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

Borehole Completion and Conceptual Hydrogeologic Model for the IFRC Well Field, 300 Area, Hanford Site

Integrated Field Research Challenge Project

BN Bjornstad
JA Horner
VR Vermeul
DC Lanigan
PD Thorne

April 2009

Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Abstract

A tight cluster of 35 new wells was installed over a former waste site, the South Process Pond (316-1 waste site), in the Hanford Site 300 Area in summer 2008. This report documents the details of the drilling, sampling, and well construction for the new array and presents a summary of the site hydrogeology based on the results of drilling and preliminary geophysical logging.

Acknowledgments

Acknowledged is the work of well-site geologists Joe Fritts and Sean Sexton, Gram, Inc. We also thank the Fluor Federal Services drilling and support staff, including Chris Wright, Dorman Blankenship, Paul Lodder, and Les Walker. Rick McCain and Alan Pearson from Stoller Hanford were instrumental in the timely collection of downhole geophysical logs. Finally, we extend our appreciation for the support of others on the Pacific Northwest National Laboratory scientific team, including John Zachara, Mark Freshley, Vince Vermeul, Mark Rockhold, Andy Ward, Jim Fredrickson, Alan Konopka, Jim McKinley, Chris Strickland, and Dean Moore.

Acronyms and Abbreviations

bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office
ERT	electrical-resistivity tomography
ft	foot, feet
gal	gallon(s)
gpm	gallons per minute
ID	inside diameter
IFRC	Integrated Field Research Challenge
in.	inch(es)
K_d	distribution coefficient; measurement of sorbtive capacity of a specific chemical constituent
m	meter(s)
mi	mile(s)
NMLS	neutron-moisture logging system
OD	outside diameter
PNNL	Pacific Northwest National Laboratory
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act of 1976
SGLS	spectral-gamma logging system

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1.0 Introduction

Pacific Northwest National Laboratory (PNNL) is leading a field study at the Hanford Site in Richland, Washington, to identify new approaches and strategies to help resolve questions about the movement of subsurface contaminants. The field study is part of the U.S. Department of Energy (DOE) Integrated Field-Scale Subsurface Research Challenge (IRFC), a new program that commits multi-investigator teams to performing large, benchmark-type experiments on formidable field-scale science issues. The field sites will provide capabilities to collect, permit, and ship environmental samples of different types to other program investigators and provide site access to those interested in testing specific concepts or technologies/techniques relevant to the study of subsurface contaminant fate and transport.

The program is managed by the Environmental Remediation Sciences Division, DOE Office of Biological and Environmental Research. Researchers will perform state-of-science field experiments at these sites to resolve the geochemical, hydrophysical, and microbiological factors that control the migration of contaminant uranium through the vadose zone (water-unsaturated sediments below the soil and above groundwater) and groundwater.

The Hanford field study involves the development, characterization, and instrumentation of a vadose zone and saturated zone field site. Researchers are evaluating hypotheses related to a uranium plume that resulted from nuclear fuel fabrication at the Hanford Site from 1943 to 1975.

The research site in the Hanford 300 Area is adjacent to the Columbia River, enabling studies of how the fluctuations in river stage influence contaminant dissipation from the aquifer and discharge to the river. The 300 Area is near the southern boundary of the Hanford Site north of Richland, allowing full access by a diverse and accomplished scientific team involving participants from PNNL, universities, and other laboratories.

In summer 2008, an array of 35 new monitoring wells was installed over the South Process Pond (316-1 waste site), a former waste site in the 300 Area. This report documents the details of the drilling, sampling, and well construction for the new array and presents a summary of the site hydrogeology based on the results of drilling and preliminary geophysical logging.

Section 2 provides historical and other background details about the site of the new well array. Section 3 presents a summary of the methodologies and equipment employed in the steps needed to develop the IFRC 300 Area well field: drilling, geologic sampling, geophysical logging, well construction, and well development. In Section 4, the hydrogeology of the IFRC research site is characterized. Sources cited in the text are provided in Section 5.

Raw data and construction details for each well are provided in a series of appendices:

- Appendix A – Compilation Borehole Summary Logs
- Appendix B – Well-Site Geologist Logs
- Appendix C – Sample Inventory Sheets
- Appendix D – Field Activity Reports
- Appendix E – Well Development and Testing Data Sheets
- Appendix F – Well Summary Sheets
- Appendix G – Downhole Geophysical Logs
- Appendix H – Survey Reports
- Appendix I – Chip Tray Photographs.

2.0 Background

The 300 Area lies in the southeastern corner of the DOE Hanford Site (Figure 2.1). The site is immediately adjacent to the Columbia River and thus enables studies of how the river stage affects contaminant dissipation from the aquifer and discharge to the river.

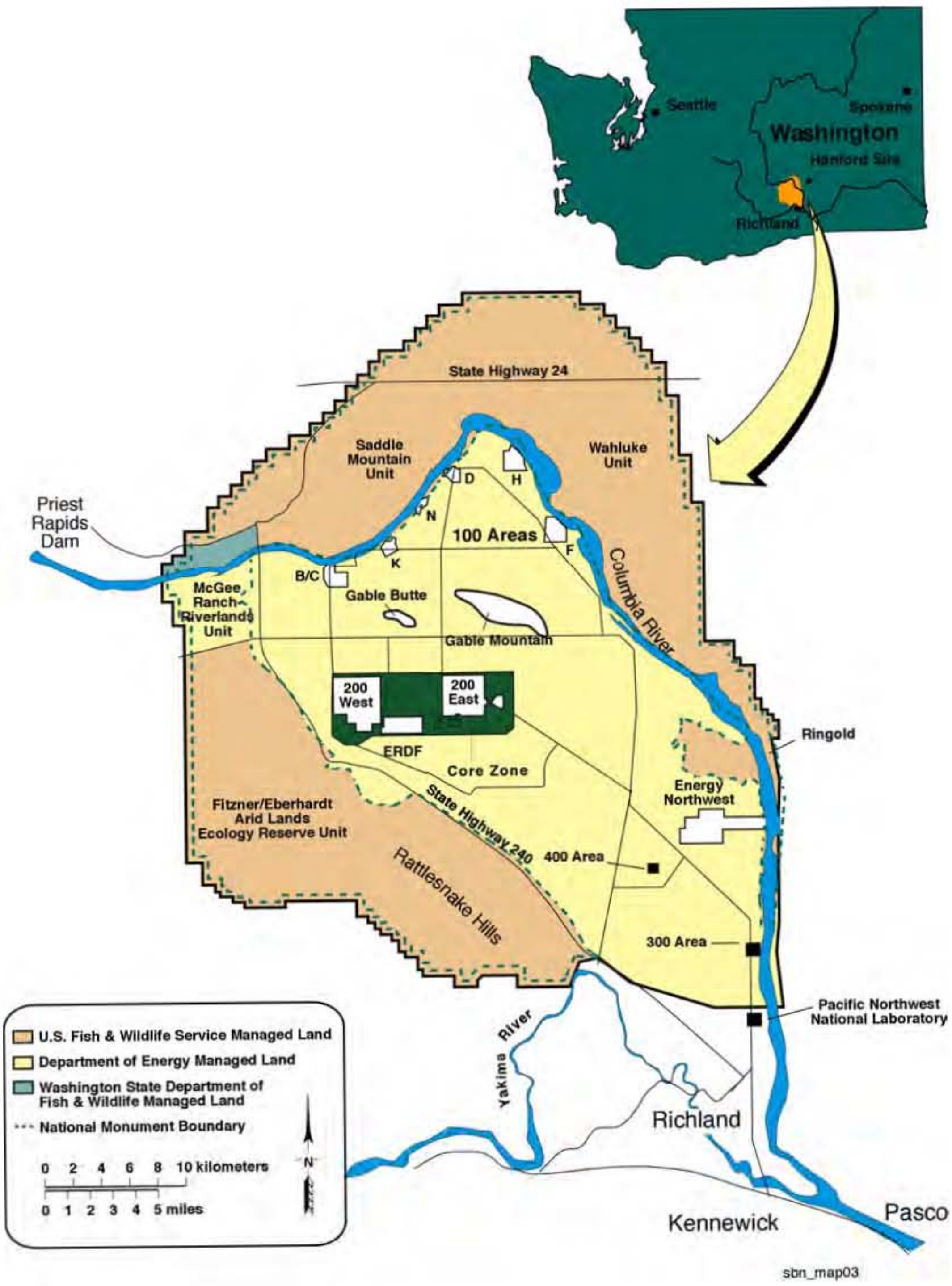

Figure 2.1. The 300 Area is located in the southeastern portion of the Hanford Site.

A tight cluster of 35 new wells was installed over a former waste site (South Process Pond [316-1]) in the Hanford Site 300 Area in 2008. The wells were drilled to characterize the subsurface and test new approaches and strategies leading to understanding and remediation of a persistent uranium contaminant plume in groundwater beneath the 300 Area (Figure 2.2).

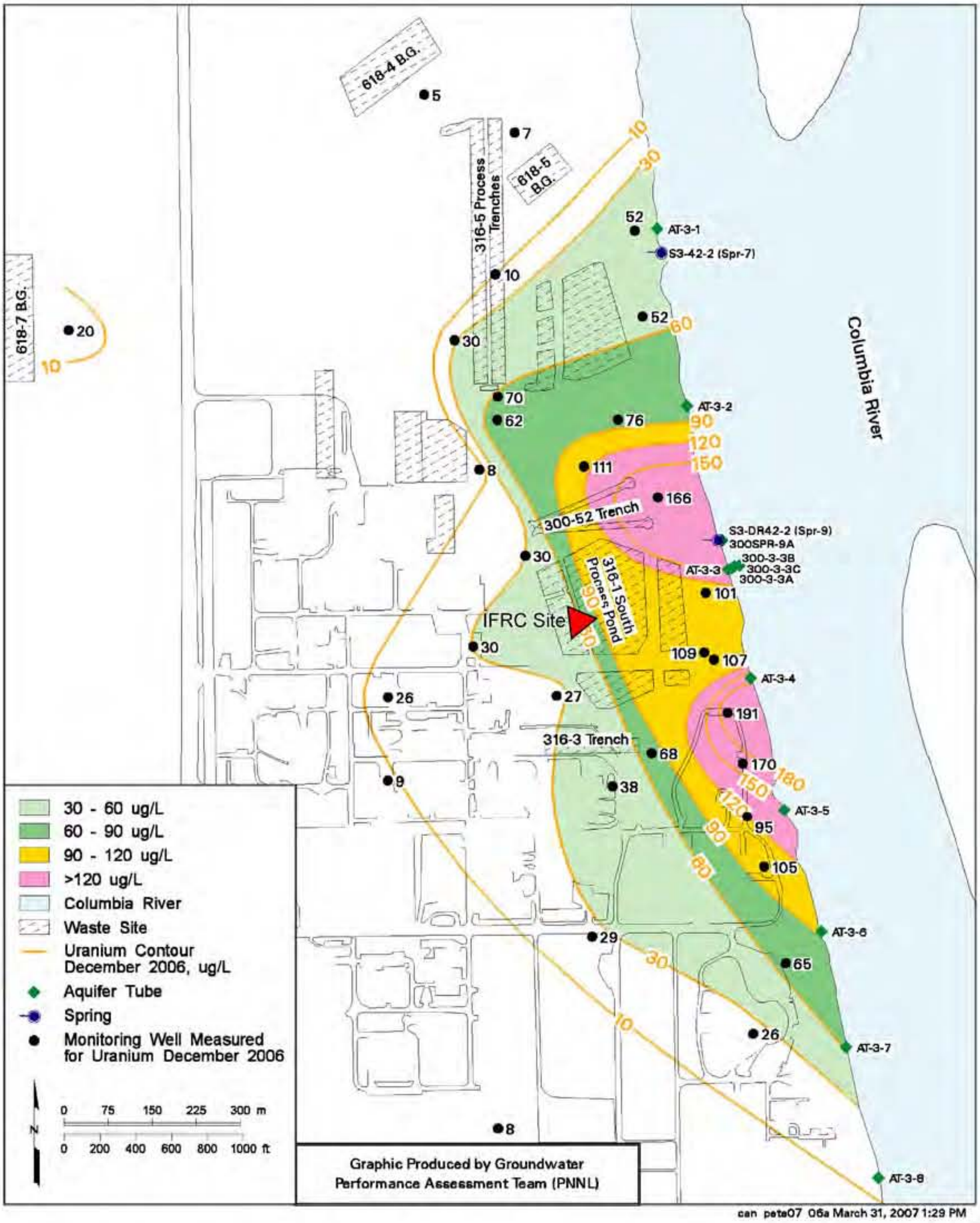

Figure 2.2. Uranium plume in groundwater beneath the Hanford Site 300 Area in December 2006. The IFRC well field is represented by the triangle in the southwestern corner of the South Process Pond, a remediated waste site.

Large volumes of process waste were disposed of at the 300 Area process ponds, including the since-remediated South Process Pond, over which the IFRC site is located. The process ponds were used for waste disposal between 1943 and 1975. Process waste later was diverted to the 300 Area process trenches from 1975 through 1994. After the ponds were drained, the near-surface contaminated sediments were excavated from the waste-disposal ponds and trenches between 1995 and 2004 as a source-control measure to minimize additional groundwater contamination.[1] The excavated ponds and trenches subsequently were backfilled and the land surface regraded to a natural state.

Groundwater wells have been installed in the 300 Area since the early 1940s for both subsurface characterization and groundwater monitoring. This monitoring network has been expanded sequentially in response to the growing size and concerns regarding the uranium contaminant plume and attendant investigations under the Resource Conservation and Recovery Act of 1976 (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (Lindberg and Bond 1979; Schalla et al. 1988; Swanson et al. 1992). Pump testing and other hydrologic investigations have been ongoing. The results of the monitoring programs and decisions made are summarized in Peterson et al. (2005).

A groundwater uranium plume has existed beneath the 300 Area since the early operations of the process ponds; the highest uranium concentrations were observed from the early 1950s to the late 1980s (Peterson et al. 2008). These concentrations decreased rapidly after disposal activities ceased in the early 1990s, and groundwater uranium concentrations have slowly decreased since then. The plume resulted from liquid process waste infiltrating through the 4- to 10-m-thick vadose zone beneath the disposal facilities. Despite source-term removal and elimination of other leak sources, the general shape of the contaminated groundwater plume has not changed significantly over the last 10 years. The plume occasionally experienced sizable water table fluctuations during pre-dam Columbia River flooding and, to a lesser extent, during present-day dam-controlled river stage fluctuations that appear to be redistributing dissolved uranium into uncontaminated capillary-fringe and deep vadose-zone sediments.

In 2003, after remediation but prior to backfilling and regrading, four deep pits (two each from beneath the North and South process ponds) were excavated with a backhoe to a depth of 10 to 20 ft to the water table (Bjornstad 2004). One of these pits (SPP#2) was excavated at the southwestern corner of the IFRC well field (Figure 2.3). A profile of the sedimentary materials of the Hanford formation exposed and sampled at that time is shown in Figure 2.4.

[1] See http://ifchanford.pnl.gov/history.

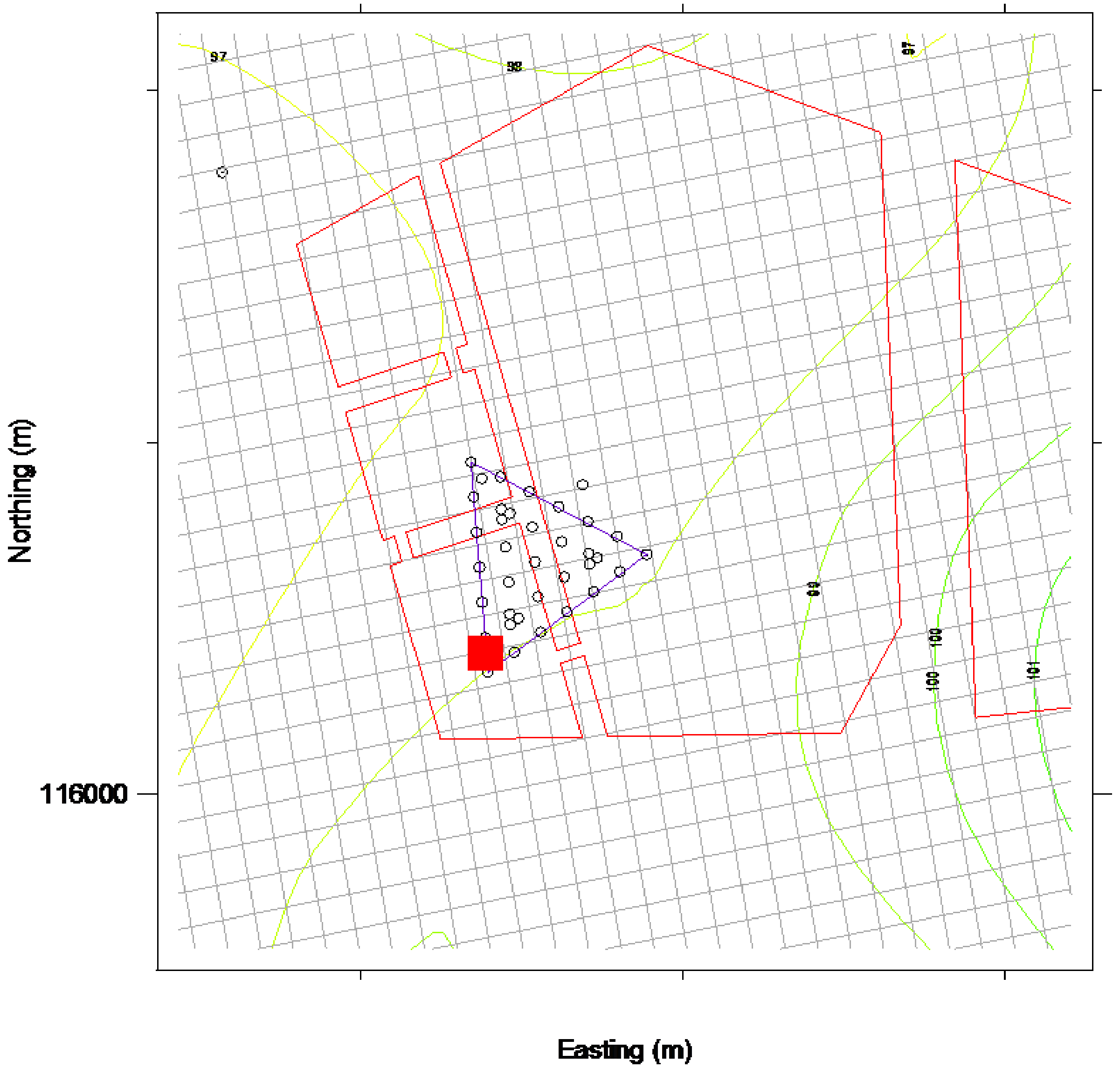

Figure 2.3. IFRC well field location in relation to the former South Process Pond (red outline). Grid spacing is 10 m. The red square is the approximate location of backhoe pit SPP#2 excavated at the base of the remediated South Process Pond in April 2003 (see Figure 2.4).

Figure 2.4. Vadose-zone backhoe pit SPP#2 excavated beneath the IFRC site in 2003. The uppermost 4 ft of the profile lack primary sedimentary structure, apparently destroyed from movement of heavy equipment over the site during remediation. Photo from Bjornstad (2004).

In 1996, a CERCLA interim remedy of monitored natural attenuation was selected for the 300 Area uranium plume based on equilibrium K_d-based reactive transport modeling. The modeling analysis implied that natural processes of groundwater flushing and desorption would lower uranium concentrations below the drinking water standards within 10 years. Subsequent monitoring has demonstrated that groundwater uranium concentrations are not decreasing as projected and persist above the drinking water standards throughout much of the 300 Area. Because of the ineffectiveness of monitored natural attenuation and regulatory mandates, the DOE Richland Operations Office initiated a Phase III Feasibility Study for the 300-FF-5 operable unit in 2005. The feasibility study included a limited field investigation to define the depth-discrete distribution and concentration of uranium in the aquifer and capillary fringe, as well as the nature of the hydrologic boundary between the Hanford and Ringold formations (Williams et al. 2007). Sonic drilling was used to recover continuous and intact large-diameter sediment cores from four limited field investigation boreholes in 2006. One of these wells (399-2-5) comprises the eastern corner of the IFRC well field. Well 399-2-5 was drilled with a cable-tool rig during an investigation of volatile organic compounds in 2007 (Peterson et al. 2008).

Groundwater levels are highly variable at the IFRC site due to seasonal and diurnal fluctuations in the Columbia River, located just east of the site. The normal high water level in late spring and early summer is about 25 ft below ground surface (bgs). The normal low water level is about 35 ft bgs, usually in late fall to early winter. Superimposed on these seasonal variations are daily fluctuations of several feet or more that can occur from fluctuating discharge from Priest Rapids Dam, situated 50 mi upstream. The base of the unconfined aquifer, defined by a fine-grained stratum at the top of the Ringold Formation, varies from 50 to 60 ft beneath the IFRC site. Therefore, depending on the season, the thickness of the unconfined aquifer ranges from 15 to 35 ft beneath the IFRC site.

3.0 IFRC 300 Area Wells

All 35 wells installed over a portion of the former South Process Pond within the 300 Area (Figure 3.1) are contained within a triangle 60 m on a side (Figure 3.2). The size, shape, and orientation of the well array were designed to take advantage of changes in the groundwater flow fields identified in Zachara et al. (2008). Prior to the start of drilling, a plan for drilling, sampling, and well installation (Bjornstad and Horner 2008) and drilling specifications (Bjornstad and Vermeul 2008) were prepared. Information gathered during drilling, sampling, geophysical logging, and well construction (Figure 3.3) is summarized in Table 3.1.

Figure 3.1. IFRC well field (circled) within the 300 Area, looking southeast. Photo: Bob Peterson (PNNL).

Field characterization data are summarized and compiled for each well in Appendix A. An example of a compilation summary log is shown in Figure 3.4. The raw data for each well, used to create the summary compilation logs in Appendix A, are documented in Appendices B through I, provided on the compact disc bound inside the back cover of printed copies of this report.

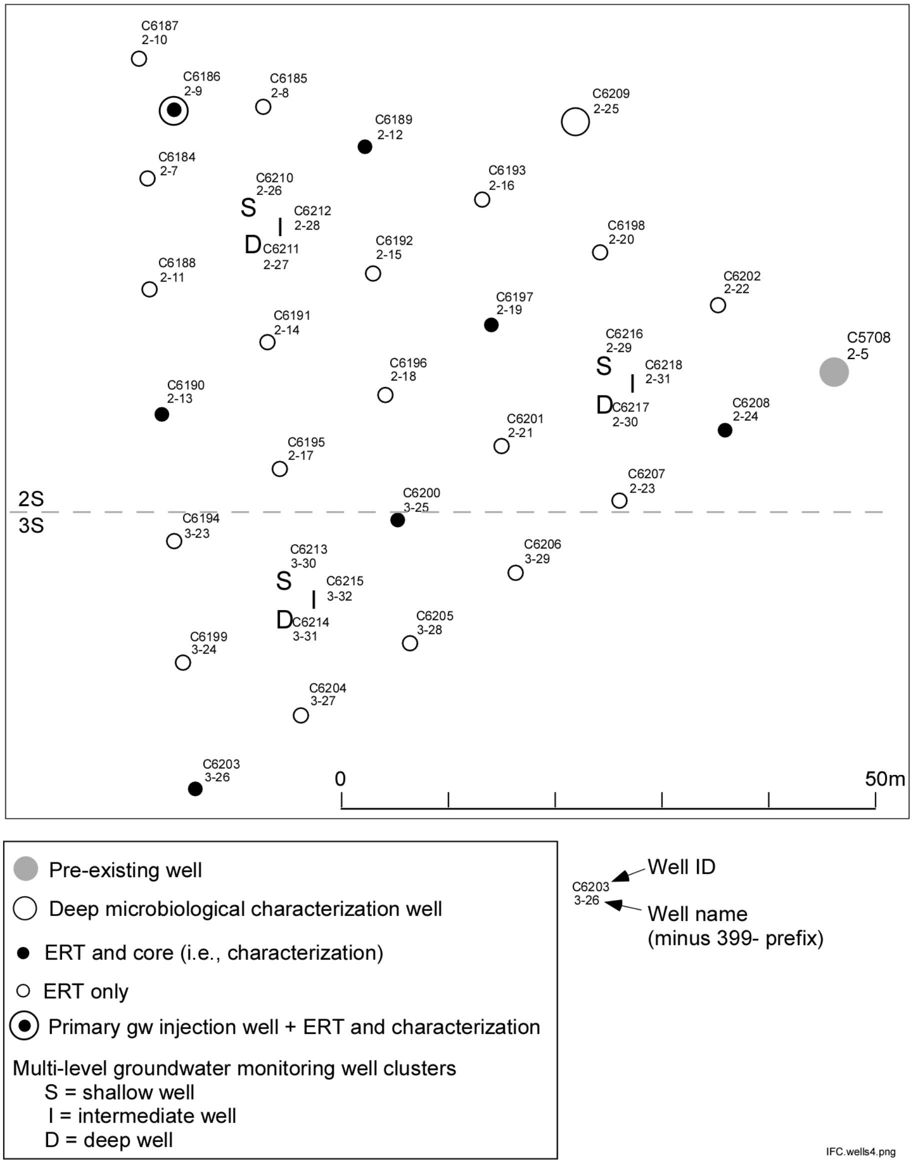

Figure 3.2. The triangular IFRC well array. Wells installed with special electrical-resistivity tomography and thermistor sensors are designated as ERT wells. See Table 3.1 and appendices for details on drilling and well construction.

