NP	148	Elephant Mtn	RRI = 222', Pomona = 277', Selah = 462', Esquatzel = 484', Cold Cr. Interbed = 594', Asotin = 614', Umatilla = 692', Mabton = 933'	NP	561	NP	NP	NP			NP	413	NP	148	148	NP	NP	NP	NP	NP	NP	74	55	
699-52-54	NP	0	92	NP	NP			NP	167.4	Elephant Mtn		NP	569	477	NP	NP			NP	402	NP	167	92	75	NP	NP	NP	NP	NP			
699-52-55	0	3	123	NP	146	146	154	NP	177.2	Elephant Mtn		574	571	451	NP	428	428	420	NP	397	3	143	120	23	NP	31	8	23	NP			Low-K constant-rate pump test in CCUg
699-52-55B	0	5	127	NP	144	144	158	NP	176.5	Elephant Mtn	RRI = 222', Pomona = 286'	574	569	447	NP	430	430	416	NP	397	5	139	122	17	NP	33	14	19	NP	46	64	
699-52-57	NP	0	75	NP	105	105	118	NP	159.7	Elephant Mtn		NP	562	487	NP	457	457	444	NP	402	NP	105	75	30	NP	55	13	42	NP			Same well as 699-51-56 (A8828)
699-53-47A	NP	0	NP	NP	NP			NP	41.5	Elephant Mtn?		NP	439	NP	NP	NP			NP	398	NP	42	41.5	NP	NP	NP	NP	NP	NP			No TOB on drillers log
699-53-48A	0	1	NP	NP	NP	NP	NP	37	43	Elephant Mtn?		443	442	NP	NP	NP	NP	NP	406	400	1	36	36	NP	NP	NP	NP	NP	6			
699-53-48B	NP	0	NP	NP	NP	NP	NP	37	44	Elephant Mtn?		NP	444	NP	NP	NP	NP	NP	407	400	NP	37	37	NP	NP	NP	NP	NP	7			
699-53-50	NP	0	NP	NP	NP			NP	36	Elephant Mtn	RRI = 145', Pomona = 192'	NP	446	NP	NP	NP			NP	410	NP	36	36	NP	NP	NP	NP	NP	NP	109	47	
699-53-55A	NP	0	NP	NP	NP			NP	258*	*RRI window	RRI= 258', Pomona = 295',	NP	577	NP	NP	NP			NP	319?*	NP	258	258	NP	NP	NP	NP	NP	NP	NP	37	TOB may be down to 300 ft depth; Hanford fm over Ellensburg
699-53-55B	0	5	NP	NP	NP			NP	251*	*RRI window	RRI = 251'	578	573	NP	NP	NP			NP	327?*	5	246	246	NP	NP	NP	NP	NP	NP	NP		
699-54-42	0	15	NP	NP	NP			75?	100*	*RRI window	RRI = 100', Pomona = 199'	513	498	NP	NP	NP			438?	413*	15	60?	60?	NP	NP	NP	NP	NP	25?	NP	99	
699-54-45A	NP	0	NP	NP	NP			NP	75*	*RRI window?		NP	495	NP	NP	NP			NP	420*	NP	75	75	NP	NP	NP	NP	NP	NP	NP		
699-54-45B	NP	0	NP	NP	NP			50	≤180	?	Selah? = 304'	NP	495	NP	NP	NP			445	≥315	NP	50	50	NP	NP	NP	NP	NP	>24			74-175' undocumented across TOB

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-54-48	0	4	NP	NP	?			?	63*	*RRI window?	RRI? = 63', Pomona? = 94'	458	454	NP	NP	?			?	395*	4	?	?	NP	NP	?	?	?	?	NP	31	Perched water @43'
699-54-49	NP	0	NP	NP	NP	NP	NP	52	59	Elephant Mtn		NP	441	NP	NP	NP	NP	NP	389	382	NP	52	52	NP	NP	NP	NP	NP	7			
699-54-57	NP	0	NP	NP	NP			NP	181	Elephant Mtn	RRI = 248', Pomona = 309'	NP	577	NP	NP	NP			NP	396	NP	181	181	NP	NP	NP	NP	NP	NP	67	61	Deepened from 199' in 1982; driller's log mislabeled as 699-55-55
699-55-40	NP	0	NP	NP	NP			95?	ETD			NP	543	NP	NP	NP			448?	ETD	NP	95?	95?	NP	NP	NP	NP	NP	?			