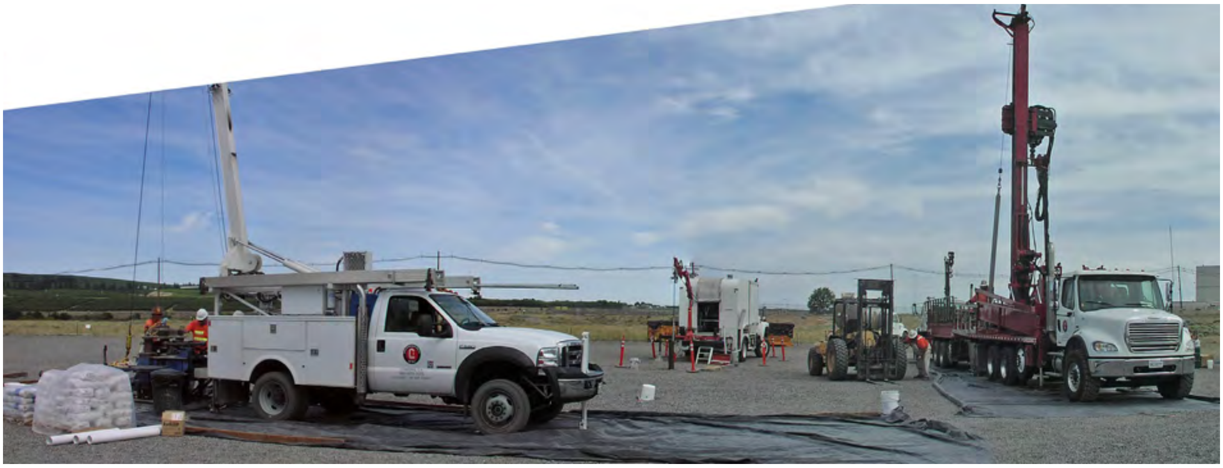

Figure 3.3. Drilling (right), geophysical logging (center), well construction (left), and well development were performed simultaneously at the IFRC site.

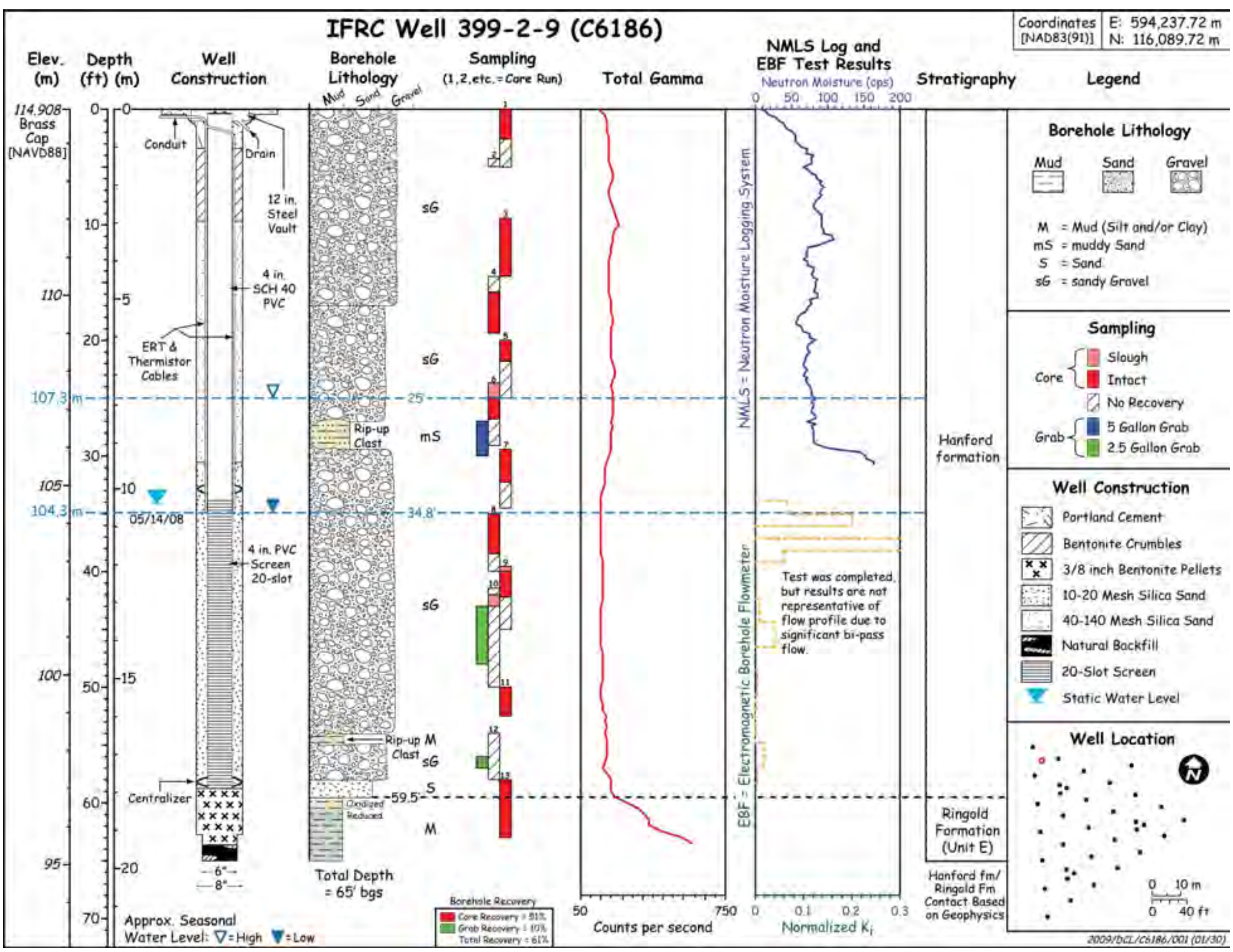

Figure 3.4. Sample compilation summary log for well 399-2-9 (C6186). See Appendix A for summary logs of all 35 new wells.

Table 3.1. Drilling, sampling, geophysical logging, and well construction information for IFRC wells

														% Recovery			Hanford/Ringold Contact Depth (ft)	
Well Name	Well ID	Function	Samples	Drilling Order	Start Drilling	End Drilling	Geophysical Logging	Total Depth (ft)	Length Screen (ft)	Top Screen Depth (ft)	Bottom Screen Depth (ft)	Bottom End Cap (ft)	Instrument Depth (ft)	Core	Grab	Total	Geologist Log	Gamma Log
399-2-7	C6184	ERT/ electrodes	Buckets	20	27-Jun	27-Jun	28–29-Jun	62.0	25	31	56	56.3	33.5	-----	75	75	55.5	53.5
399-2-8	C6185	ERT/ electrodes	Buckets	23	7-Jul	8-Jul	10-Jul	60.0	25	31	56	56.3	33.5	-----	80	80	52.5	52.5
399-2-9	C6186	ERT/electrodes characterization GW injection	Intact Lexan core	1	12-May	13-May	Complete	65.0	25	33.5	58.5	58.8	58.5 (?)	52.5	9.5	62	59.5	59.5
399-2-10[a]	C6187	ERT/ electrodes	Buckets	31	17-Jul	17-Jul	18-Jul	65.0	25	34.7	59.6	59.9	33.5/58/5	-----	81.5	81.5	56	59
399-2-11	C6188	ERT/ electrodes	Buckets	30	16-Jul	17-Jul	21-Jul	65.0	25	31	56	56.3	33.5	-----	78.5	78.5	55.5	55.5
399-2-12	C6189	ERT/electrodes characterization	Intact Lexan core	11	17-Jun	18-Jun	23-Jun	65.0	25	31	56	56.3	33.5	65.9	9.4	75.3	52	53
399-2-13[b]	C6190	ERT/electrodes characterization	Intact Lexan core	4	22-May	22-May	Complete	62.6	25	31.2	56.2	56.5	33.7	44.5	6.5	50.8	54	55.5
399-2-14[c]	C6191	ERT/ electrodes	Buckets	9	13-Jun	16-Jun	7-Jun	58.5	25	30.7	55.7	56.0	33.2	-----	93	93	52?	54.5
399-2-15	C6192	ERT/ electrodes	Buckets	17	25-Jun	25-Jun	28-Jun	61.0	25	31	56	56.3	33.5	-----	88.5	88.5	55	55
399-2-16	C6193	ERT/ electrodes	Buckets	15	24-Jun	24-Jun	27-Jun	62.0	25	31	56	56.3	33.5	-----	79.8	79.8	54	54
399-2-17	C6195	ERT/ electrodes	Buckets	8	12-Jun	13-Jun	19-Jun	63.0	25	31.2	56.2	56.5	33.7	-----	74.5	74.5	56.5	55.5
399-2-18[d]	C6196	ERT/ electrodes	Buckets	6	3-Jun	11-Jun	14-Jun	65.0	25	33	58	58.3	33.5	-----	95.5	95.5	57	57
399-2-19[e]	C6197	ERT/electrodes characterization	Intact Lexan core	3	20-May	20-May	Complete	60.8	25	31.3	56.3	56.6	33.8	66.5	0	66.5	57	54
399-2-20	C6198	ERT/ electrodes	Buckets	16	25-Jun	25-Jun	27-Jun	62.0	25	31	56	56.3	33.5	-----	80.6	80.6	55	55.5
399-2-21	C6201	ERT/ electrodes	Buckets	7	12-Jun	12-Jun	16-Jun	61.7	25	31.1	56.1	56.4	33.6	-----	79.4	79.4	55	55
399-2-22	C6202	ERT/ electrodes	Buckets	29	14-Jul	16-Jul	17-Jul	65.0	25.1	33.4	58.5	58.8	34.1	-----	72.3	72.3	56	58
399-2-23	C6207	ERT/ electrodes	Buckets	24	8-Jul	8-Jul	10-Jul	60.0	25	31	56	56.3	33.5	-----	78.3	78.3	55	55.5
399-2-24	C6208	ERT/electrodes characterization	Intact Lexan core	5	23-May	2-Jun	Complete	65.2	25	33	58	58.3	33.5	35	45.5	80.5	58	58
399-3-23	C6194	ERT/ electrodes	Buckets	28	10-Jul	10-Jul	13-Jul	65.0	25	31	56	56.3	33.5	-----	63.1	63.1	52.5	53.5
399-3-24	C6199	ERT/ electrodes	Buckets	27	9-Jul	10-Jul	12-Jul	65.0	25	31	56	56.3	33.5	-----	90	90	52.5	52.5
399-2-25	C6209	Deep microbiological characterization GW monitoring	Intact core and buckets	34	22-Jul	25-Jul	27-Jul	171.0	60	62	122	124.9	N/A	N/A	N/A	N/A	53	58
399-3-25	C6200	ERT/electrodes characterization	Intact Lexan core	10	16-Jun	17-Jun	20-Jun	65.0	25	31.6	56.6	56.9	33.1	63.8	7.7	71.5	57.5	57
399-2-26	C6210	Shallow GW monitoring	Buckets	14	23-Jun	24-Jun	26-Jun	62.0	5	30	35	59.4	N/A	-----	77.4	77.4	57	58

Table 3.1. (contd)

Well Name	Well ID	Function	Samples	Drilling Order	Start Drilling	End Drilling	Geophysical Logging	Total Depth (ft)	Length Screen (ft)	Top Screen Depth (ft)	Bottom Screen Depth (ft)	Bottom End Cap (ft)	Instrument Depth (ft)	% Recovery			Hanford/Ringold Contact Depth (ft)	
														Core	Grab	Total	Geologist Log	Gamma Log
399-3-26[f]	C6203	ERT/electrodes characterization	Intact Lexan core	2	14-May	15-May	Complete	66.0	20	32	52	52.3	33.5	51.5	16.5	68	52	52
399-2-27	C6211	Deep GW monitoring ERT/electrodes	Buckets	32	17-Jul	18-Jul	None	63.5	2	54.7	56.7	59.1	58.5	-----	67.7	67.7	57.5	-----
399-2-28	C6212	Intermediate GW monitoring	Buckets	21	27-Jun	30-Jun	None	65.0	2	42	44	56.3	N/A	-----	80	80	56.5	-----
399-3-27	C6204	ERT/ electrodes	Buckets	26	9-Jul	9-Jul	11-Jul	62.0	25	31	56	56.3	33.5	-----	84.7	84.7	50.5	50.5
399-2-29	C6216	Shallow GW monitoring	Buckets	18	26-Jun	26-Jun	None	61.5	5	29.7	34.7	55	N/A	-----	82.9	82.9	55.5	-----
399-3-28	C6205	ERT/ electrodes	Buckets	25	8-Jul	9-Jul	10-Jul	64.5	25	31	56	56.4	33.5	-----	79.8	79.8	55.5	56.5
399-2-30	C6217	Deep GW monitoring ERT/electrodes	Buckets	35	24-Jul	25-Jul	None	64.0	2	54	56	58.9	58.5	-----	95.3	95.3	55.5	-----
399-3-29	C6206	ERT/ electrodes	Buckets	22	30-Jun	30-Jun	3-Jul	64.0	25	31	56	56.3	33.5	-----	83.6	83.6	53	52.5
399-2-31	C6218	Intermediate GW monitoring	Buckets	12	19-Jun	20-Jun	24-Jun	63.0	2	42	44	56.4	N/A	-----	80.2	80.2	55.5	55.5
399-3-30	C6213	Shallow GW monitoring	Buckets	19	26-Jun	27-Jun	None	61.5	5	30	35	55.3	N/A	-----	82.1	82.1	55.5	
399-3-31[g]	C6214	Deep GW monitoring ERT/electrodes	Buckets	13	20-Jun	23-Jun	25-Jun	63.0	2	53.2	55.2	59.6	33.6/58.6	-----	76.2	76.2	55.5	55.5
399-3-32	C6215	Intermediate GW monitoring	Buckets	33	18-Jul	18-Jul	None	63.0	2	42.2	44.2	56.6	N/A	-----	54	54	56	-----

(a) Borehole was deepened to 67.5 ft (casing to 65 ft) to enable geophysical logging.
(b) Shallow refusal; offset hole 1 m east.
(c) Redrill out bottom of hole.
(d) Bottom bentonite seal bridged; redrill bottom.
(e) Tagline lost; redrill hole.
(f) Unintentionally drilled an extra 10 ft during final cleanout.
(g) No recovery 45–55 ft.
N/A = not applicable.

3.1 Drilling

The IFRC well field consists of 36 evenly distributed wells (Figure 3.2). The electrical-resistivity tomography (ERT) wells were spaced 10 m apart. At three locations, a tighter three-well cluster also was installed to monitor shallow, intermediate, and deep levels within the unconfined aquifer. All of the wells were drilled using the resonant sonic drilling method (Figure 3.5). One of the wells (399-2-5) at the eastern corner of the well field was a pre-existing well, drilled with the cable-tool method in 2007 to a depth of 131 ft (6 ft into the Ringold lower mud unit) as part of a volatile organic compound investigation (Peterson et al. 2008). Only a single deep well (399-2-25), a new microbiological characterization well, was drilled to the top of basalt bedrock at 171 ft depth. The remaining 34 wells were drilled to depths of 50–60 ft into the top of a fine-grained subunit of the Ringold Formation at the base of the unconfined aquifer. Drilling of the first new well (399-2-9) began on May 12, 2008. Drilling ended with well 399-2-25 on July 25, 2008 (Table 3.1). The total drilled footage for the 35 new wells was 2318 ft.

Figure 3.5. A resonant sonic drill rig was used to drill the 35 new IFRC boreholes.

A single string of 7-5/8-in.-0D (6-7/8-in.-ID) carbon steel casing was used to maintain an open borehole in the 34 shallow boreholes. During drilling, boreholes were advanced by vibrating a 6-in. core barrel into the formation to obtain intact core material below the bottom of the casing. Next, the casing was advanced, via sonic vibration, over the cored interval, and the hole was cleaned out to the bottom of the casing before the next core sample was collected. In a single deep well (399-2-25), three strings of telescoping casing were used to preclude aquifer intercommunication between the unconfined and deeper aquifers. Drilling details and other documentation for each of the new wells are provided in Appendices A, B, and D.

3.2 Sampling

More than 1100 geologic samples were collected for physical, chemical, or microbiological analysis from the 35 new IFRC wells (Table 3.2; Appendix C). Seven borings were preselected as characterization holes in which an attempt was made to collect continuous, intact (Lexan-lined) core via 5-ft-long split spoons (Figure 3.6 and Figure 3.7). Lexan core was collected also at selected intervals within the single deep borehole (399-2-25). Up to five core samples (1 ft long by 3-3/4 in. in diameter) were collected with each core run. The ends of the Lexan liners were geologically logged and photographed before the core ends were capped and sealed.

Table 3.2. Geologic samples by borehole

		No. of Sample Intervals				
Well Name	Well ID	Bulk Grab[a]	Lexan Core[b]	Smear-Zone Grab[c]	Microbiology	Total Samples
399-2-07	C6184	19		1	3	23
399-2-08	C6185	19		1	2	22
399-2-09	C6186	2	35	2		39
399-2-10	C6187	21		1	1	23
399-2-11	C6188	17		1	1	19
399-2-12	C6189	4	45	1	1	51
399-2-13	C6190	3	28	1		32
399-2-14	C6191	40		1	1	42
399-2-15	C6192	22		1	1	24
399-2-16	C6193	22		1	6	29
399-2-17	C6195	31		1	1	33
399-2-18	C6196	46		1		47
399-2-19	C6197		41	1		42
399-2-20	C6198	22		1	3	26
399-2-21	C6201	32		1	1	34
399-2-22	C6202	19			2	21
399-2-23	C6207	17		1	4	22
399-2-24	C6208	18	30	2	1	51
399-2-25	C6209	70	42	1	15	128
399-2-26	C6210	23		1	3	27
399-2-27	C6211	19		1	1	21
399-2-28	C6212	27			3	30

Shallow characterization wells.
Deep characterization well.
(a) Collected in 2-gal plastic buckets.
(b) Collected in Lexan liners, 1 ft long x 3-3/4 in. OD.
(c) Collected in 5-gal plastic buckets.

Table 3.2. (contd)

Well Name	Well ID	No. of Sample Intervals: Bulk Grab[a]	Lexan Core[b]	Smear-Zone Grab[c]	Microbiology	Total Samples
399-2-29	C6216	21		1	3	25
399-2-30	C6217	30	5	1	1	37
399-2-31	C6218	27		1	1	29
399-3-23	C6194	22		1	3	26
399-3-24	C6199	18			3	21
399-3-25	C6200	2	43	2	1	48
399-3-26	C6203	2	31			33
399-3-27	C6204	18		1	5	24
399-3-28	C6205	22		1	5	28
399-3-29	C6206	23		1	3	27
399-3-30	C6213	23		1	3	27
399-3-31	C6214	26		1	1	28
399-3-32	C6215	25		1	1	27
Total No. of Samples		752	300	34	80	1166

Shallow characterization wells.
Deep characterization well.
(a) Collected in 2-gal plastic buckets.
(b) Collected in Lexan liners, 1 ft long x 3-3/4 in. OD.
(c) Collected in 5-gal plastic buckets.

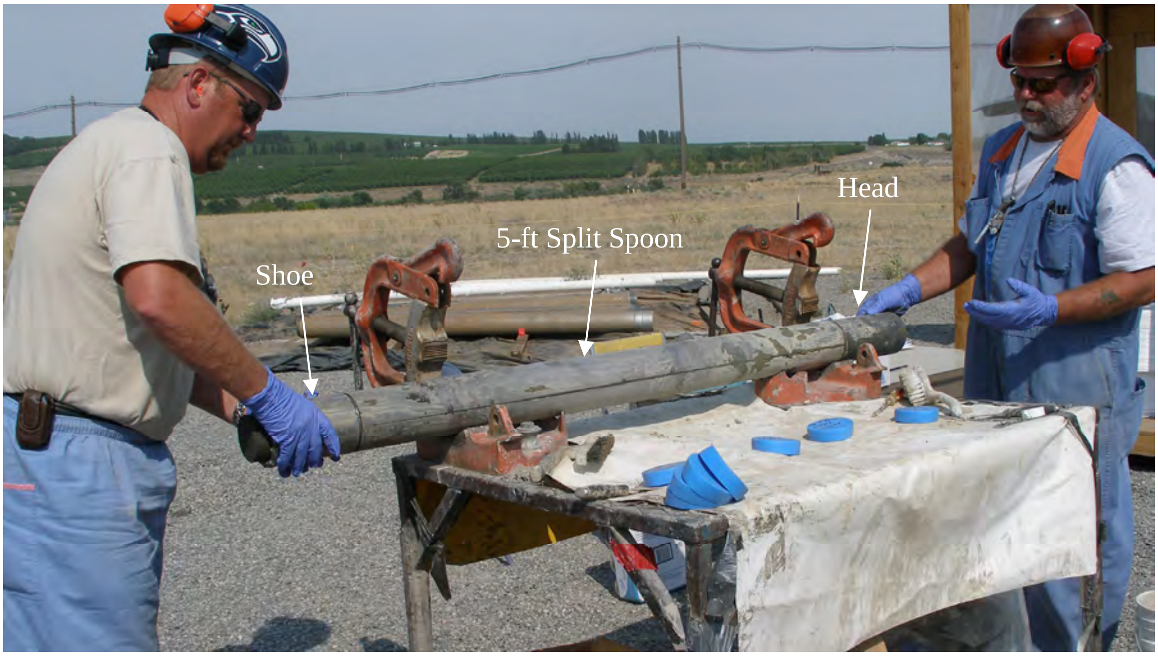

Figure 3.6. Sediment-filled split-spoon sampler. Notice cohesive Ringold Formation core protruding from shoe. Sediment core naturally expanded upon release of highly compressive drilling stresses.

Figure 3.7. Capped Lexan-lined cores were collected after the split-spoon sampler was opened.

In the remaining 27 shallow boreholes, bulk core samples were collected by emptying core runs directly from the core barrel into plastic sleeves approximately 2 ft long (Figure 3.8, left). After the plastic sleeves were sliced open, the sediment inside was geologically logged and photographed before it was transferred into 2-gal buckets (Figure 3.8, right).

Figure 3.8. Bulk core and grab samples were collected from all IFRC wells not sampled via split spoon. Sediment core (left) was extruded via sonic vibration out of the core barrel into a knotted plastic sleeve. For grab-sample collection (right), core was transferred from the plastic sleeve into labeled 2-gal plastic buckets. Each bucket held 2 to 3 ft of core.

An additional 34 special bulk grab samples were collected in 5-gal containers from the smear zone (zone of water table fluctuation between 25 to 35 ft depth) for most of the new IFRC wells (Table 3.2). All samples were carefully labeled, inventoried, and transferred to temporary storage onsite (Figure 3.9) or directly to PNNL laboratories.

Figure 3.9. Samples were stored temporarily within a locked seatainer on site. All samples were carefully labeled upon collection and later inventoried.

The more than 1100 samples collected included 300 intact Lexan-lined core samples and 752 bulk grab samples (Table 3.2). Sample recovery was fair to excellent. Core recovery in the seven characterization boreholes, which attempted to collect continuous, intact core samples inside the segmented Lexan-lined split spoon, generally ranged from 50% to 70%. In one borehole (399-2-24), core recovery was a poor 35% because the loose Hanford formation material kept falling out of the bottom of the split spoon upon retrieval. Core recovery improved significantly for the Hanford formation after a core catcher (Figure 3.10) was placed at the bottom of the split spoon.

Recovery of bulk grab samples that were emptied directly from the core barrel into plastic sleeves proved more successful (50–95%) when compared to split-spoon sampling. Core recovery using this method, albeit not preserving the primary fabric and structure, provided good-quality samples believed to be representative of the formation, both texturally and geochemically. Core recovery always improved upon encountering the cohesive and compact fine-grained sediments of the Ringold Formation in each of the holes, irrespective of sampling method. Sample inventory sheets for each of the new IFRC wells are located in Appendix C.

Figure 3.10. A plastic core catcher helped to keep loose Hanford formation sediments from falling out of the split spoon during core sampling.

3.3 Geophysical Logging

Downhole geophysical logging was performed on 29 of the 35 new wells (Table 3.1). Immediately after drilling to total depth and prior to well construction, logging occurred with the spectral-gamma logging system (SGLS) and neutron-moisture logging system (NMLS) geophysical logging tools (Figure 3.11). The NMLS was employed for only the vadose-zone portion, while the SGLS probe was used over the entire length of the logged boreholes. The single deep microbiology characterization borehole was logged three times, once for each temporary casing string (0–60, 60–120, and 120–167 ft). Of the nine multilevel groundwater-monitoring wells, only one borehole in each of the three-well clusters was logged with the SGLS and NMLS (Table 3.1). The decision to log only a single well in each cluster was made to save time and expense and reduce redundancy for boreholes that lay in proximity to each other.

Geophysical logs are a useful indicator of vadose-zone moisture as well as lithology and grain-size distribution of the suprabasalt sediments. Downhole geophysical logs for all new IFRC wells are located in Appendix G.

Figure 3.11. Downhole geophysical logging was accomplished through the temporary 7-5/8-in. (OD) steel casing via Stoller's spectral-gamma logging system.

3.4 Well Construction

All new wells were completed with 4-in.polyvinyl chloride (PVC) casing and 20-slot screens (see Appendices A and F). The 25 shallow wells not designated as groundwater monitoring wells were constructed with 25-ft well screens over the saturated interval of the Hanford formation. A single exception was well 399-3-26, which was installed with a shorter 20-ft screen. The three multilevel groundwater monitoring clusters each had 2-ft screens installed at the bottom and middle portions of the unconfined aquifer and 5-ft screens installed at the top of the unconfined aquifer. The deep microbiology characterization well (399-2-25) had a single 60-ft screen completed over the semiconfined Ringold Formation (Unit E) aquifer.

Special ERT electrodes in addition to thermistors were installed on the outside of the PVC to the bottom of the screen (Figure 3.12) in 28 of the 35 new wells. Excluded were the 6 shallow and 6 intermediate-depth groundwater monitoring wells (Table 3.1) and the deep microbiology characterization well (399-2-25).

During construction, the annulus of each of the 28 wells was filled with 10-20 mesh silica sand to within 2 ft of the top and bottom of the well screen (Figure 3.13). Above this was placed finer 40-140 mesh sand to within 10 ft of the surface. These specific materials were selected because an annulus filled with permeable sand is needed to maximize the functionality of the ERT and temperature sensors within the well. A coarser sand (10-20 mesh) was used across the screened interval to keep the sand from passing through the screen. Around the casing above the screen, a finer sand (40-140 mesh) that more effectively retains vadose zone moisture was used. See Figure 3.14 for a comparison of these two different sand sizes. Filter-pack sand was not placed in the annulus within 10 ft of the surface.

However, a waiver was granted by the Washington State Department of Ecology allowing for a less than 18-ft surface seal stipulated in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

Figure 3.12. ERT electrode and thermistor sensors and cables were affixed at regular intervals down the outside of the 4-in. PVC screen and casing. A centralizer (shown) placed at the top and bottom of the screen kept the screen centered within the well and prevented it from coming into direct contact with the formation.

Figure 3.13. Silica sand was added to the well annulus between the 4-in. PVC well casing and 6-7/8-in. (ID) temporary steel casing during well construction. Hydraulic casing jacks, located in center, were used to back pull the temporary casing during well construction.

Figure 3.14. Comparison between coarser 10-20 mesh silica sand (left), used around 20-slot well screens, and the finer 40-140 mesh sand placed in the annular space above the screen

Electrical-resistivity tomography and thermistor sensors were installed also around the outside of the deep groundwater monitoring wells. In these wells, 10-20 mesh silica sand was placed within 2 ft above and below the 2-ft well screen. Then a 5-ft bentonite seal was emplaced (via tremie pipe) above the screen before 40-140 mesh silica sand was installed to 10 ft bgs. The other six groundwater monitoring wells were installed as conventional wells with a continuous bentonite seal from near-surface to within 2 ft of the top of the screen. The sand was surged periodically during placement to settle and compress the sand pack, to eliminate the formation of any voids during installation.

Only one new well (the deep microbiology characterization well, 399-2-25) was completed above ground; the remaining 34 wells were installed as surface-mount completions (Figure 3.15). These consisted of a metal well vault encased into a 6-in.-thick cement pad at the surface. Removal of the metal well-vault cover permits access to the PVC well inside near ground level. A diagonal drain hole from the bottom of the well vault through the cement pad was installed to allow any excess condensation, rain, or snowmelt to drain out into the formation instead of collecting in the vault and possibly down the well. A 2-in. PVC conduit passing laterally through a side hole in the well vault to the outside of the surface cement pad was also installed to allow passage of the ERT and thermistor cables out of the well without interfering with closure of the protective vault cover. The compilation borehole summary logs (Appendix A) provide a graphic summary of the well construction details provided in Appendix F.

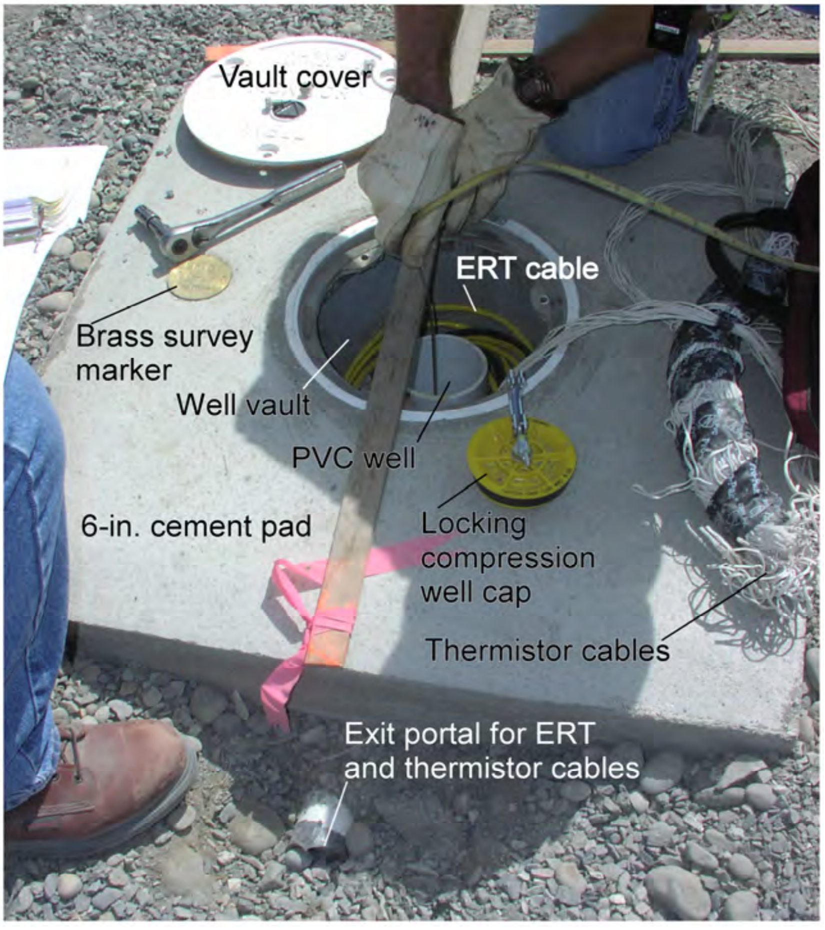

Figure 3.15. All but one of the new IFRC wells was completed at ground level to allow for easier and safer movement of vehicles and equipment across the crowded well field.

3.5 Well Development

After drilling and well installation, it was important to 1) flush out impurities in the well and sand pack, 2) replace the stagnant drilling slurry within the well with fresh formation groundwater, and 3) evaluate the hydraulic properties and integrity of the well. During well development, between 540 and 3700 gal of purge water were pumped from each well at rates from 20 to 90 gpm (Table 3.3). Purge water was pumped into a temporary storage tank (Figure 3.16), and transported to modu-tanks at the Purgewater Storage and Treatment Facility for evaporative storage and treatment.

Drawdown and recovery of water within the wells were monitored during development. In the first few wells, transducers were placed in one or more adjacent observation wells to detect any drawdown during pumping. This practice was discontinued when it became clear that no drawdown was likely because of the extremely high transmissivity of the Hanford formation.

In the 25 ERT wells, pumping was performed twice, at two separate points within the longer 25-ft well screens. With one exception (399-2-9), the upper part of the screened interval was pumped and developed first before the pump was lowered approximately 10 ft to the lower part of the screen. Pumping in the groundwater monitoring wells, on the other hand, was performed at only a single stage because of shorter screen lengths. More details on well development are presented in Appendix E.

Figure 3.17, a panoramic view of the IFRC wells during completion, illustrates the high density of the wells.

Figure 3.16. Water was pumped out of 4-in. PVC wells into a storage tank during well development.

Table 3.3. Well development data for the 35 IFRC wells

		First Pumping				Second Pumping				
Well	Screen Depth (ft)	Pump Intake Depth (ft)	Duration (min)	Rate (gpm)	Turbidity (NTU)	Pump Intake Depth (ft)	Duration (min)	Rate (gpm)	Turbidity (NTU)	Total Volume Pumped (gal)
399-2-07	31–56	40	30	50	1.16	50	15	86	2.66	2551
399-2-08	31–56	40	30	50	1.63	50	19	86	3.72	2849
399-2-09	33.5–58.5	50.9	38	30–60	4.89	40.9	27	60	6.79	3120
399-2-10	34.7–59.7	41	28	45.5	2.73	51	22	85.5	1.58	3281
399-2-11	31–56	41.3	33	50	6.64	51.3	41	87	6.29	3500
399-2-12	31–56	40	30	50–55	3.38	50	17	85	7.15	2834
399-2-13	31.2–56.2	39.6	24	49–53	2.57	49.6	29	60–80	3.34	3115
399-2-14	30.7–55.7	40	31	50–55	1.77	50	19	82–85	1.67	3146
399-2-15	31–56	40	30	50–55	3.42	50	19	86	3.49	3246
399-2-16	31–56	40	30	50	3.97	50	17	86	7.57	2864
399-2-17	31.2–56.2	40	31	50–55	1.96	50	19	86	2.41	3146
399-2-18	33–58	40	25	73	5.12	50	18	74	2.45	3157
399-2-19	31.3–56.3	42	31	50–64	5.02	53.7	23	50	4.14	2840
399-2-20	31–56	40	30	50	3.43	50	16	84	5.52	2839
399-2-21	31.1–56.1	40	20	50	0.98	50	13	74	5.20	3025
399-2-22	33.4–58.5	40.2	26	47	1.43	50.2	13	47	5.40	2209
399-2-23	31–56	40	30	50	2.41	50	18	86	4.49	2884
399-2-24	33–58	40.6	25	50	5.10	50.6	52	75–80	3.61	2860
399-3-23	31–56	41.5	32	50	1.38	51.5	16	68	3.46	3744
399-3-24	31–56	41.3	36	50	3.41	51.3	10	87	7.08	2500
399-3-25	31.6–56.6	40	34	50	2.85	50	15	85	3.95	2952
399-3-26	32–52	39.7	31	55–60	4.94	48.7	30	45–50	3.52	3280
399-3-27	31.4–56.4	40	30	50	1.13	50	16	84	0.97	2837
399-3-28	31.6–56.6	41	32	50	2.97	51	21	87	6.98	3500
399-3-29	31–56	40	26	50	1.79	50	10	84	2.79	2190
Shallow Groundwater Monitoring Wells										
399-2-26	30–35	41.5	41	30	1.82	– –	– –	– –	– –	1200
399-2-29	30–35	41	40	50	0.71	– –	– –	– –	– –	1877
399-3-30	30–35	40	31	20	3.78	– –	– –	– –	– –	656
Intermediate Groundwater Monitoring Wells										
399-2-28	42–44	43	35	20	12.30	– –	– –	– –	– –	627
399-2-31	42–44	40	53	20	5.02	– –	– –	– –	– –	768
399-3-32	42.2–44.2	41	29	18.5	7.99	– –	– –	– –	– –	537

Table 3.3. (contd)

Well	Screen Depth (ft)	First Pumping: Pump Intake Depth (ft)	First Pumping: Duration (min)	First Pumping: Rate (gpm)	First Pumping: Turbidity (NTU)	Second Pumping: Pump Intake Depth (ft)	Second Pumping: Duration (min)	Second Pumping: Rate (gpm)	Second Pumping: Turbidity (NTU)	Total Volume Pumped (gal)
Deep Groundwater Monitoring Wells										
399-2-27	54.7–56.7	51	31	22.5–43	8.36	– –	– –	– –	– –	1543
399-2-30	54.4–56.4	50	35	26	1.44	– –	– –	– –	– –	1170
399-3-31	53.2–55.2	50	35	55	0.42	– –	– –	– –	– –	2080
Deep Microbiology Characterization Well										
399-2-25	31.6–56.6	70	57	20	16.20	– –	– –	– –	– –	1078

Figure 3.17. The high density of IFRC wells in various stages of completion

4.0 Hydrogeology

Sediments overlying basalt bedrock at the IFRC site belong to three geologic units: 1) backfill materials, 2) the Hanford formation, and 3) the Ringold Formation. The structure and relationships of these stratigraphic units, from oldest to youngest, are shown in Figure 4.1. The water table lies within the Hanford formation everywhere within the IFRC site (Figure 4.1). The locations of cross sections A-A' and B-B' are noted in Figure 4.2. More detailed cross sections (C through F) within the IFRC site are shown in Figure 4.3 through 4.6.

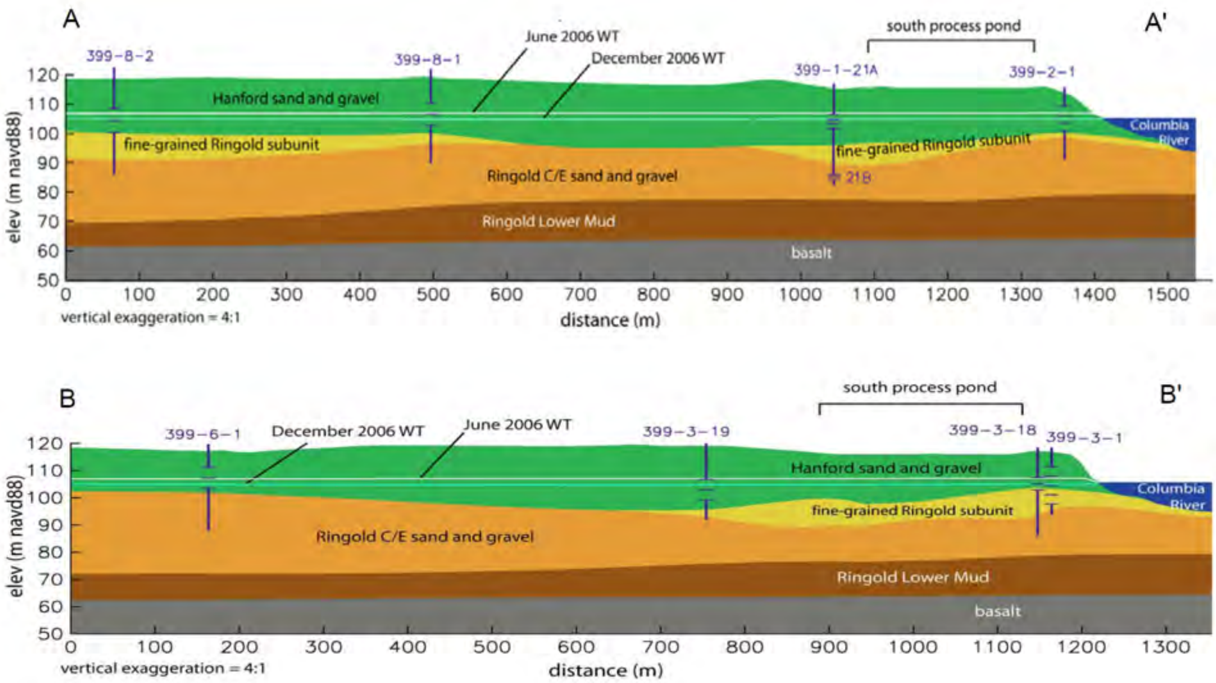

Figure 4.1. Cross sections through the 300 Area showing major hydrostratigraphic units (modified from Williams et al. 2008)