699-55-44	0	10	NP	NP	NP			NP	ETD		RRI = 100'?	521	511	NP	NP	NP			NP	421?*	10	90?	90?	NP	NP	NP	NP	NP	NP		≥60'	>100' = RRI?
699-55-50A	0	10	NP	NP	NP			?	100	Elephant Mtn		445	435	NP	NP	NP			?	345	10	90	90	NP	NP	NP	NP	NP	?			
699-55-50D	0	10	NP	NP	NP			NP	91	Elephant Mtn		442	432	NP	NP	NP			NP	351	10	81	81	NP	NP	NP	NP	NP	NP			
699-55-55	0	2	NP	NP	NP			NP	294*	*Window into Selah Interbed		564	561.8	NP	NP	NP			NP	270*	2	292	292	NP	NP	NP	NP	NP	NP	NP		Older well (699-54-57) from 1955 with same name, TOB = 180 ft; Window thru basalt recharges Ellensburg Fm
699-55-57	0	2	NP	NP	NP			NP	170	Elephant Mtn		569	567	NP	NP	NP	NP	NP	NP	399	2	168	168	NP	NP	NP	NP	NP	NP			
699-55-60A	0	4	NP	NP	NP			NP	ETD			574	570	NP	NP	NP			NP	ETD	4	?	?	NP	NP	NP	NP	NP	NP			
699-55-60B	NP	0	NP	NP	NP			NP	278*	*Window into RRI?		NP	576	NP	NP	NP			NP	298*	NP	278	278?	NP	NP	NP	NP	NP	NP	NP		
699-55-63	NP	0	NP	NP	NP			NP	179	Elephant Mtn		NP	573	NP	NP	NP			NP	394.0	NP	179	179	NP	NP	NP	NP	NP	NP			Hole abandoned
699-55-65A	0	2	NP	NP	NP			?	ETD			581	579	NP	NP	NP			?	ETD	2	?	?	NP	NP	NP	NP	NP	?			Hole abandoned
699-55-65B	0	2	NP	NP	NP			125?	140	Elephant Mtn		581	579	NP	NP	NP			456?	441	2	123?	123?	NP	NP	NP	NP	NP	15?			Hole abandoned
699-55-65C	NP	0	NP	NP	NP			135	140	Elephant Mtn		NP	581	NP	NP	NP			446	441	NP	135	135	NP	NP	NP	NP	NP	5			
699-55-70	0	1	NP	NP	NP			83?	205	Elephant Mtn?		571	570	NP	NP	NP			488?	366	1	82?	82?	NP	NP	NP	NP	NP	122?			
699-56-42A	NP	0	NP	NP	NP			NP	90	Elephant Mtn	RRI= 114'	NP	535	NP	NP	NP			NP	445	NP	90	90	NP	NP	NP	NP	NP	NP	24		Picks from Golder geologist (Moser) log; Fault @180' repeats EM/RRI section?
699-56-42B	NP	0	NP	NP	NP			NP	100	Elephant Mtn	RRI = 137'	NP	547	NP	NP	NP			NP	447	NP	100	100	NP	NP	NP	NP	NP	NP	37		Picks from Golder geologist (Moser) log; Fault zones from 120-137' and 160' repeats EM/RRI section?
699-56-42C	NP	0	NP	NP	NP			NP	95	Elephant Mtn	RRI = 161'	NP	531	NP	NP	NP			NP	436	NP	95	95	NP	NP	NP	NP	NP	NP	66		Picks from Golder geologist (Moser) log; Fault zones from 200-210' repeats EM/RRI section?

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-56-42D	NP	0	NP	NP	NP			NP	48	Elephant Mtn	RRI = 360', Pomona = 406.5', Selah = 593.5, Esquatzel = 624'	NP	563	NP	NP	NP			NP	515	NP	48	48	NP	NP	NP	NP	NP	NP	312	47	No faulting reported
699-56-42E	NP	0	NP	NP	NP			NP	85	Elephant Mtn	RRI = 180', Pomona = 395', Selah = 575', Esquatzel = 601'	NP	541	NP	NP	NP			NP	456	NP	85	85	NP	NP	NP	NP	NP	NP	95	215	Picks from Golder geologist (Moser) log; Fault zones at 229' repeats EM/RRI section?
699-56-42F	NP	0	NP	NP	NP			NP	40	Elephant Mtn	RRI = 386', Pomona = 422'	NP	578	NP	NP	NP			NP	538	NP	40	40	NP	NP	NP	NP	NP	NP	346	36	No faulting reported
699-56-43	0	NP	15	NP	53	NP	53	NP	65	Elephant Mtn?	?	541	NP	526	NP	488	NP	488	NP	475.9	15	38	NP	38	NP	12	NP	12	NP?			Switch to HT @53'
699-56-51	0	2	NP	NP	NP			NP	103	Elephant Mtn?		440.5	438.5	NP	NP	NP			NP	337.5	2	101	101	NP	NP	NP	NP	NP	NP			Driller log mislabled well 699-56-50
699-56-53	NP	0	NP	NP	NP	NP	NP	?	100	Elephant Mtn	RRI = 204, Pomona = 266'	NP	436	NP	NP	NP	NP	NP	?	336	NP	42?	42?	NP	NP	NP	NP	NP	58	104	62	Unclear where (or if) CCU and Ringold are present; driller log mislabeled 699-57-53
699-57-41A	0	10	NP	NP	NP			NP	75	Pomona?	Selah = 250', Esquatzel = 260, Asotin = 329', unnamed interbed = 480'	707	697	NP	NP	NP			NP	632	10	65	65	NP	NP	NP	NP	NP	NP	NP	NP	Fault zone @ 395' produces repeated section?
699-57-41B	NP	0	NP	NP	NP			NP	65	Pomona?	Selah = 203', Esquatzel = 218', Cold Cr Interbed = 283'. Asotin = 302, unnamed interbed = 416, Umatilla = 431'	NP	711	NP	NP	NP			NP	646	NP	65	65	NP	NP	NP	NP	NP	NP	NP	NP	

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-57-41C	NP	0	NP	NP	NP			NP	123	*Window into Selah Interbed	Esquatzel = 142', Asotin = 238'	NP	709	NP	NP	NP			NP	586	NP	123	123	NP	NP	NP	NP	NP	NP	NP	NP	
699-57-41E	NP	0	NP	NP	NP			NP	35	Pomona		NP	698	NP	NP	NP			NP	663	NP	35	35	NP	NP	NP	NP	NP	NP	NP	NP	
699-57-41F	NP	0	NP	NP	NP			NP	80	Pomona	Selah = 261, Esquatzel = 272', Asotin = 440'	NP	708	NP	NP	NP			NP	628	NP	80	80	NP	NP	NP	NP	NP	NP	NP	NP	Fault zones 190-194.5', 220', 335-357', 571-573 - repeated sections
699-57-59	0	1.5	NP	NP	154	154	158	NP?	ETD			576.5	575	NP	NP	423	423	419	NP?	ETD	1.5	152	152	NP	NP	>36	4	>36?	NP?			
699-58-41A	0	NP	NP	NP	NP			NP	15	Pomona		710	NP	NP	NP	NP			NP	695	15	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	15' loess over basalt; fault zone from 110-185' repeats section of Pomona basalt
699-58-41B	0	15	NP	NP	NP			NP	75	Pomona		704	689	NP	NP	NP			NP	629	15	60	60	NP	NP	NP	NP	NP	NP	NP	NP	Fault zone from 155-195' repeats section of Pomona basalt
699-58-41C	0	15	NP	NP	NP			NP	80*	*Window into RRI	Pomona = 96'	703	688	NP	NP	NP			NP	623*	15	65	65	NP	NP	NP	NP	NP	NP	NP	16	TOB = top RRI
699-58-41D	NP	0	NP	NP	NP			NP	18	Elephant Mtn	RRI = 49', Pomona = 72'	NP	702	NP	NP	NP			NP	684	NP	18	18	NP	NP	NP	NP	NP	NP	31	23	
699-58-41E	0	NP	NP	NP	NP			NP	10	Elephant Mtn	RRI = 50', Pomona = 115', Selah = 345', Esquatzel = 365'	700	NP	NP	NP	NP			NP	690	10	NP	NP	NP	NP	NP	NP	NP	NP	40	65	Fault zone 75-90' repeats RRI?