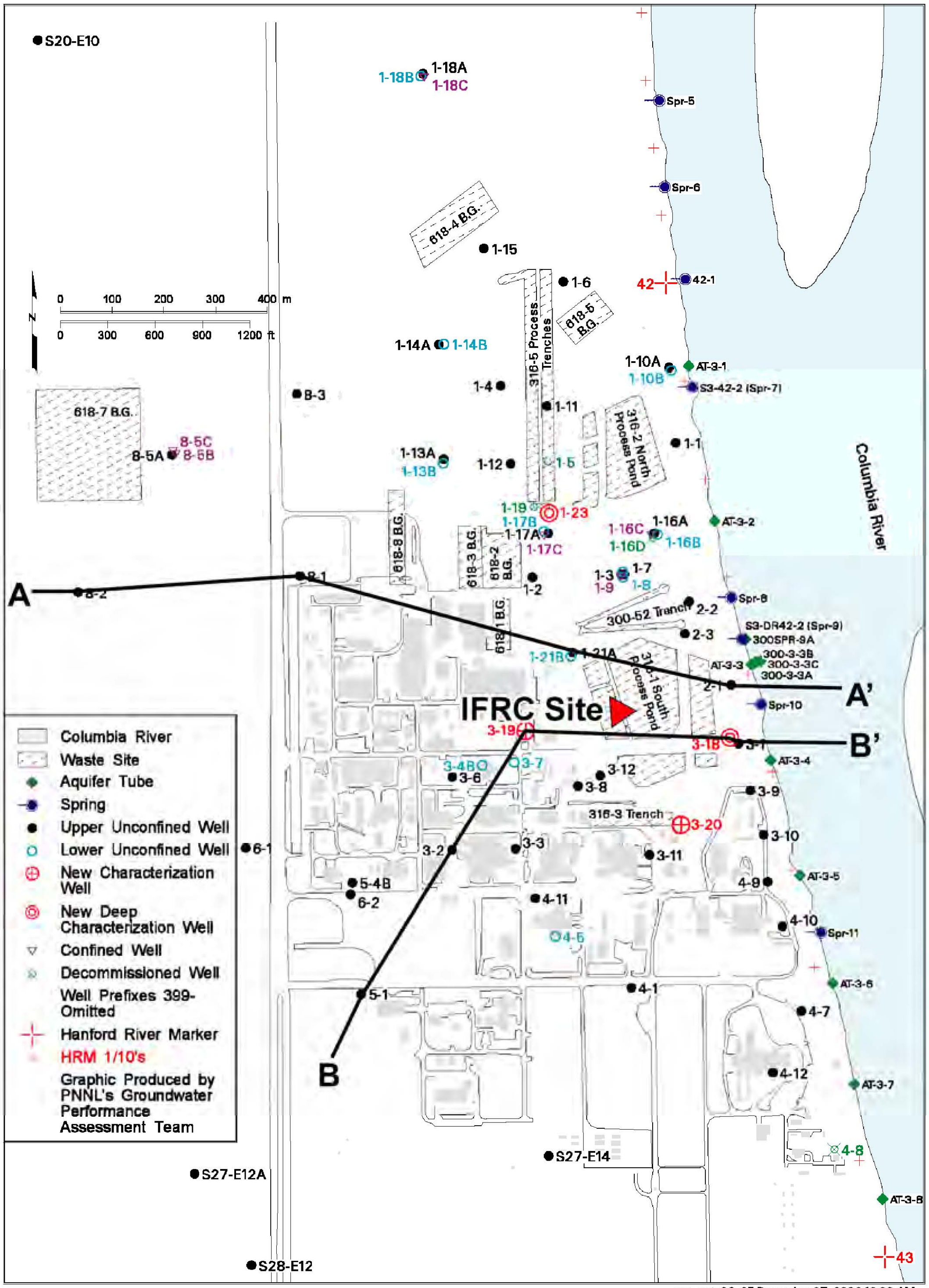

Figure 4.2. Cross section locations

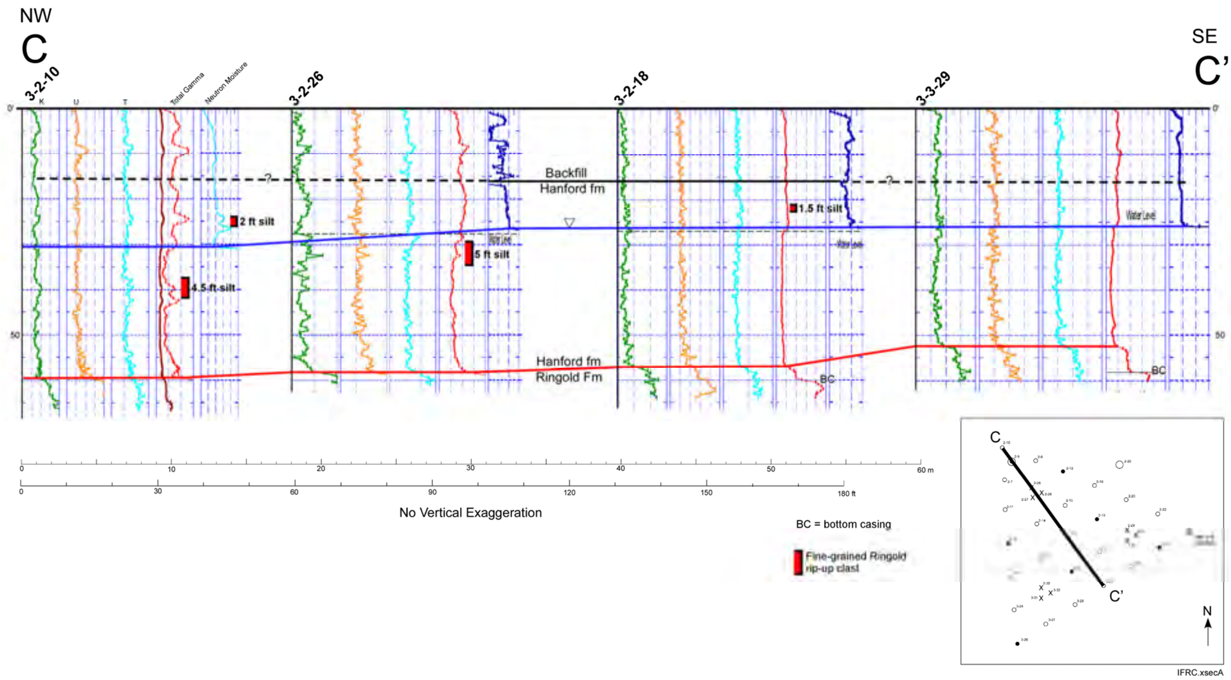

Figure 4.3. Hydrogeologic cross section C-C' based on geophysical logs

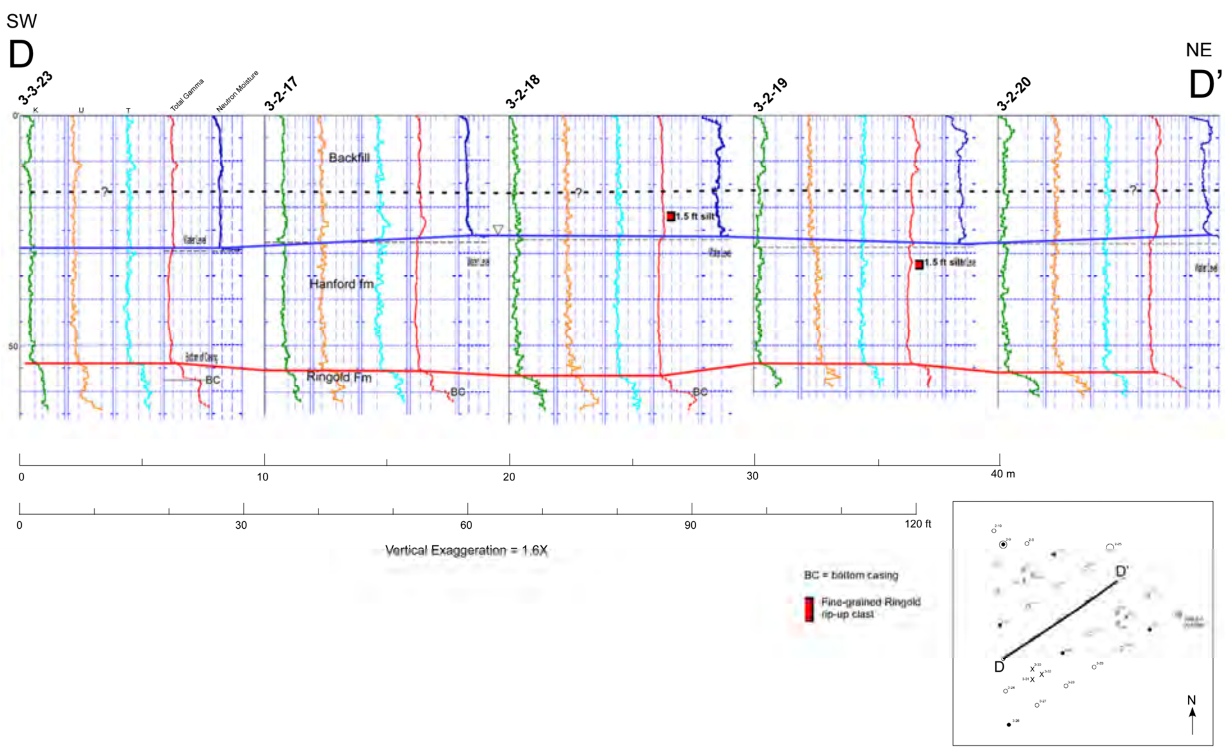

Figure 4.4. Hydrogeologic cross section D-D' based on geophysical logs

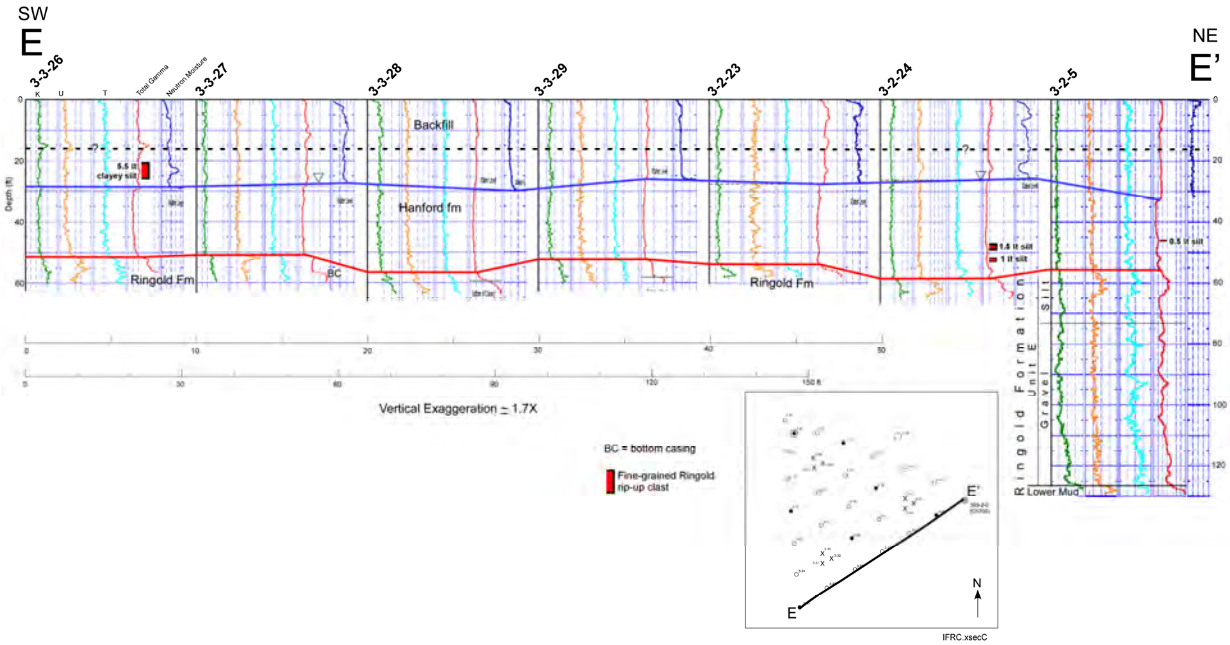

Figure 4.5. Hydrogeologic cross section E-E' based on geophysical logs

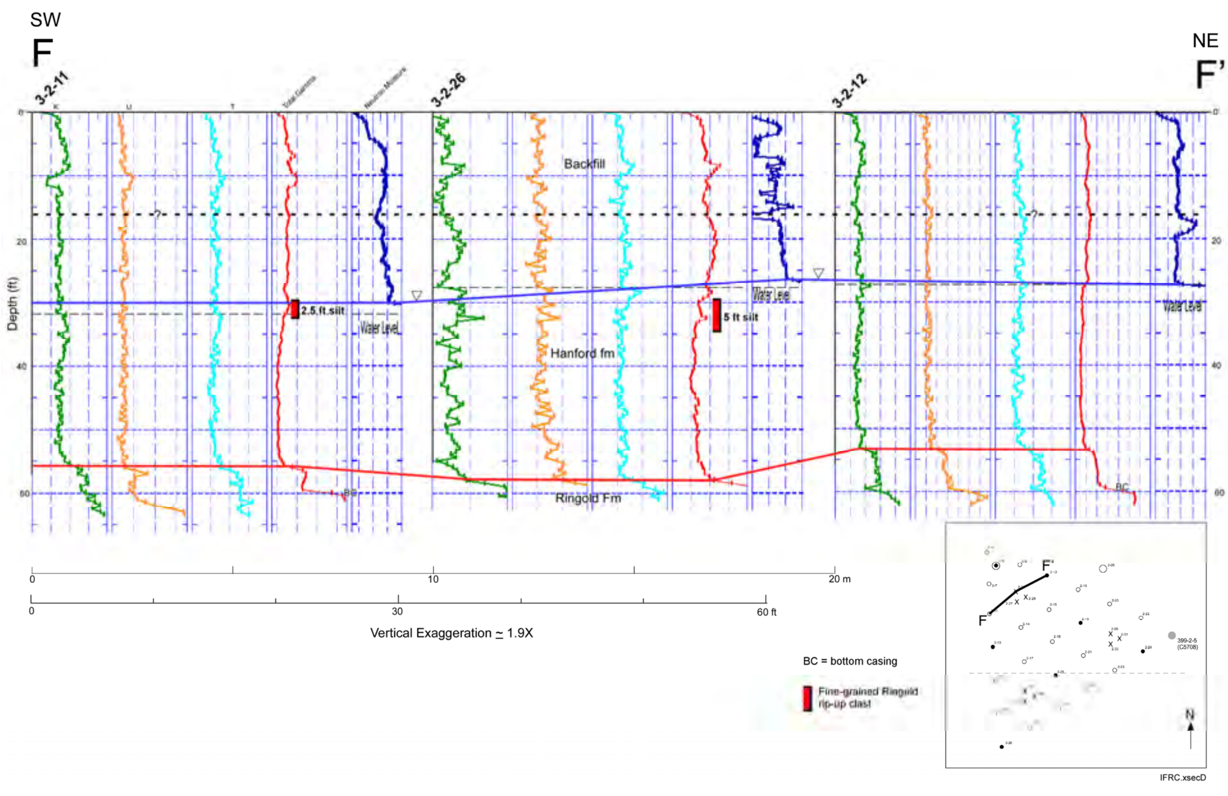

Figure 4.6. Hydrogeologic cross section F-F' based on geophysical logs

The stratigraphy and lithology of the suprabasalt sediments at the IFRC site are represented in Figure 4.7 for the single deep well (399-2-25) at this location. Close-up photographic images of the different units are presented in Appendix I within small chip tray samples collected for each well.

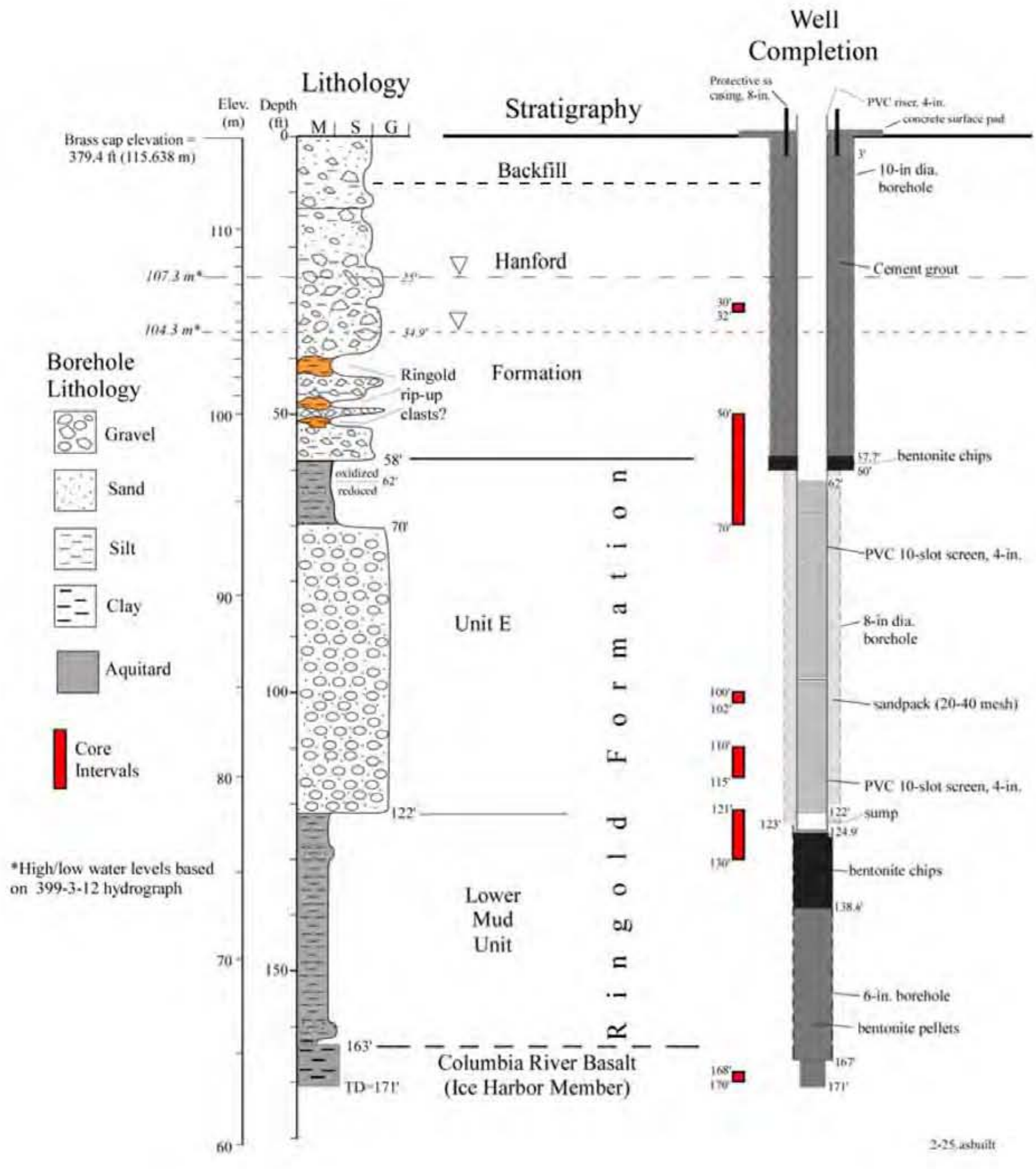

Figure 4.7. Stratigraphy and lithology represented in deep microbiology characterization well 399-2-25 (C6209). See also Compilation Borehole Summary Log in Appendix A.

4.1 Columbia River Basalt

Basalt bedrock lies approximately 160 ft deep beneath the IFRC site. The uppermost basalt flow in this area is the Ice Harbor Member, dated at 8.5 million years before present (DOE 1988). Near the top of the basalt, drilling slowed significantly through a hard, dense clay zone containing vesicular basalt fragments (Figure 4.8) before refusal was ultimately encountered at 170 ft bgs. The clay appears to be an alteration product due to an extended period of weathering of the basalt flow top prior to burial by the Ringold Formation. The color of the highly weathered basalt ranged from black through gray and green with occasional reddish iron-oxide stringers.

Figure 4.8. Core segment, weathered basalt of the Ice Harbor Member, from the bottom of well 399-2-25. The 1-ft-long Lexan-lined core consists of irregular fragments of black vesicular basalt in a highly weathered and green-gray mottled alteration-clay matrix. Light-colored material effervesces in contact with dilute hydrochloric acid, indicating the presence of calcium carbonate.

4.2 Ringold Formation

The Ringold Formation ranges in age from late Miocene to Pliocene (8.5 to 3.4 million years) and consists of mostly fluvial-lacustrine sediments laid down during tectonic downwarping and infilling of the Pasco Basin, one of many synclinal basins of the Yakima Fold Belt (DOE 1988).

Immediately overlying the weathered basalt surface are roughly 40 ft of dark-colored, fine-grained sediments (Figure 4.9) of the Ringold lower mud unit. These sediments are predominantly compact and cohesive, massive to weakly laminated, gray to gleyed-green and blue deposits that vary in grain size among clay, silt, and fine sand. Occasionally, dark fibrous fragments of decomposed wood were found preserved in the Ringold lower mud unit (Figure 4.10). This organic matter, in combination with the fine texture and structure of these deposits, indicates a fluvial-overbank and crevasse-splay origin.

Overlying the Ringold lower mud unit is coarser, gravel-dominated sediment, about 50 ft thick, belonging to the Ringold Formation (Unit E). This conglomerate unit, approximately 4.8 to 6.7 million years old (Lindsey 1995), is a compacted bimodal mixture of well-rounded and polished clast-supported pebbles and cobbles compacted within a matrix of fine to medium sand (Figure 4.11); variable amounts of silt or clay may occur within the matrix. Within each of the two modes, sediment sorting is moderate to good, with few particles from medium-sand to fine-pebble size. Sand grains within the matrix are predominantly felsic (i.e., composed principally of quartz, feldspar, and mica). Individual pebble and cobble-size clasts, especially those composed of basalt, often display clay skins and weathering (alteration) rinds. Colors within this unit are dark gray to black, indicating this unit is undergoing chemical reduction at the IFRC site. This sedimentary facies represents deposition within a high-energy, shallow, braided-stream (fluvial) environment (Lindsey 1995).

Figure 4.9. The Ringold lower mud unit at 160-ft depth in well 399-2-25 is predominantly a compact, homogeneous, dark greenish-gray, weakly stratified, fine sandy silt.

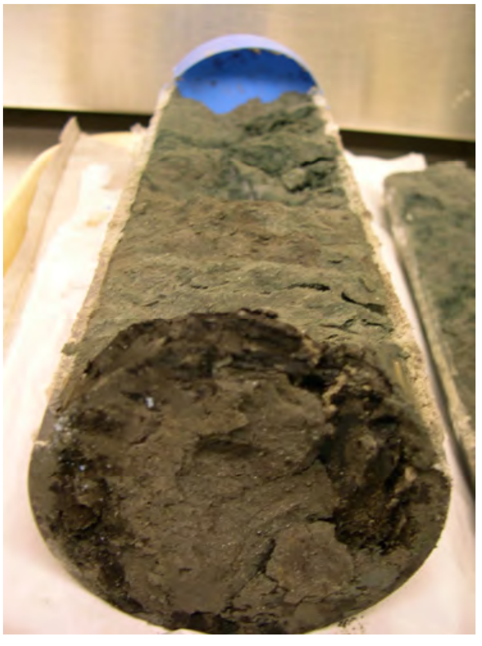

Figure 4.10. Dark fibrous wood fragments in laminated, micaceous, fine sandy silt of the Ringold lower mud unit at 129-ft depth, well 399-2-25

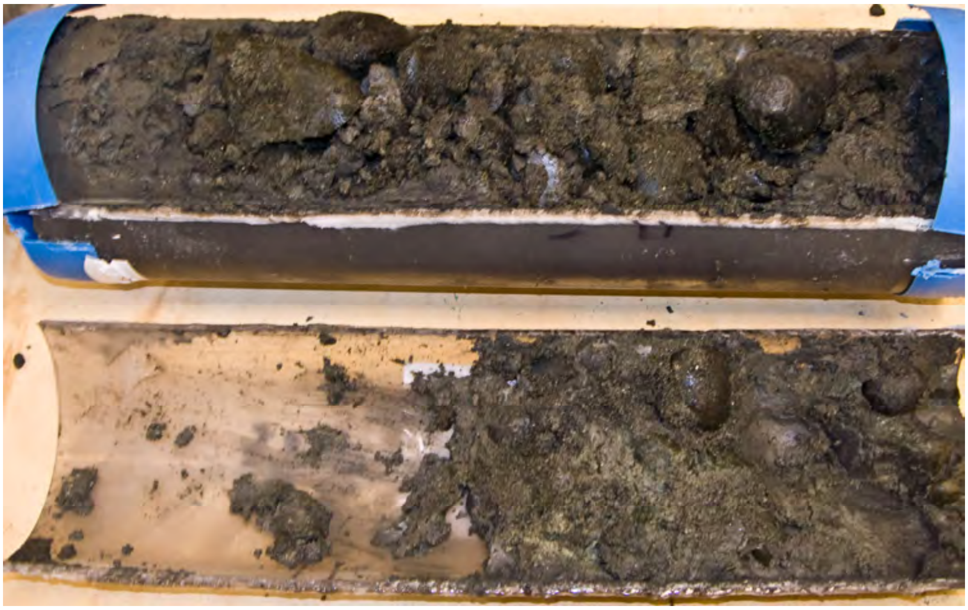

Figure 4.11. Ringold Formation Unit E. Silty sandy gravel of Ringold Unit E from the 110-ft depth in well 399-2-25.

Ringold Unit E gravel-dominated sediments are well exposed at the surface along the base of an erosional escarpment of the Ringold Formation along the White Bluffs (Figure 4.12). These exposures conveniently reveal the two-dimensional stratigraphic and structural characteristics of the sediments that cannot be observed in one-dimensional boreholes.

Figure 4.12. Ringold Formation Unit E conglomerate (member of Wooded Island [Lindsey 1995]) exposed near river level along the White Bluffs within 1 mile of the IFRC. Left: In the outcrop, these clast-supported, bimodal deposits may be crudely stratified and weakly imbricated, with occasional lenses of well-sorted fine- to medium-grained sand. Right: Light-colored pebble- to cobble-size clasts are mostly quartzite, granite, and gneiss; dark clasts are dominantly basalt, andesite, and volcanic porphyry (Campbell 1983). Note quarter for scale. Unlike the IFRC site, the Ringold Unit E in these outcrops has undergone chemical oxidation as indicated by a pervasive yellow-to brown iron-oxide stain, which coats all sedimentary particles. The vertical nature of the exposures signifies the semiconsolidated nature of these compacted and cemented sediments.

Overlying the Ringold Unit E is another fine-grained subunit of the Ringold Formation, up to 12 ft thick within the IFRC. This unit consists of a cohesive and compact, well-sorted fine sand grading upward into silty sand to silt (Figure 4.13). This is also known as the "fine-grained Ringold subunit" identified in previous reports (Williams et al. 2008; Peterson et al. 2008). Away from the IFRC site, the fine-grained Ringold subunit is locally absent or overlain by more of the Ringold Unit E gravel-dominated sediments, suggesting these fine-grained strata represent a discontinuous lens, stratigraphically equivalent to Ringold Unit E, within the 300 Area.

All but the top of these fine-grained strata show dark, chemically reduced shades of gray, green, and blue. At the top of the unit, however, is a rapid color change to shades of yellow, orange, or brown silt, up to 8 ft thick (Figure 4.14). The color boundary does not appear to occur along a textural or structural boundary because the sediments above and below the boundary appear to be lithologically the same (Figure 4.13, right). For this reason, it appears the color contrast is the result of oxidation along the boundary with the highly permeable and transmissive flood deposits (Hanford formation) that lie directly above.

Figure 4.13. Fine-grained strata at the top of the Ringold Formation. Left: core samples collected from 59.5- to 65-ft depth in reduced silts and fine sands of the Ringold Formation in well 399-2-25. Top of the core is to the upper right. Right: Sharp contact exists between oxidized pale-brown (left) and reduced dark greenish-gray (right) silt layers in well 399-3-30 at the 57-ft depth. Top of the core is to the left.

A map of the top of the reduced zone within the Ringold fine-grained unit is shown in Figure 4.15. The fact that the surface of the oxidized-reduced boundary conforms with the Hanford–Ringold contact suggests a diffusion front of more oxygenated groundwater permeates down into the low-permeability Ringold Formation from the highly transmissive Hanford formation. The oxidized zone at the top of the Ringold Formation (Figure 4.14) is generally about 2–5 ft thick, except to the north where it is up to 8 ft thick.

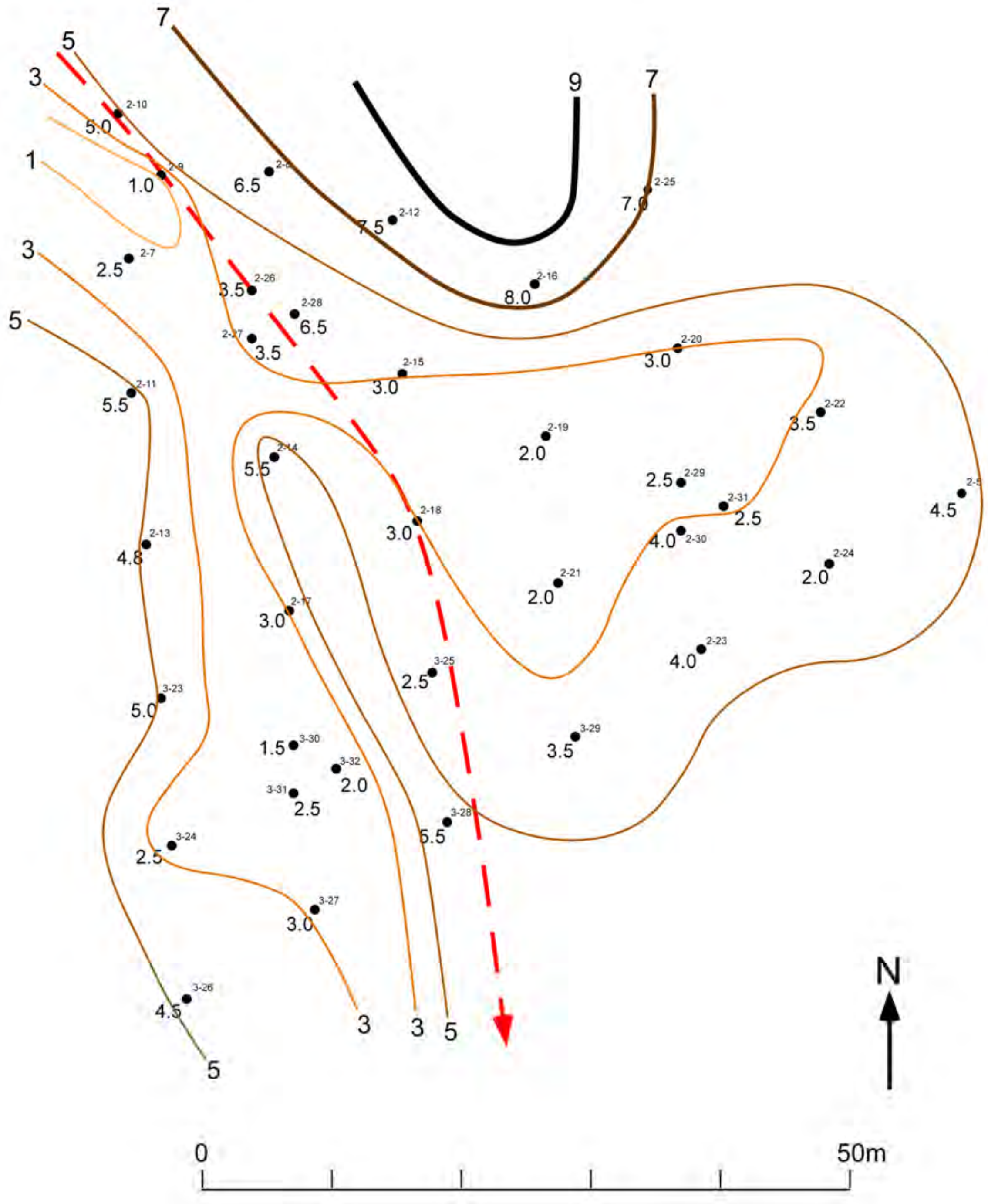

Figure 4.14. Isopach map showing the thickness of the oxidized zone atop the Ringold fine-grained unit beneath the IFRC site. The oxidized zone is thinnest parallel to, but not directly over, the paleochannel eroded into the top of the Ringold Formation (dashed arrow).

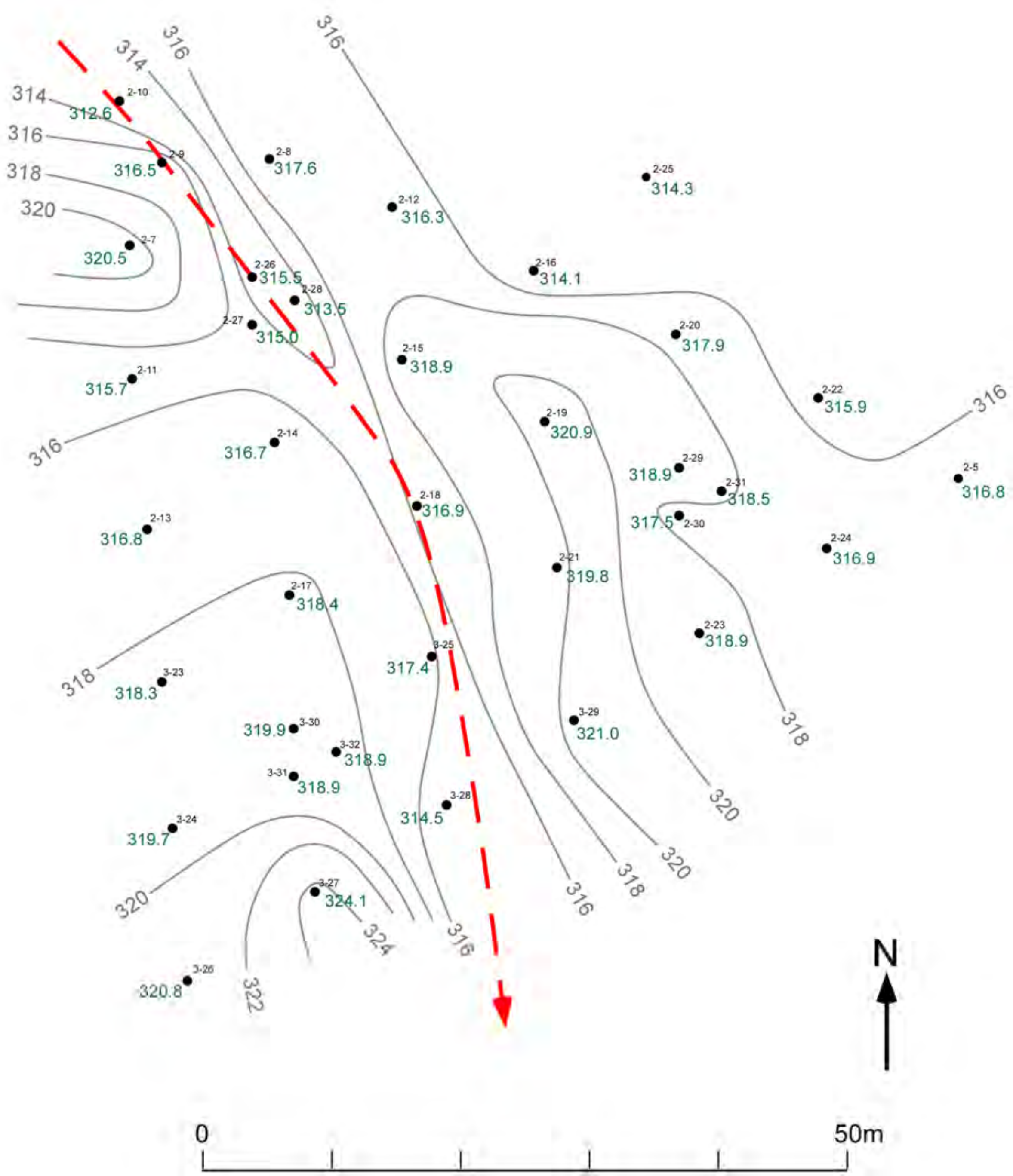

Figure 4.15. Structure contour map of the top of the reduced zone in the Ringold fine-grained unit. The top of the reduced zone generally conforms with a paleochannel (dashed line) eroded into the Ringold Formation.

4.3 Hanford Formation

Overlying the Ringold Formation beneath the IFRC site are up to 50 ft of heterogeneous sand and gravel with variable amounts of silt and clay of the Hanford formation. The Hanford formation encompasses all the sediments deposited during Pleistocene-age cataclysmic floods. Most Ice Age floods originated from periodic outbursts of glacial Lake Missoula, although some floods may have originated from other sources as well (Bjornstad 2006).