699-58-41F	0	5	NP	NP	NP			NP	70	Pomona	Selah = 248', Esquatzel = 390', Cold Cr Interbed = 492', Asotin = 538'	699.5	694.5	NP	NP	NP			NP	629.5	5	65	65	NP	NP	NP	NP	NP	NP	NP	NP	Fault zone at 283' repeats Selah/Pomona section
699-58-48	NP	NP	NP	NP	NP			NP	0			NP	NP	NP	NP	NP			NP	?	NP	NP	NP	NP	NP	NP	NP	NP	NP			CRB at surface
699-59-55	NP	0	NP	NP	NP?			?	ETD			NP	432	NP	NP	NP?			?	ETD	NP	?	?	NP	NP	NP?	NP?	NP?	NP			Drilling terminated prematurely because of potential for cave in from sand removal via air rotary drilling.
699-59-58	NP	0	NP	NP	92	92	NP?	NP?	ETD			NP	499	NP	NP	407	407	ETD (379?)	NP?	ETD	NP	92	92	NP	NP	>25?	>25 (28?)	<140 (129?)	NP?			Uniform zS bed from 92-104'
699-60-53B	NP	NP	NP	NP	NP			NP	0	Elephant Mtn	RRI = 78', Pomona 102'	NP	NP	NP	NP	NP			NP	?	NP	NP	NP	NP	NP	NP	NP	NP	NP	78	24	Basalt at surface

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-60-53C	NP	NP	NP	NP	NP			NP	0	Elephant Mtn	RRI = 77', Pomona = 102'	NP	NP	NP	NP	NP			NP	?	NP	NP	NP	NP	NP	NP	NP	NP	NP	77	25	Basalt at surface
699-60-53F	NP	NP	NP	NP	NP			NP	0	Elephant Mtn	RRI = 76', Pomona = 100', Selah = 286'	NP	NP	NP	NP	NP			NP	821	NP	NP	NP	NP	NP	NP	NP	NP	NP	76	24	Basalt at surface
699-60-57	NP	0	NP	NP	NP			133	145	Asotin		NP	471	NP	NP	NP			338	326	NP	133	125	8	NP	NP	NP	NP	12	NP	NP	
699-60-59	NP	0	NP	NP	NP			NP	180	Asotin	Umatilla = 221', Mabton = 462', Priest Rapids = 574'	NP	509	NP	NP	NP			NP	329	NP	180	180	NP	NP	NP	NP	NP	NP	NP	NP	
699-60-60	NP	0	NP	NP	NP			NP	128	Esquatzel		NP	513	NP	NP	NP			NP	385	NP	128	128	NP	NP	NP	NP	NP	NP	NP	NP	
699-61-53	NP	NP	NP	NP	NP			NP	0	Elephant Mtn	RRI = 76', Pomona = 96', Selah = 278', Esquatzel = 295', Asotin = 362'	NP	NP	NP	NP	NP			NP	765	NP	NP	NP	NP	NP	NP	NP	NP	NP	76	20	On Gable Mtn, basalt at surface
699-61-55A	NP	NP	NP	NP	NP			NP	0	Asotin	Unnamed Interbed = 69', Umatilla = 71', Mabton = 223'	NP	NP	NP	NP	NP			NP	463.0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
699-61-55B	NP	NP	NP	NP	NP			NP	0	Asotin	Umatilla = 60', Mabton = 218', Priest Rapids = 326'	NP	NP	NP	NP	NP			NP	464	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
699-61-57	NP	NP	NP	NP	NP			NP	0	Pomona	Selah = 121', Esquatzel = 150', Asotin = 249', Cold Creek = 330, Umatilla = 337', Mabton = 503'	NP	NP	NP	NP	NP			NP	444	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	
699-61-62	0	2	NP	NP	NP			115?	177.5	Umatilla		498	496	NP	NP	NP			383?	320	2	113?	113?	NP	NP	NP	NP	NP	63?	NP	NP	

Table E.1. (contd)

Well Name	Contact Depths (ft)											Contact Elevations (ft)									Thickness (ft)											Comments
	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Basalt Member	Deeper Contacts	Holocene	Top H1	Top H2	Top H3	Top CCU	Top CCUz	Top CCUg	Top Ringold	TOB	Holocene	Hanford fm	H1	H2	H3	CCU	CCUz	CCUg	Ringold Fm	Elephant Mtn	Rattlesnake Ridge Interbed	
699-61-66	NP	0	NP	NP	NP			140?	216.5	Umatilla		NP	524	NP	NP	NP			384?	307.4	NP	140?	140?	NP	NP	NP	NP	NP	77?	NP	NP	Increase in $CaCO_3$ + mud @140'
699-62-43B	0	5	NP	NP	NP			65	ETD			422	417	NP	NP	NP			357	ETD	5	65	65	NP	NP	NP	NP	NP	>3			
699-62-53	NP	0	NP	NP	NP			NP	26	Elephant Mtn	RRI = 56', Pomona = 124', Selah = 298', Esquatzel= 340'	NP	439	NP	NP	NP			NP	413	NP	26	26	NP	NP	NP	NP	NP	NP	30	68	Drilled ~30 degrees from vertical - therefore true depths are different
699-63-51	0	2	NP	NP	NP			20	ETD			425	423	NP	NP	NP			405	ETD	2	18	18	NP	NP	NP	NP	NP	?			Ringold lower mud @25'?