Repeated cataclysmic floods stripped away large volumes of Palouse loess, carved deep coulees into the underlying basalt bedrock, and created the Channeled Scabland of eastern Washington. All floodwater converged upon the Pasco Basin before being funneled through a single narrow outlet at Wallula Gap in the southeastern Pasco Basin. Floodwaters ponded temporarily behind this hydraulic constriction and formed Lake Lewis, which locally resulted in thick accumulations of flood deposits upstream within the Pasco Basin. As many as 100 separate flood events may have occurred during the last glaciation, although the exact frequency and number of floods is debatable. However, because no significant discontinuities have been observed within the Hanford formation sequence beneath the IFRC site (see Figure 2.4), it is possible that the entire sequence may have been deposited during the last Ice Age flood about 15,000 calendar years before present.

Each cataclysmic flood transported massive amounts of sediment, all within a period of a week or less. In the turbid column of floodwater was a stratified mixture of sediments being transported by the floods (Figure 4.16). At the base of the flow, along the sediment–water interface, floodwaters carried everything, from large boulders that bounced and rolled along the bottom to finer-grained particles (sand to clay), as tractive bedload. Above the zone of traction, however, only the small particles of sand, silt, and clay were entrained within the highly turbulent floodwaters.

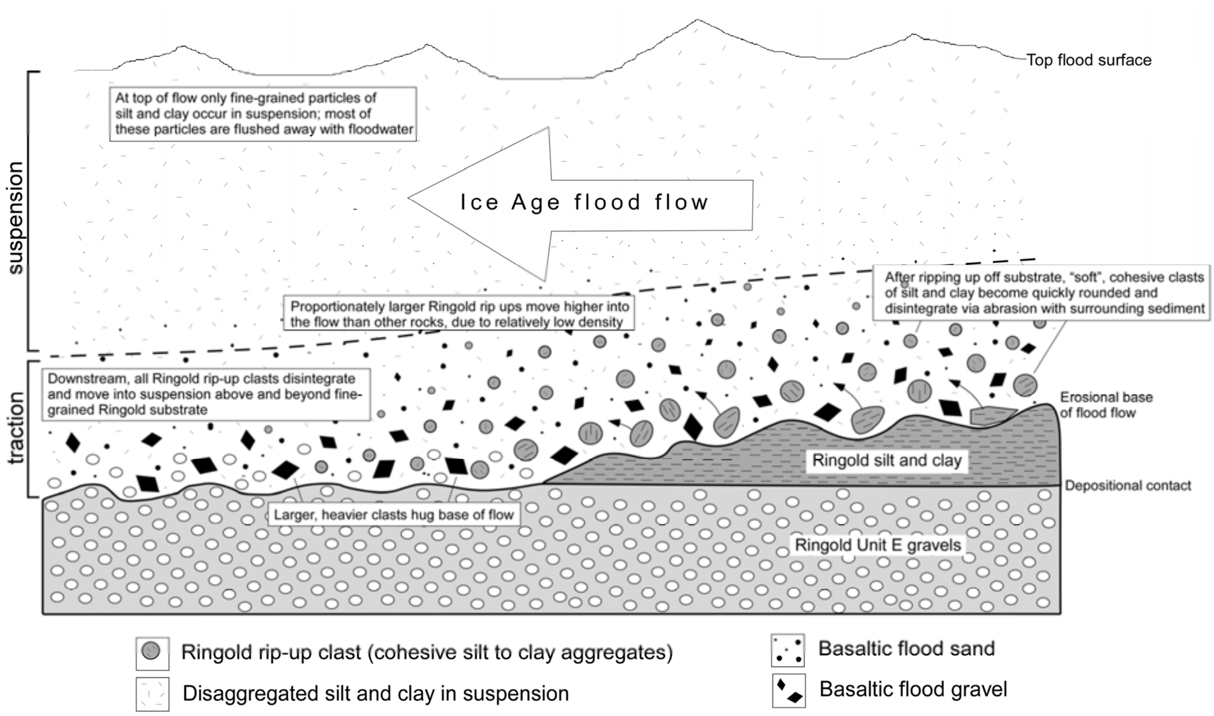

Figure 4.16. Model for sediment transport and stratification during an Ice Age flood

The Hanford formation in the 300 Area consists predominantly of unconsolidated sediments that cover a wide range in grain size, from boulder-size gravel at one end of the grain-size spectrum to clay at the other end. A poorly sorted mixture, dominated by gravel, with lesser amounts of sand and silt is the dominant lithology for the Hanford formation within the 300 Area (Figure 4.17).

Figure 4.17. Typical appearance of gravel-dominated facies of the Hanford formation within the 300 Area. The sediment is loose, composed of brownish-gray, clast-supported, poorly sorted, silty, sandy, pebble-cobble gravel. Clasts are mostly subangular to subrounded basalt; other clasts include granitics, gneiss, and quartzite as well as other volcanics. Some of the larger clasts were broken apart during sonic drilling, whereas most smaller clasts are unbroken, an indication that the sonic drilling method produces relatively representative samples for characterization. This grab sample was collected from the 20- to 22-ft depth in borehole 399-3-31.

The concentration of basalt rock fragments is much higher in the Hanford formation compared to the underlying Ringold Formation. This is especially true of the sand-sized fraction, which in the Hanford formation consists of up to 70–80% basalt compared to the sand fraction of the Ringold Formation, which typically consists of only 5–15% dark mafic grains. The reason for this is the Ice Age floods, which eroded the basalts underlying the Channeled Scabland of the Columbia Plateau. The Ringold Formation, on the other hand, is derived from mostly metamorphic and plutonic rocks eroded from the margins of the Columbia Plateau and transported to the Pasco Basin via the Columbia River.

Three facies exist for the Hanford formation in the Pasco Basin: 1) gravel-dominated, 2) sand-dominated, and 3) interbedded sand- and silt-dominated (DOE 2002). The gravel-dominated facies were deposited in the central portion of the basin adjacent to the present Columbia River, at lower elevations and where the energy during flooding was the greatest. The interbedded sand- and silt-dominated facies lie around the margins of the basin and in slackwater areas. The sand-dominated facies, which is the most voluminous facies at the Hanford Site, was deposited in the large area between the other two. The 300 Area, which lies at a low elevation adjacent to the Columbia River, received the full brunt of high-energy floodwaters and therefore is composed exclusively of gravel-dominated facies of the Hanford formation. High-energy flood flows are indicated where a train of braided, anastamosing flood channels developed along the center of the basin (Figure 4.18).

Figure 4.18. Network of interconnected braided channels created by the last cataclysmic Ice Age floods (arrows). During flooding, up to 900 ft of water submerged this entire landscape, except for the highest ridges like Rattlesnake Mountain. Channels were partially to totally backfilled with Hanford formation sediments during flooding. The IFRC site is marked with an X.

Flood deposits of the Hanford formation in the 300 Area are relatively heterogeneous and anisotropic. Some weak bedding and stratification were apparent in excavated pit exposures. However, because of the complex hydrodynamics involved in cataclysmic flooding, individual beds do not appear to extend very far laterally. For example, in Figure 4.19, most beds are discontinuous across the width of the trench.

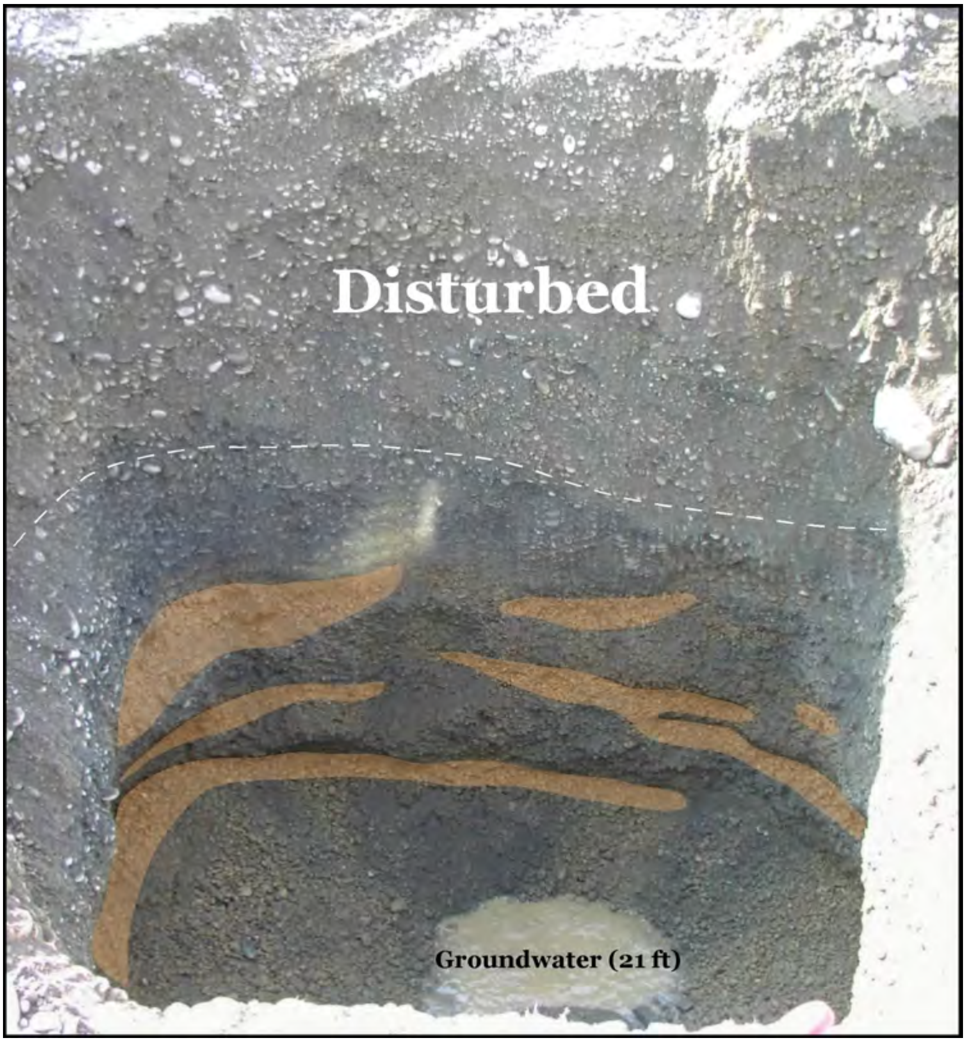

Figure 4.19. Profile of vadose-zone pit excavated in the east side of the South Process Pond (SSP#1) in 2003. Higher concentrations of oxidized, yellow-brown Ringold silt and clay matrix fill occur within subhorizontal layers (highlighted by artificial coloring). Matrix fill in nonhighlighted areas consists of predominantly higher-permeability basaltic sand with little or no fines.

Discordant clastic dikes (Fecht et al. 1999), which are common to the sand- and interbedded sand- to silt-dominated facies of the Hanford formation, rarely occur in the gravel-dominated facies, including the 300 Area.

A well-defined unconformity exists along the sharp contact between the coarse-grained Hanford and fine-grained Ringold formations. During the main onslaught, floodwaters scoured the Ringold Formation and eroded the surface before backfilling channels with coarse flood deposits during the waning stages of flooding (Figure 4.18). The topography on the top of the Ringold Formation is illustrated in Figure 4.20. The low area that runs diagonally across the IFRC site is interpreted as a channel eroded into the Ringold Formation during Ice Age flooding. The channel is filled with highly permeable Hanford formation sediments and underlain by low-permeability, silty sediments of the Ringold Formation. Therefore, it is a likely place for channelized flow of groundwater to occur.

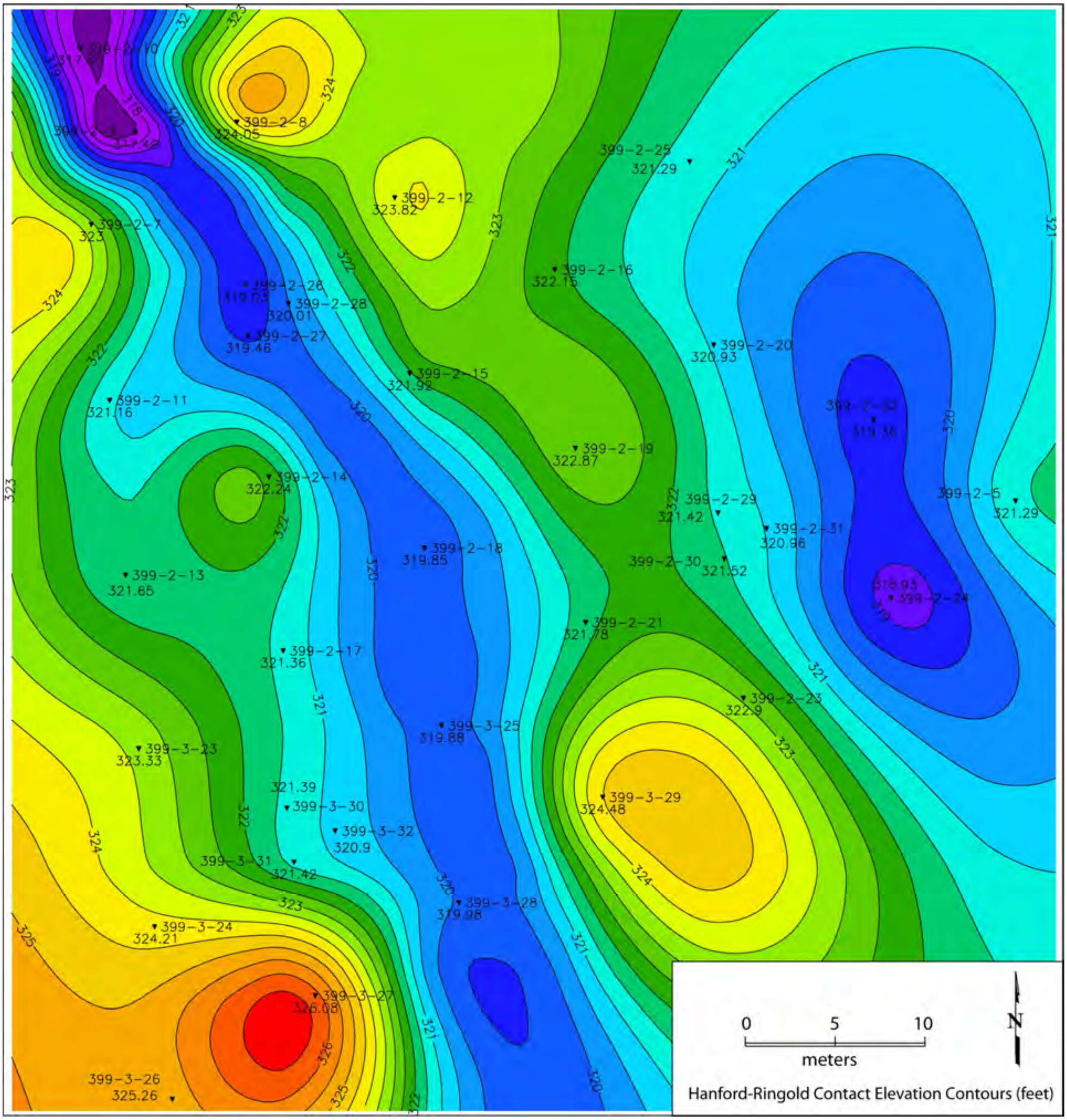

Figure 4.20. Structure-contour map illustrating the uneven, eroded surface of the Ringold Formation. A flood paleochannel appears to run midway, from northwest to southeast through the IFRC site. The channel is flanked with higher-elevation erosional remnants of the Ringold Formation.

In Figure 4.21 and Figure 4.22 are several images showing the sharp contact between the dark, coarse-grained Hanford formation and oxidized brownish silt at the top of the Ringold Formation.

Figure 4.21. Hanford–Ringold formations contact. Left: Contact lies between coarse basaltic sand and gravel in right-hand core and next core, composed of oxidized Ringold Formation silt at the 57-ft depth (well 399-2-25). Right: Loose, basaltic sand and gravel of the Hanford formation (foreground) overlie oxidized (middle) and reduced (background) greenish-gray silt of the Ringold Formation (well 399-3-28).

Figure 4.22. Sharp contact at the top of the Ringold Formation silt-dominated sediment in well 399-2-23 (left) and 399-2-14 (right). Notice the loose gravel in right-hand photo has little or no matrix.

Within the Hanford formation, loose, clast-supported, muddy sandy gravel is the predominant sediment type (see Figures 4.17 and 4.23). Lenses of matrix-supported gravelly sand occur sporadically. (The terms *mud* and *muddy* are used to describe undifferentiated silt- to clay-size particles.) The maximum size of gravels from the vadose zone observed in excavations within the South Process Pond (Bjornstad 2004) was boulders up to several feet in diameter (Figure 2.4). Roundness on basalt gravel clasts is usually immature (subangular to subrounded) because of relatively recent erosion, transport, and rapid burial of the locally derived basaltic detritus. Gravel clasts of other compositions (quartzite, granite, gneiss, and volcanic porphyries) are commonly more rounded as a result of reworking by the floods of older fluvial deposits (e.g., Ringold and Ellensburg formations).

The matrix filling between gravel clasts is highly variable. The matrix may be filled or partially filled with sand, silt, or clay, or may be absent altogether, creating an openwork fabric (Figure 4.23).

Figure 4.23. Gravel-dominated facies with openwork fabric within the Hanford formation. Left: Grab sample of loose, basaltic, pebble gravel was collected for microbiological characterization. Right: Clean, matrix-free pebble gravel on the right transitions to sandy, matrix-filled gravel to the left.

Occasionally the matrix fill consists of almost pure yellowish silt or clayey silt, apparently derived from reworked Ringold mud (Figure 4.24). Typically, however, silt and clay are not a major component of high-energy, gravel-dominated flood deposits (DOE 2002; Bjornstad 2006). This is because the fine particles of silt and clay tended to remain in suspension during the short-duration (week or less) high-energy Ice Age flood events. Floodwaters never slowed down enough for the fine particles to settle out of suspension before all the water flushed out of the basin. Coarser particles of sand and gravel, on the other hand, could settle out and were deposited during flooding because of their larger size and higher density.

Figure 4.24. Flood gravels with fine-grained, reworked Ringold Formation matrix in the Hanford formation. Left: Matrix of olive to yellow Ringold Formation silt may be derived from erosion beneath the IFRC site or upstream off the White Bluffs. Grab sample from well 399-2-14, 18- to 19.5-ft depth. Right: The matrix surrounding clast-supported gravel in this core consists of a mottled mixture of multi-genetic brown Ringold Formation silt and dark gray basaltic sand (well 399-2-25, 52-ft depth).

The IFRC site is different from most other locations, however, because it lies close to at least two sources of fine-grained Ringold Formation silt and clay. One source is directly beneath the site, and the other is the White Bluffs erosional escarpment immediately upstream (Figure 4.25). Thus, it appears that significant amounts of fine-grained Ringold Formation silt and clay were incorporated into flood deposits as Ringold rip-up clasts before the clasts had a chance to totally disaggregate and move into suspension with the floodwater (see Figure 4.18). Once in suspension, however, most fine particles of silt and clay were flushed out of the basin along with the ocean-bound floodwater.

Figure 4.25. Aerial view, looking northeast, toward the IFRC site. The White Bluffs are an erosional escarpment that exposes hundreds of feet of Pliocene-age, fine-grained sediments of the Ringold Formation. Ice Age floods flowed from the upper left and upper right. Photo: Bob Peterson (PNNL).

4.3.1 Ringold Formation Rip-Up Clasts

Unique to the flood deposits are rounded rip-up clasts of semiconsolidated, fine-grained Ringold Formation (Figure 4.26 and Figure 4.27). These include clasts of calcium-carbonate-cemented caliche as well as clasts of compacted mud, originally deposited during Ringold time in either floodplain-overbank or lake environments (Figure 4.28). These same types of sediment are exposed in the Ringold Formation within the White Bluffs immediately across the river as well as upstream of the 300 Area. Generally, Ringold rip-up clasts are larger than adjacent clasts (see Figure 4.18), reflecting their short transport distance and lower bulk density in contrast to lithified clasts. The rounded nature of rip-up clasts indicates they were transported as detrital “grains,” along with other materials, during flooding. In about half of the new wells (17 of 35) at the IRFC site, fine-grained rip-up clasts were encountered during drilling (see Appendix A).

Figure 4.26. Rounded rip-up clasts removed from a backhoe excavation in 2003 within SPP#2 at the south end of the IFRC site (see Figures 2.3 and 2.4). These boulder-sized clasts, composed of cohesive Ringold Formation silt and clay, were ripped off the White Bluffs escarpment just upstream of, or from beneath, the 300 Area during a cataclysmic Ice Age flood.

Figure 4.27. Interiors of two fine-grained Ringold Formation rip-up clasts removed by backhoe from beneath the South Process Pond in 2003. On the left is a well-laminated silt, originally deposited in a lake that filled the Pasco Basin between 3 to 5 million years ago. On the right is an olive-yellow silt with relict plant and animal traces from a Ringold Formation paleosol. Both sediment types are exposed in exposures of Ringold Formation in the White Bluffs, upstream of the 300 Area.

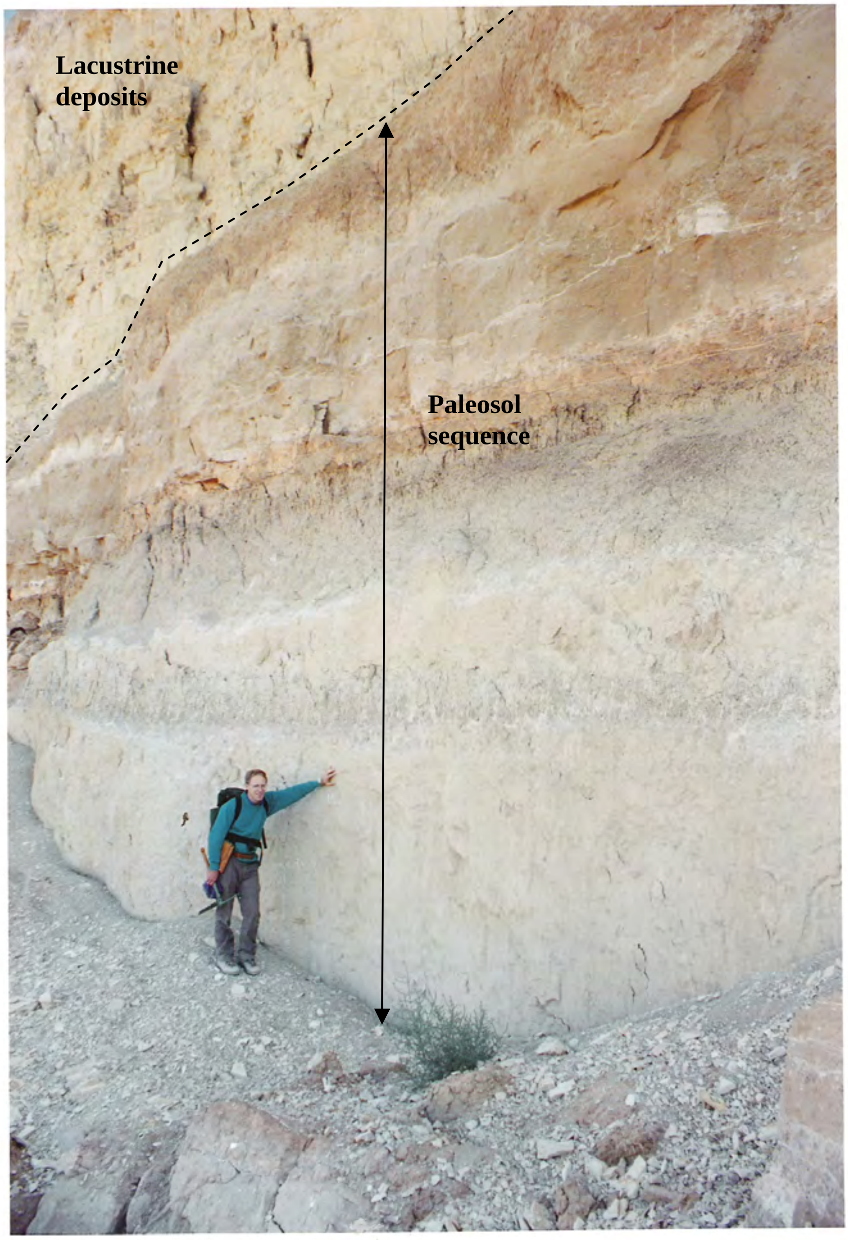

Figure 4.28. Olive to brown and yellow fine-grained upper Ringold Formation deposits (member of Savage Island) exposed upriver along the White Bluffs within a mile of the 300 Area. Here a thick paleosol sequence is overlain by laminated lacustrine (lake) deposits. Deposits like these are a probable source for the many reworked Ringold clasts observed within the Hanford formation in the 300 Area.

Two other examples of rip-up clasts identified in new IFRC wells are shown in Figure 4.29 and Figure 4.30.

Figure 4.29. Loose, basaltic pebbly sand overlies the top of a semiconsolidated Ringold Formation rip-up clast within the Hanford formation at 30- to 33-ft depth, well 399-2-14. This rip-up clast is similar to the oxidized silt of the Ringold Formation that directly underlies the IFRC site.

Figure 4.30. Portion of a 5.5-ft-thick semiconsolidated Ringold Formation rip-up clast, composed of cohesive clayey silt, in well 399-3-26 from 21- to 22-ft depth. The inclined lamination in this vertical drill core indicates this sediment was not deposited in situ but rotated in transit and redeposited during an Ice Age flood.

Because some contaminants (including uranium) may have an affinity for mud-sized particles, the character and distribution of concentrated fine-grained material in the subsurface has special relevance. Although clast-supported pebble- to boulder-size gravel is the dominant sediment size in the 300 Area, the matrix between gravel clasts varies significantly between relatively permeable gray to black basaltic sand (Figure 4.27) and relatively impermeable brownish mud (see Figure 4.24). The sediment color is an indication of the type of matrix present. The color most often associated with coarse-grained facies of the Hanford formation is dark gray to black, due to a composition of mostly unweathered basaltic rock fragments eroded off the Channeled Scabland during Pleistocene flooding.

However, the character of the flood sediment is different in the 300 Area and unlike most other flood deposits, for it does have more concentrated fines in the form of rip-up clasts as well as beds with fine-grained, brown, matrix-filling Ringold Formation materials (Figure 4.24). The brown color, derived from the Ringold Formation, is the result of a much longer period of weathering—over many millions of years—compared to the Hanford formation, which is only about 15,000 years old. As mentioned, the fine-grained Ringold matrix is unusual for the Hanford formation and probably the result of the 300 Area being directly across the river and just downstream of an abundant supply of Ringold detritus during Ice Age flooding (see Figure 4.25). It is possible that some of the brown fine-grained intervals may be associated with concentrations of Ringold rip-up clasts that disintegrated during or soon after deposition by the floods. Rip-up clasts are relatively unconsolidated and, not surprisingly, do not survive flood transport far from their source (see Figure 4.16), which explains why they are not observed far inland of the 300 Area and the Columbia River.

4.4 Man-Made Backfill

The contact between backfill and Hanford formation is difficult to discern based on drill cuttings or geophysical logs because the texture of the sediments is essentially the same (compare Figure 4.32 with Figure 4.17). The contact is apparent, however, based on photographs of several backhoe pits excavated in 2003 (see examples in Figures 2.4 and 4.19). Disturbed sediments appear relatively homogeneous with no visible structure; this is in contrast to the in situ Hanford formation, which shows sedimentary fabric in the form of layering, stratification, and clast imbrication.

Based on these photographs, the zone of anthropogenic disturbance extends below the bottom of the process pond excavation. Movement of heavy equipment and other disturbances at the base of the excavated ponds caused disturbance for up to several meters below these excavations. Thus, there may be only a few meters of undisturbed Hanford formation sediments within the vadose zone along the western side of the IFRC site.

The 300 Area process ponds were used for the disposal of uranium-contaminated wastes between 1943 and 1975. Contaminated soils were selectively removed from beneath the ponds from 1994 to 2005. The configuration of the uneven bottom of the process ponds at the end of remediation is shown in Figure 4.31. After remediation, excavations were backfilled with locally derived gravel-dominated sediments of the Hanford formation. Following backfilling, the surface was brought up to a common elevation of about 115 m (377 ft).

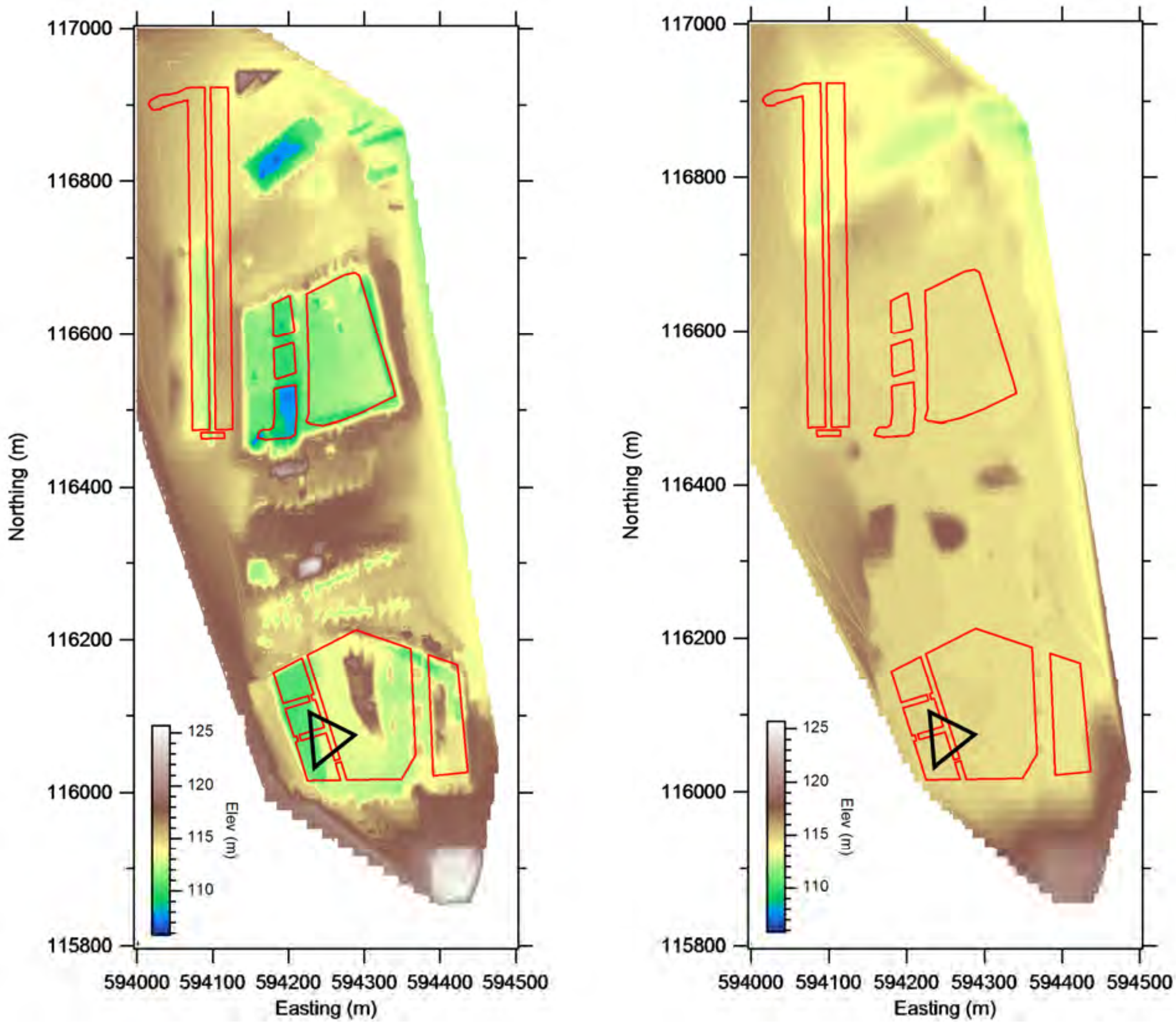

Figure 4.31. Surface topography in the vicinity of the 300 Area process ponds and trenches. Left: topography after remedial excavation and prior to emplacement of backfill. Right: surface as it exists today after remediation and backfilling. Triangle shows the location of the IFRC well field over the southwestern corner of the South Process Pond. Elevation of the land surface over the former South Process Pond today is about an even 115 m (377 ft).

Backfill materials consist of grayish-brown, poorly sorted, homogeneous mixtures of loose basaltic gravel and sand with lesser amounts of silt (Figure 4.32), derived from excavated and mixed, gravel-dominated facies of the Hanford formation. Figure 4.31 (left) shows the South Process Pond was not excavated to a constant depth. Therefore, the thickness of the backfill varies across the IFRC site. For example, the depth of remedial excavation went to approximately 110-m elevation on the west side in contrast to only about 113 m on the east side of the IFRC site. This translates to a backfill thickness of about 5 m (~16 ft) on the western side and approximately 2 m (~7 ft) along the eastern side of the IFRC site.

Figure 4.32. Backfill materials from 2- to 5-ft depth in well 399-2-11. This material is very similar to that of the Hanford formation from which it is derived. However, backfill sediments are likely more isotropic than the Hanford formation because the sedimentary fabric (horizontal to subhorizontal layering and stratification) was destroyed during excavation and backfilling.

5.0 References

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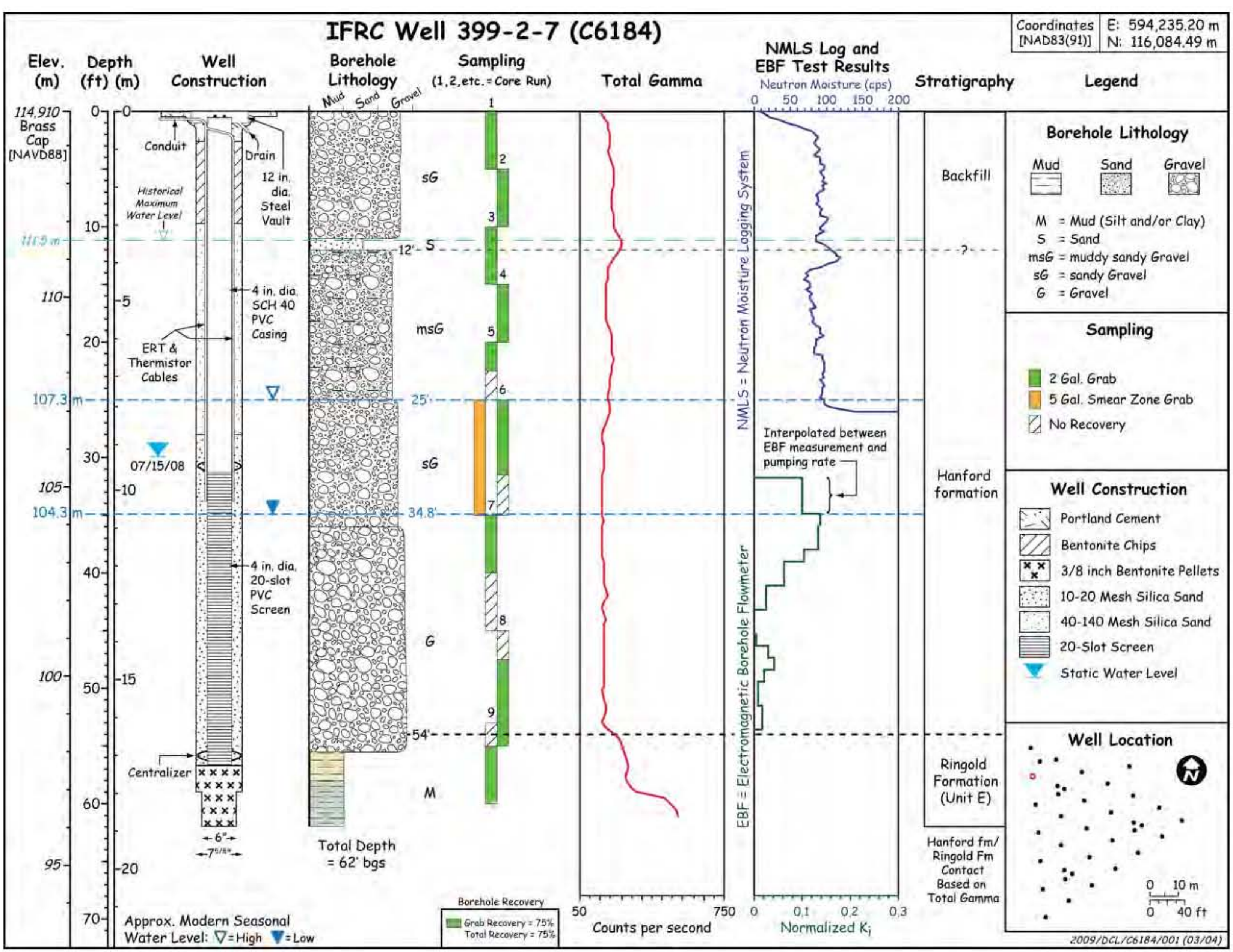
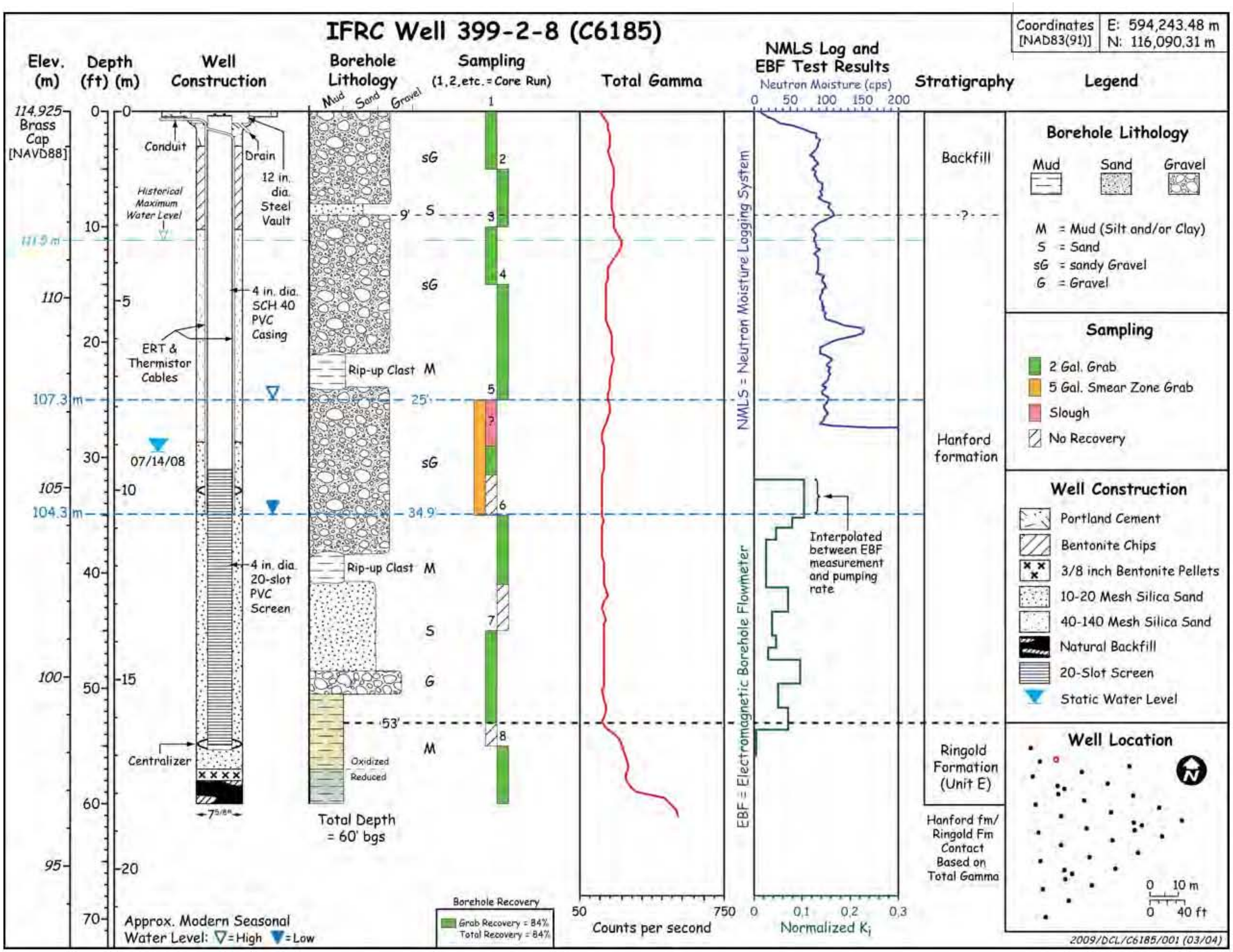
Appendix A

Compilation Borehole Summary Logs


IFRC Well 399-2-7 (C6184)
Coordinates [NAD83(91)]
E: 594,235.20 m
N: 116,084.49 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.910 Brass Cap [NAVD88]
Conduit
Drain
12 in. dia. Steel Vault
Historical Maximum Water Level
111.9 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
07/15/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
S
12'
msG
25'
sG
34.8'
G
54'
M
Total Depth = 62' bgs
Borehole Recovery
Grab Recovery = 75%
Total Recovery = 75%
50
750
Counts per second
NMLS = Neutron Moisture Logging System
Interpolated between EBF measurement and pumping rate
EBF = Electromagnetic Borehole Flowmeter
0 0.1 0.2 0.3
Normalized Ki
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6184/001 (03/04)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Coordinates [NAD83(91)]
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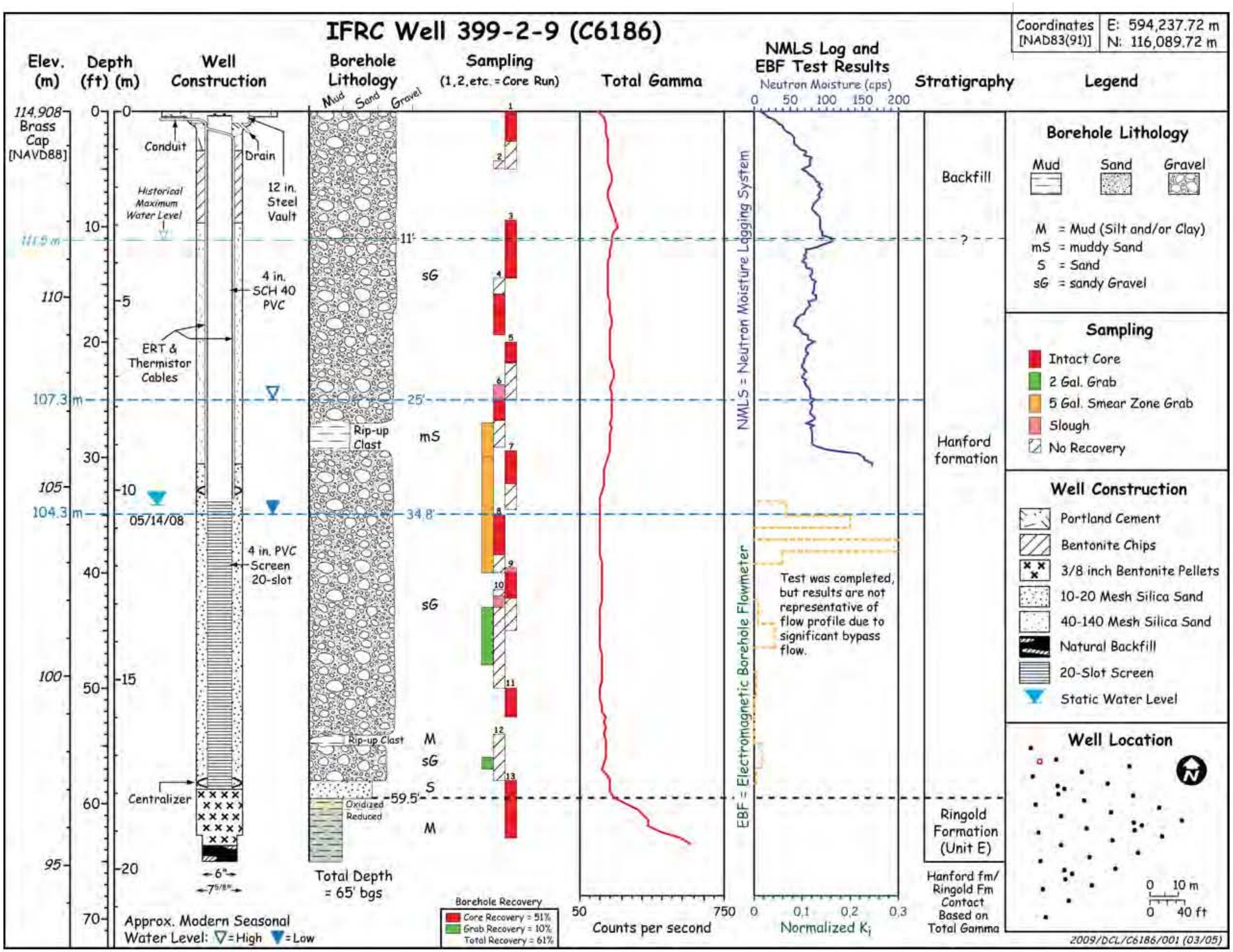
N: 116,090.31 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.925 Brass Cap [NAVD88]
Conduit
Drain
12 in. dia. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
07/14/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
sG
9'
S
Rip-up Clast
M
25'
34.9'
G
53'
Oxidized
Reduced
Total Depth = 60' bgs
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Counts per second
Normalized K$_i$
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Borehole Recovery
Grab Recovery = 84%
Total Recovery = 84%
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
2009/DCL/C6185/001 (03/04)