699-63-55	NP	0	NP	NP	NP			NP?	112*	*Window into RRI	RRI = 70, Pomona = 112'	NP	427.1	NP	NP	NP			NP?	357*	0	68	68	NP	NP	NP	NP	NP?	NP	NP	42	Changed from DB to HT @70'
699-63-58	0	2	NP	NP	NP			NP	120	Pomona		493	491	NP	NP	NP			NP	373	2	118	118	NP	NP	NP	NP	NP	NP	NP	NP	
699-64-62	NP	0	NP	NP	NP			90?	ETD			NP	501	NP	NP	NP			411?	ETD	NP	90?	90?	NP	NP	NP	NP	NP	?			
699-65-50	0	40	NP	NP	NP			102?	578	Elephant Mtn		469	429	NP	NP	NP			367?	-109	40	62?	62?	NP	NP	NP	NP	NP	476?			TOR = LM @105, TOR could be as high as 60'
699-65-59A	0	2	NP	NP	NP			108?	ETD			508.5	506.5	NP	NP	NP			400.5?	ETD	2	106?	106?	NP	NP	NP	NP	NP	?			Ringold LM @200'
699-65-59B	NP	0	NP	NP	NP			95?	ETD			NP	507.6	NP	NP	NP			413?	ETD	NP	95?	95?	NP	NP	NP	NP	NP	?			Decommissioned in 1995
699-65-59C	NP	0	NP	NP	NP			105?	ETD			NP	506.1	NP	NP	NP			401?	ETD	NP	105?	105?	NP	NP	NP	NP	NP	?			
699-65-72	?	?	?	NP	?	?	?	?	?			?	?	?	NP	?			?	?	?	?	?	?	NP	?	?	?	?			
699-66-64	NP	0	NP	NP	NP			?	ETD			NP	506.7	NP	NP	NP			?	ETD	NP	?	?	NP	NP	NP	NP	NP	?			
699-67-51	NP	0	NP	NP	NP	NP	NP	145	ETD			NP	525	NP	NP	NP	NP	NP	380	ETD	NP	145	145	NP	NP	NP	NP	NP	>105			
699-69-45	0	5		NP	NP			90	ETD			488	483	NP	NP	NP			398	ETD	5	85	85	NP	NP	NP	NP	NP	>210			
699-70-68	NP	0	NP	NP	NP			50?	ETD			NP	527	NP	NP	NP			477?	ETD	NP	50?	50?	NP	NP	NP	NP	NP	?			
699-71-52	0	3	NP	NP	NP			120	ETD			525	522	NP	NP	NP			405	ETD	3	117	117	NP	NP	NP	NP	NP	>90			
699-72-73	NP	0	NP	NP	NP			90?	ETD			NP	483.5	NP	NP	NP			393.5?	ETD	NP	90?	90?	NP	NP	NP	NP	NP	>110			Cemented starting @90', Ringold LM @170'
699-73-61	NP	0	NP	NP	NP			120?	ETD			NP	533	NP	NP	NP			413?	ETD	NP	120?	120?	NP	NP	NP	NP	NP	?			Color change from gray to tan/brown @ 120'

NP = not present; NR = not reached; ETD = exceeds total depth

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