IFRC Well 399-2-9 (C6186)
Coordinates [NAD83(91)]
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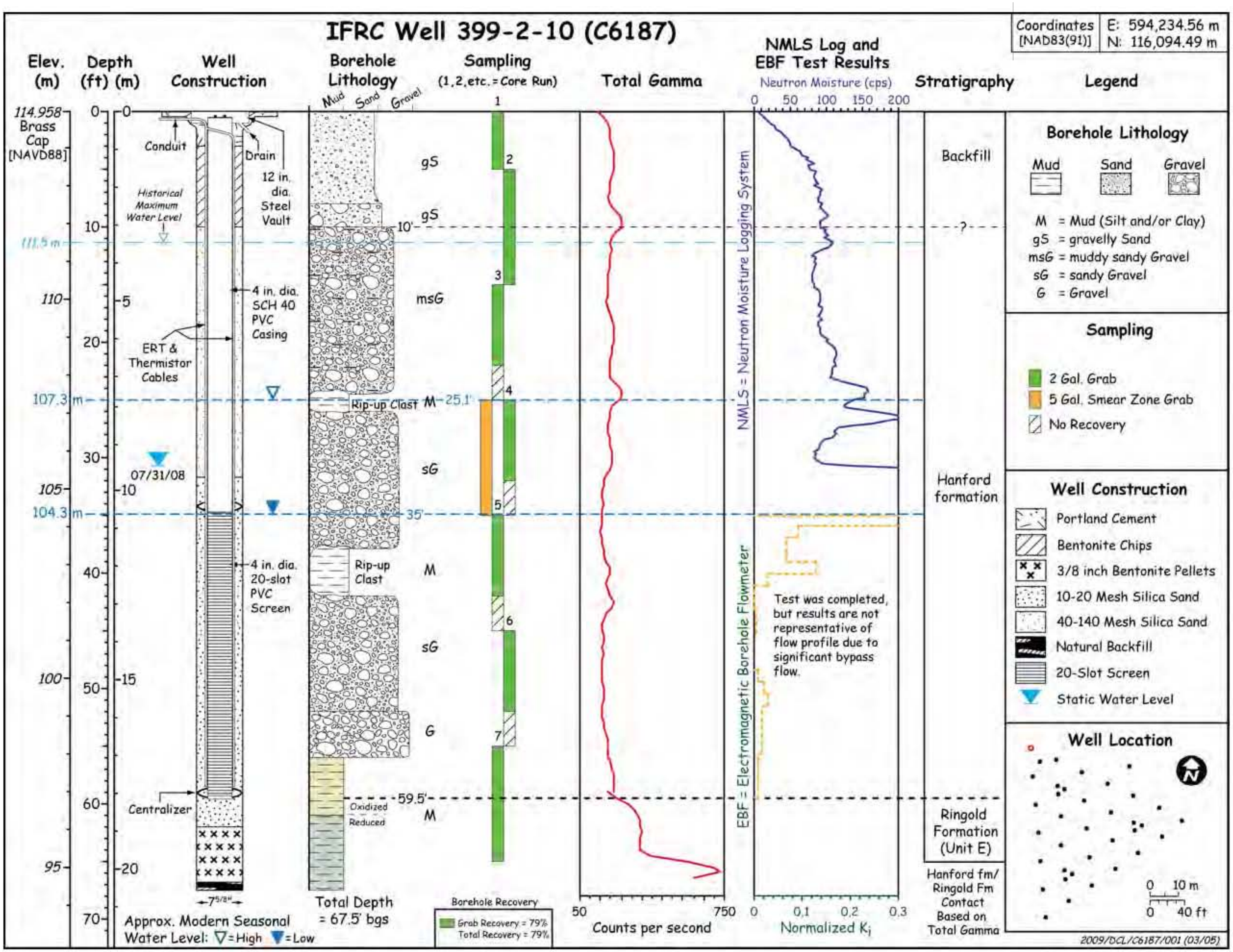
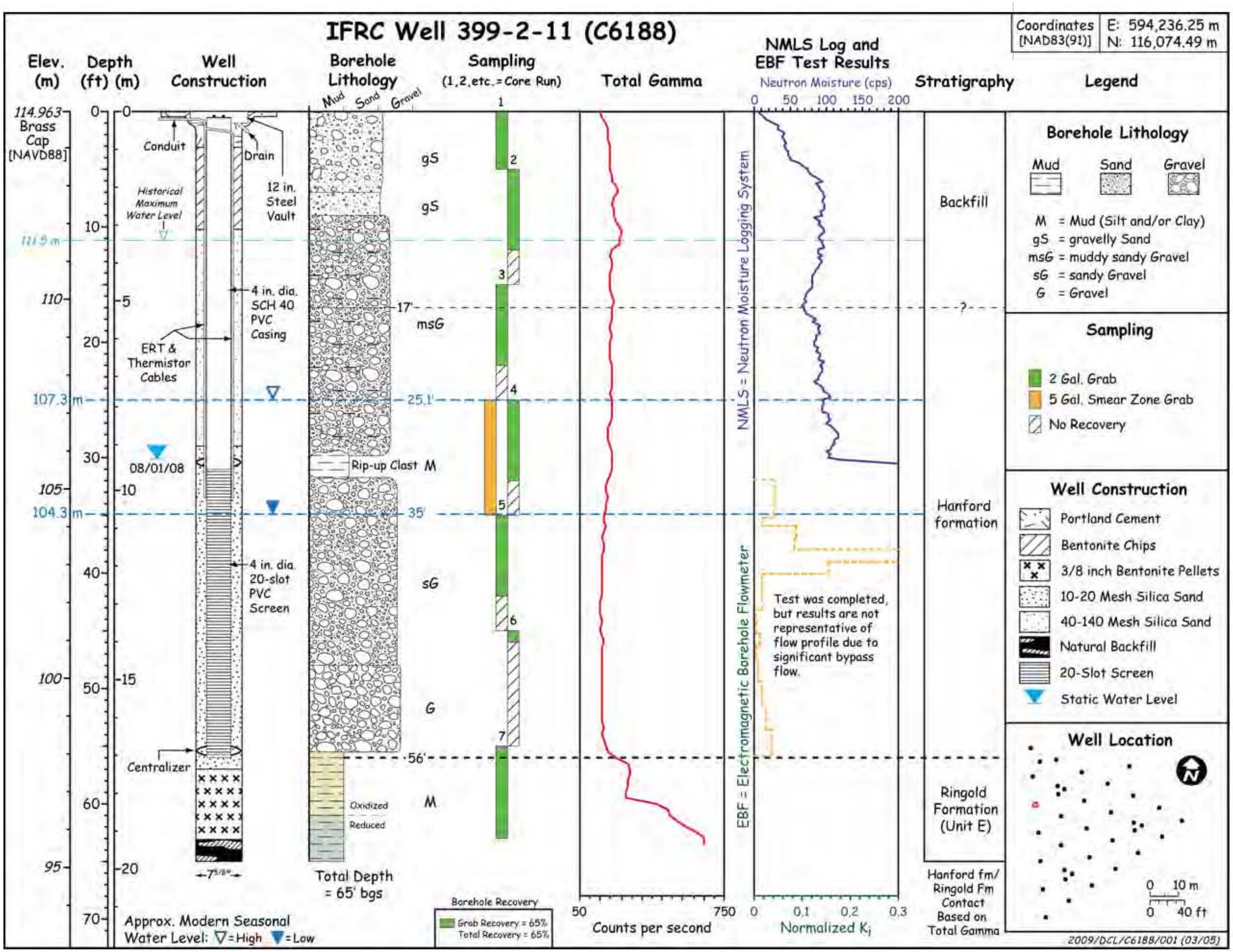
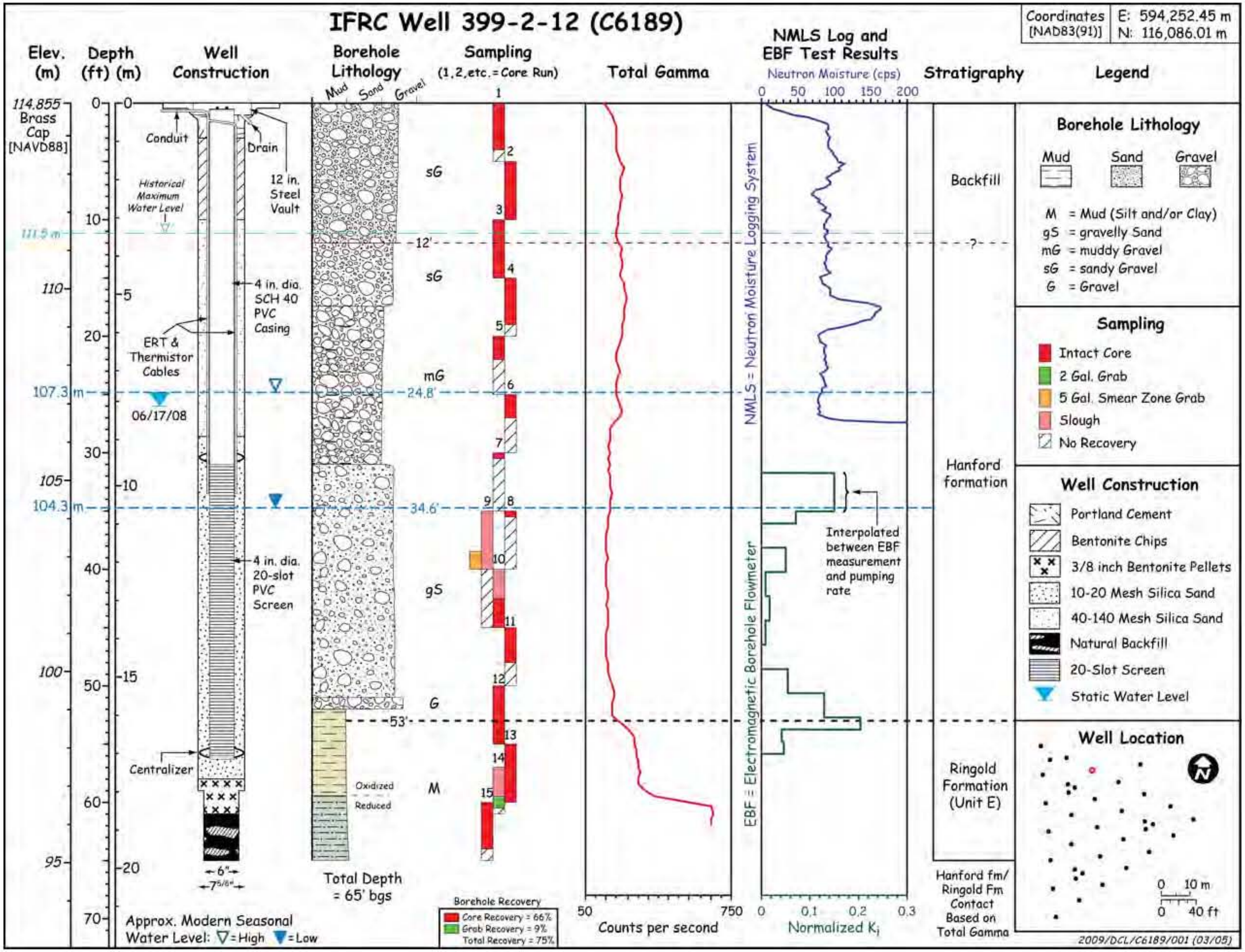
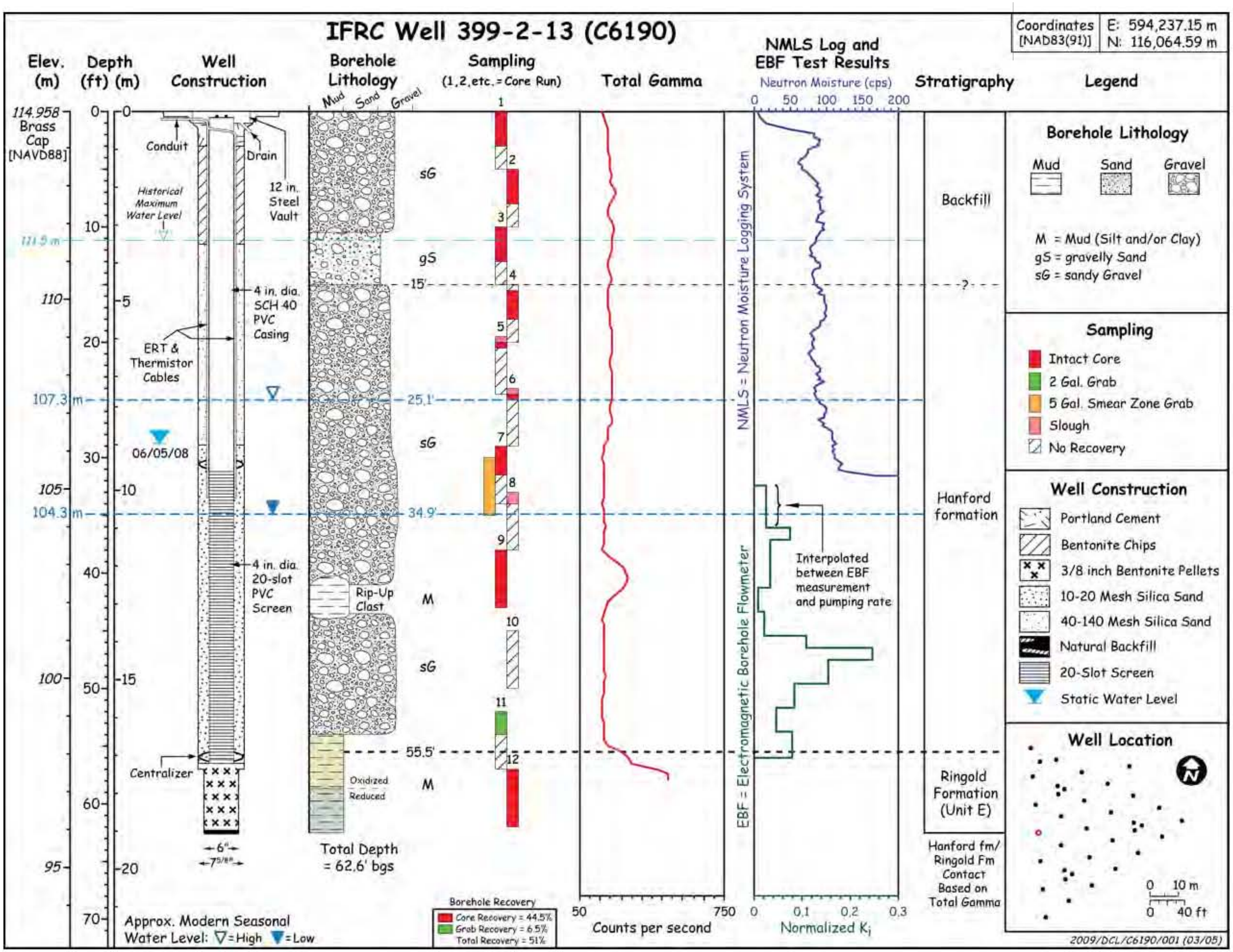
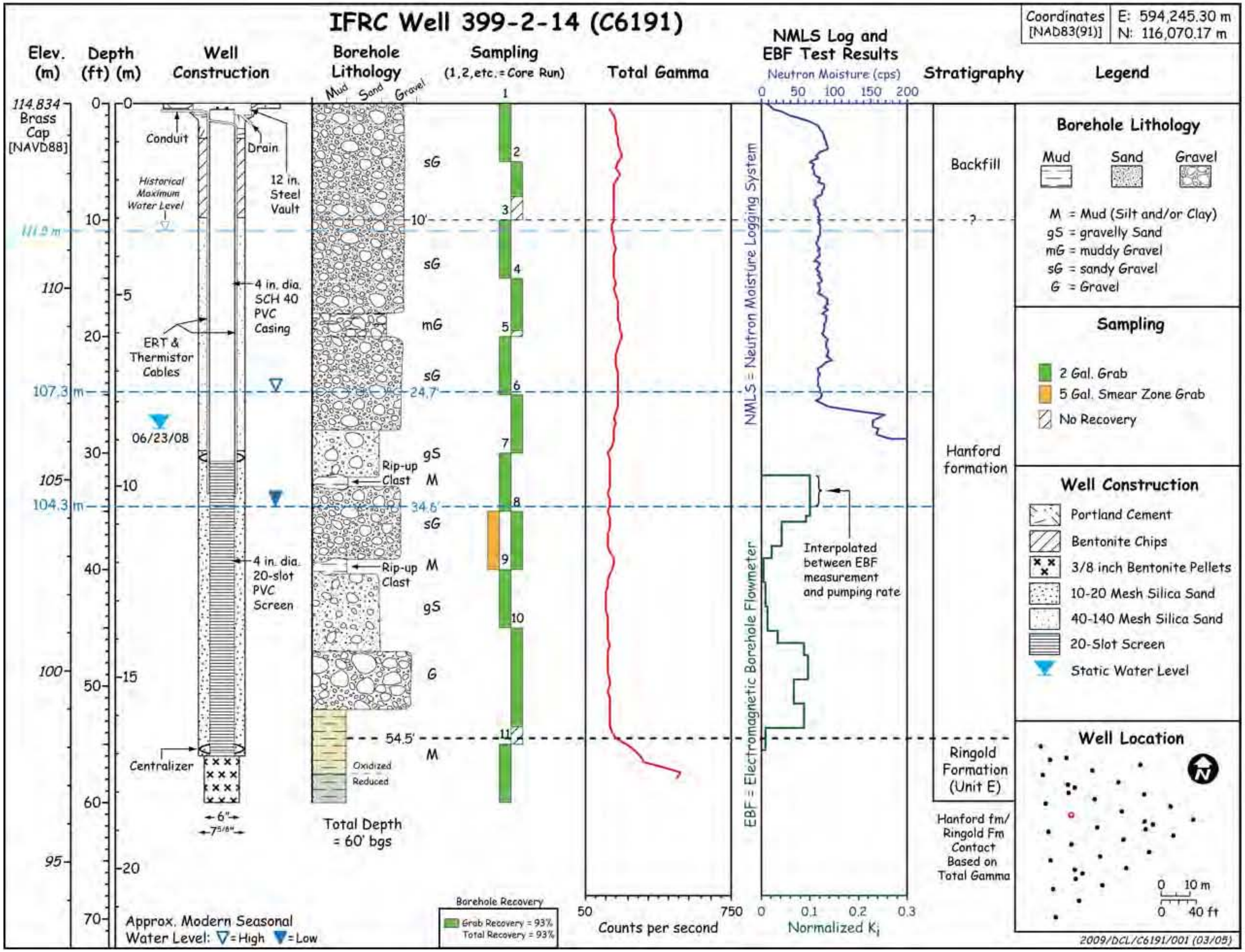
N: 116,089.72 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.908 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.9 m
4 in. SCH 40 PVC
ERT & Thermistor Cables
107.3 m
25'
11'
Rip-up Clast
105
104.3 m
05/14/08
34.8'
4 in. PVC Screen 20-slot
100
Rip-up Clast
Centralizer
59.5'
Oxidized
Reduced
95
6"
7 5/8"
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
sG
mS
sG
M
sG
S
M
Borehole Recovery
Core Recovery = 51%
Grab Recovery = 10%
Total Recovery = 61%
50 750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
0 0.1 0.2 0.3
Normalized Ki
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
mS = muddy Sand
S = Sand
sG = sandy Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6186/001 (03/05)


IFRC Well 399-2-10 (C6187)
Coordinates [NAD83(91)]
E: 594,234.56 m
N: 116,094.49 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.958 Brass Cap [NAVD88]
Conduit
Drain
12 in. dia. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
Rip-up Clast
25.1'
07/31/08
104.3 m
35'
4 in. dia. 20-slot PVC Screen
Rip-up Clast
Centralizer
59.5'
Oxidized
Reduced
Total Depth = 67.5' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
gS
gS
10'
msG
M
sG
M
sG
G
M
Borehole Recovery
Grab Recovery = 79%
Total Recovery = 79%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
Normalized Ki
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6187/001 (03/05)

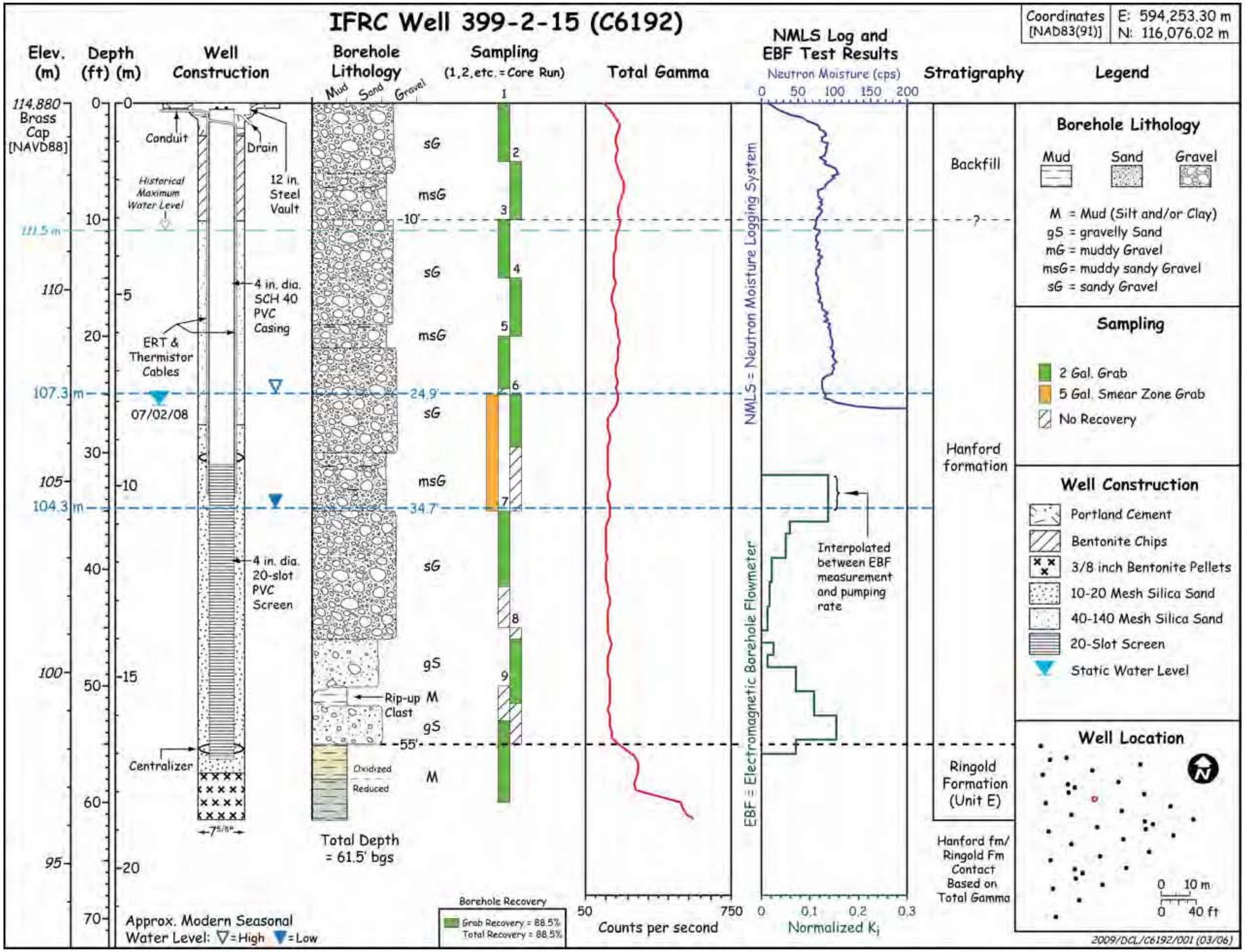

IFRC Well 399-2-11 (C6188)
Coordinates [NAD83(91)]
E: 594,236.25 m
N: 116,074.49 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling
(1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.963 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
08/01/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
gS
msG
Rip-up Clast
M
sG
G
Oxidized
Reduced
17'
25.1'
35'
56'
Total Depth = 65' bgs
Borehole Recovery
Grab Recovery = 65%
Total Recovery = 65%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
Normalized K_i
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
M = Mud (Silt and/or Clay)
gS = gravelly Sand
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
2009/DCL/C6188/001 (03/05)


IFRC Well 399-2-12 (C6189)
Coordinates [NAD83(91)]
E: 594,252.45 m
N: 116,086.01 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.855 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
12'
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.8'
06/17/08
104.3 m
34.6'
4 in. dia. 20-slot PVC Screen
Centralizer
53'
Oxidized
Reduced
sG
mG
gS
G
M
Total Depth = 65' bgs
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Core Recovery = 66%
Grab Recovery = 9%
Total Recovery = 75%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K_i
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
G = Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6189/001 (03/05)

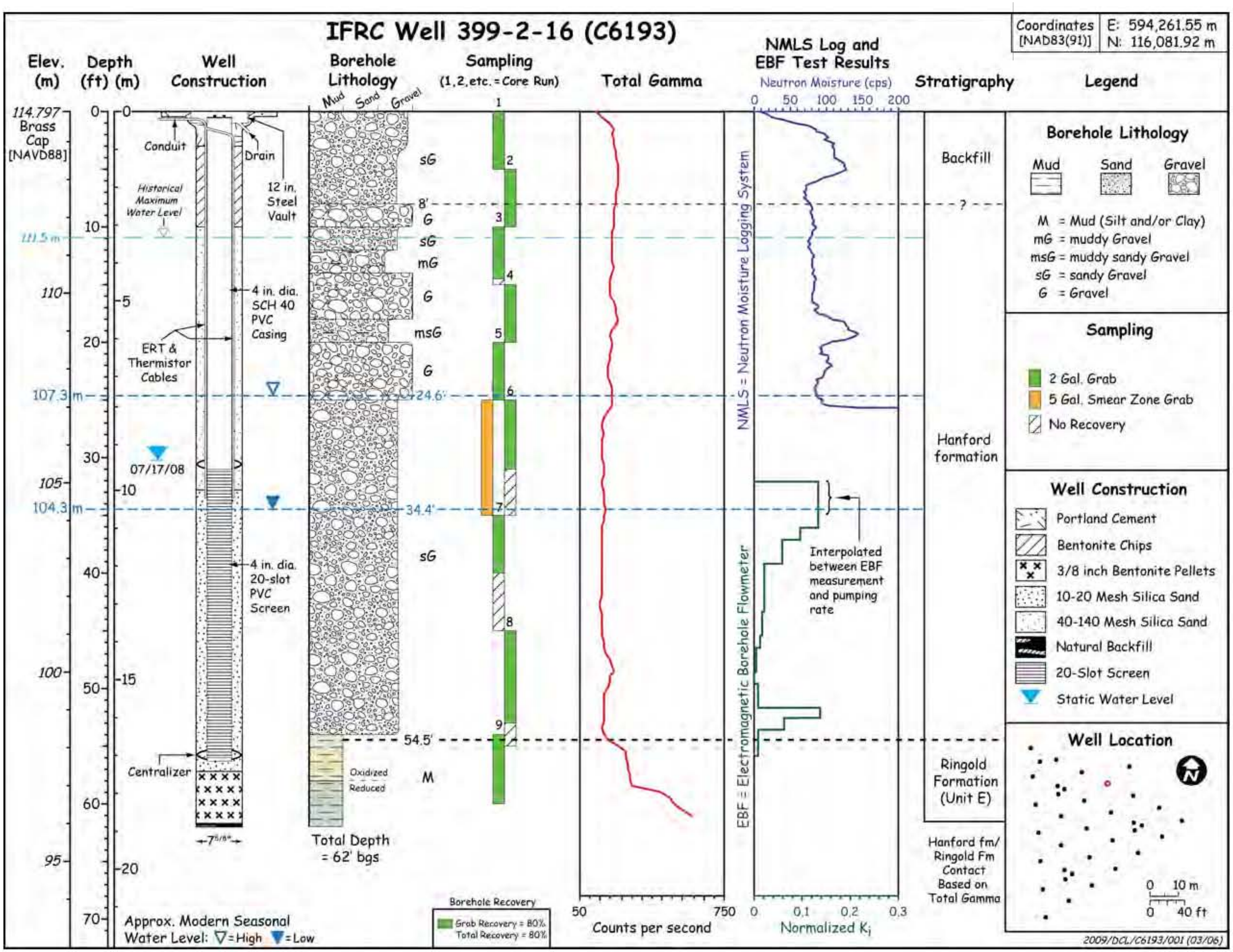

IFRC Well 399-2-13 (C6190)
Coordinates [NAD83(91)]
E: 594,237.15 m
N: 116,064.59 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling
(1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.958 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/05/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
sG
gS
sG
M
Rip-Up Clast
sG
Oxidized
Reduced
M
15'
25.1'
34.9'
55.5'
Total Depth = 62.6' bgs
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Counts per second
Normalized K_i
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
Borehole Recovery
Core Recovery = 44.5%
Grab Recovery = 6.5%
Total Recovery = 51%
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6190/001 (03/05)



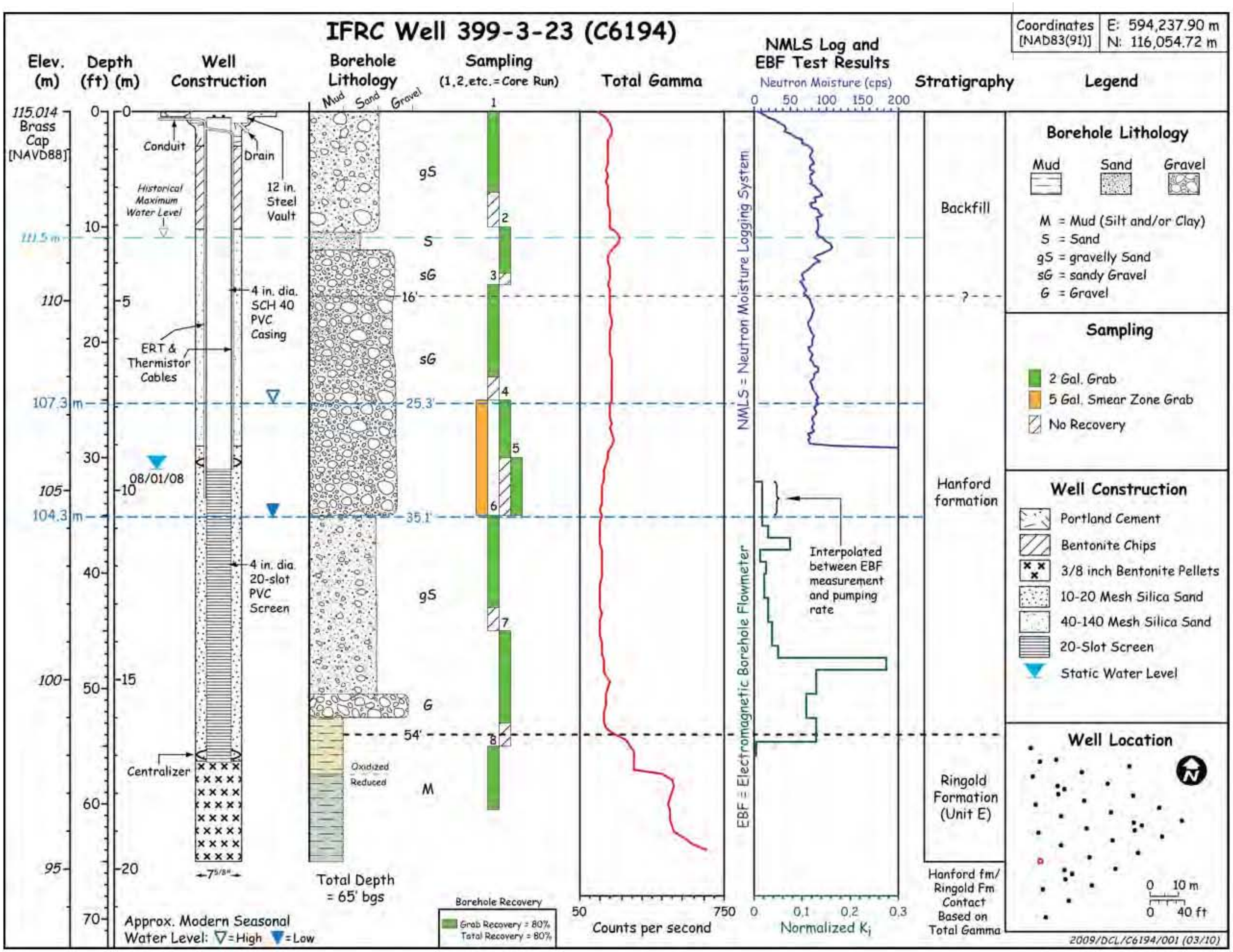
IFRC Well 399-2-14 (C6191)
Coordinates [NAD83(91)]
E: 594,245.30 m
N: 116,070.17 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.834 Brass Cap [NAVD88]
Conduit
Drain
Historical Maximum Water Level
12 in. Steel Vault
111.9 m
10'
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.7'
06/23/08
Rip-up Clast
104.3 m
34.6'
4 in. dia. 20-slot PVC Screen
Rip-up Clast
54.5'
Centralizer
Oxidized
Reduced
6"
7 5/8"
Total Depth = 60' bgs
sG
sG
mG
sG
gS
M
sG
M
gS
G
M
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 93%
Total Recovery = 93%
Counts per second
Normalized K_i
2009/DCL/C6191/001 (03/05)

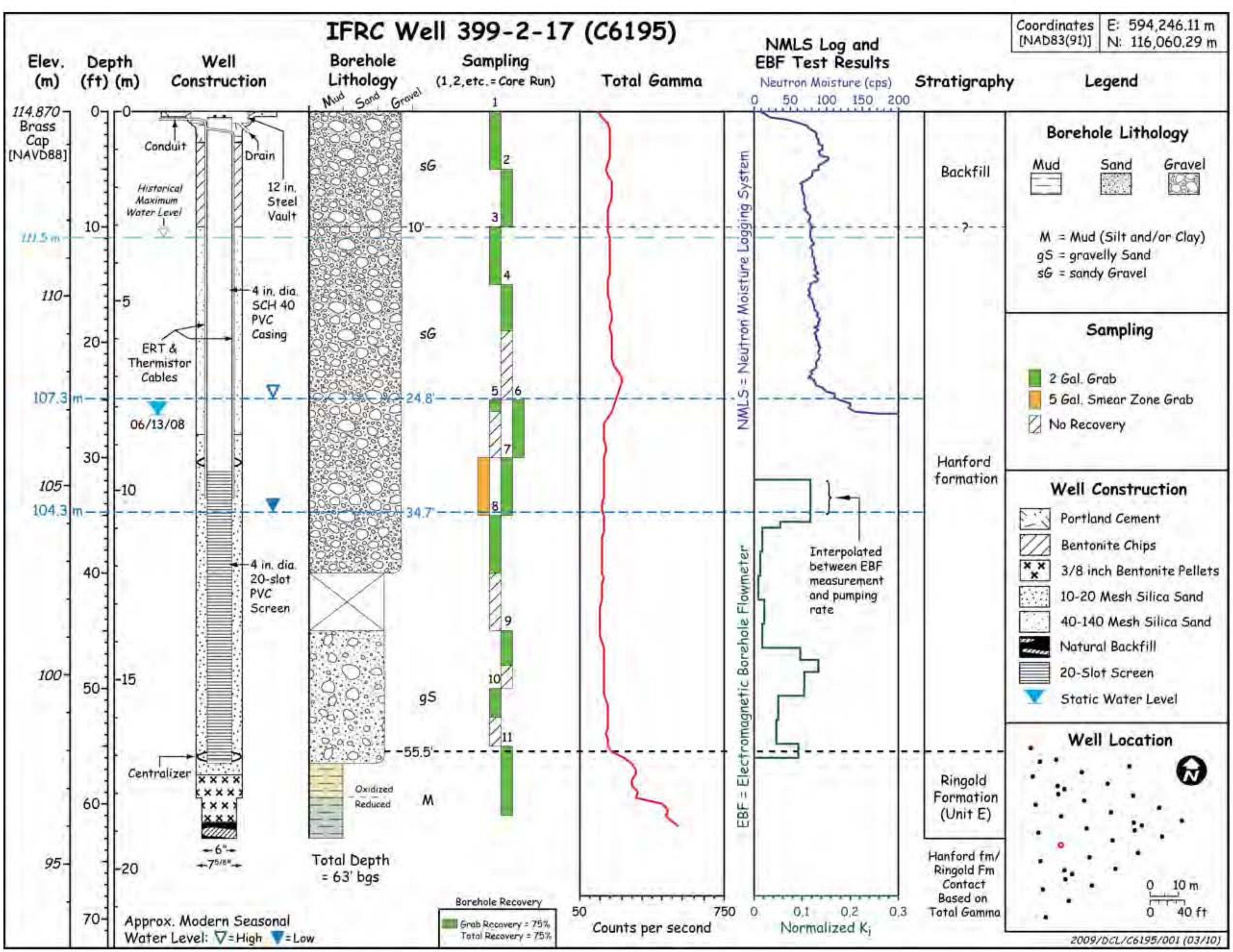


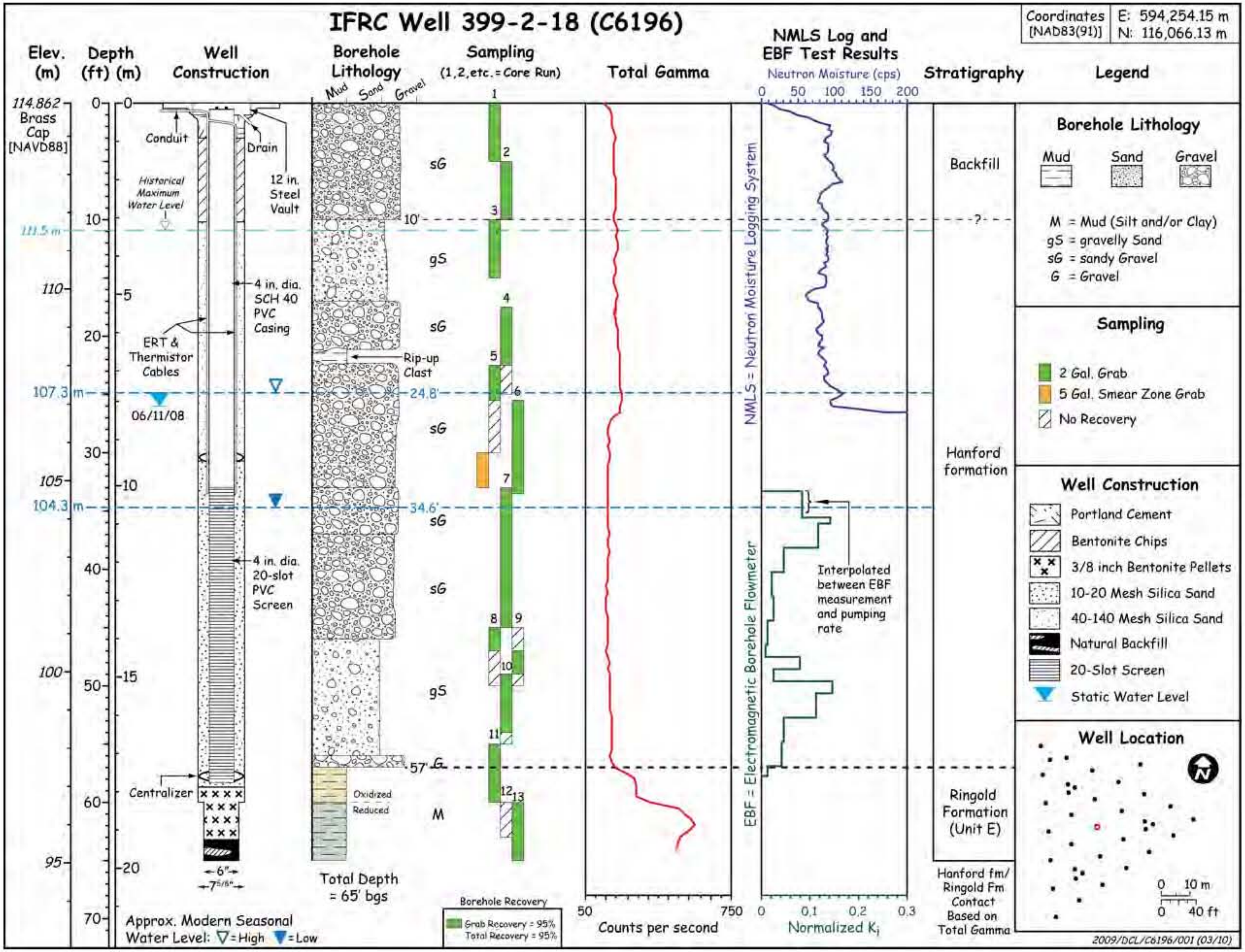
IFRC Well 399-2-15 (C6192)
Coordinates [NAD83(91)]
E: 594,253.30 m
N: 116,076.02 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.880 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
07/02/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
sG
msG
sG
msG
sG
msG
sG
gS
Rip-up Clast
M
gS
M
Oxidized
Reduced
10'
24.9'
34.7'
55'
Total Depth = 61.5' bgs
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Borehole Recovery
Grab Recovery = 88.5%
Total Recovery = 88.5%
50
750
Counts per second
0 0.1 0.2 0.3
Normalized K_i
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
2009/DCL/C6192/001 (03/06)

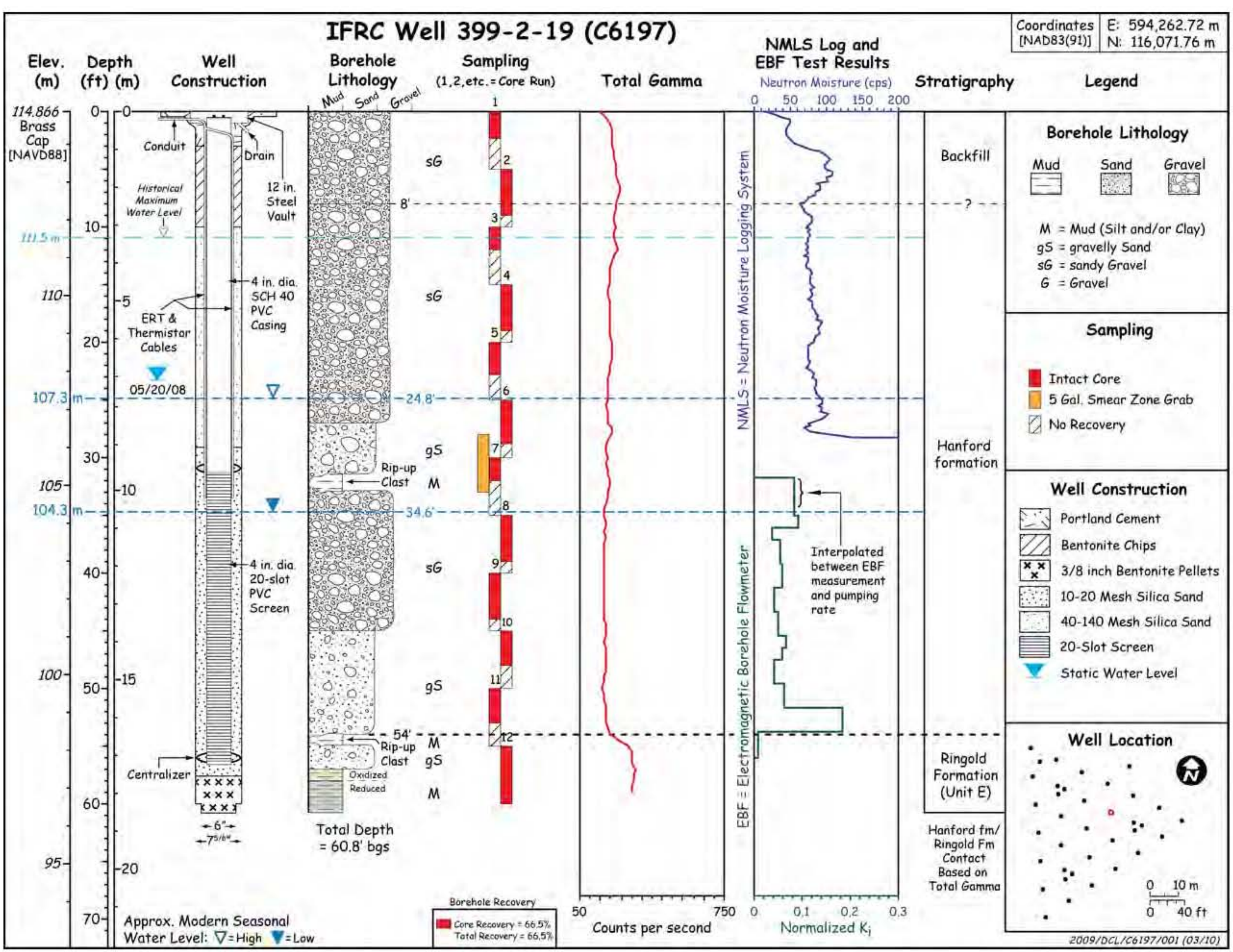


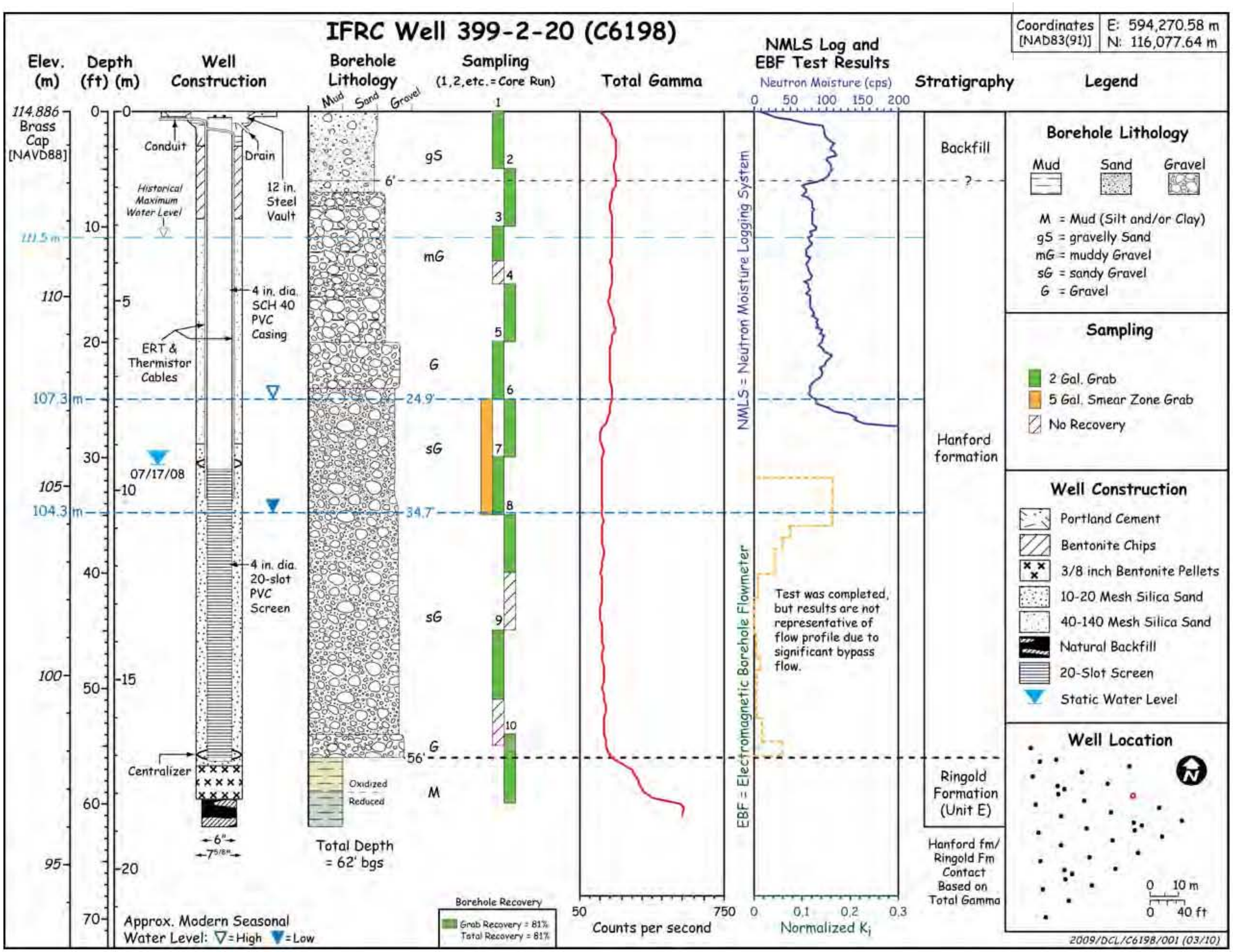
IFRC Well 399-2-16 (C6193)
Coordinates [NAD83(91)]
E: 594,261.55 m
N: 116,081.92 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.797 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.6'
07/17/08
104.3 m
34.4'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
54.5'
Oxidized
Reduced
Total Depth = 62' bgs
8'
sG
G
mG
msG
M
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
Borehole Recovery
Grab Recovery = 80%
Total Recovery = 80%
Counts per second
Normalized K_i
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud Sand Gravel
M = Mud (Silt and/or Clay)
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6193/001 (03/06)

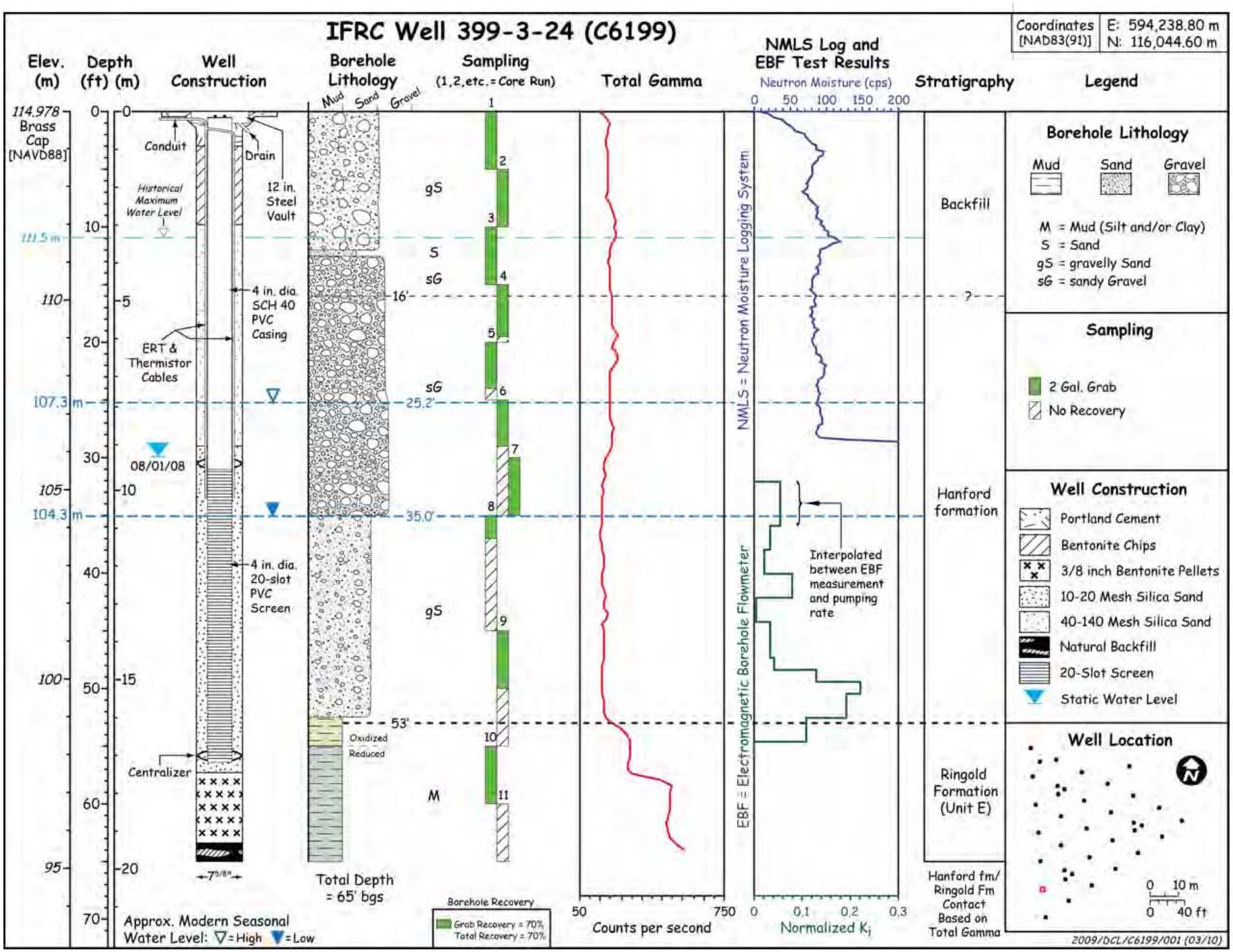

IFRC Well 399-3-23 (C6194)
Coordinates [NAD83(91)]
E: 594,237.90 m
N: 116,054.72 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud
Sand
Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
115.014 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
08/01/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
Oxidized
Reduced
gS
S
sG
sG
gS
G
M
16'
25.3'
35.1'
54'
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 80%
Total Recovery = 80%
Counts per second
Normalized K_i
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6194/001 (03/10)

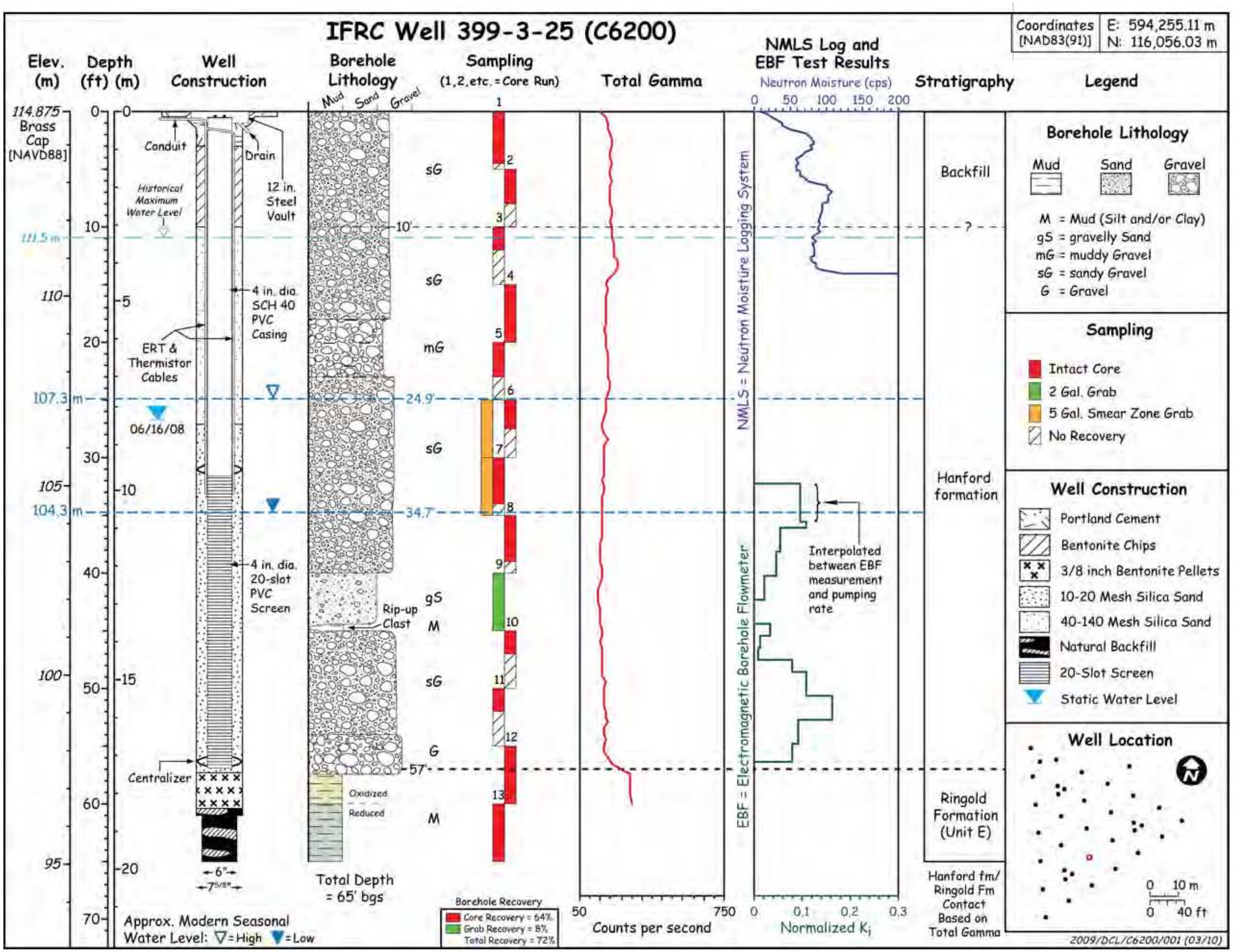

IFRC Well 399-2-17 (C6195)
Coordinates [NAD83(91)]
E: 594,246.11 m
N: 116,060.29 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.= Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.870
Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/13/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
sG
gS
M
10'
24.8'
34.7'
55.5'
Oxidized
Reduced
Total Depth = 63' bgs
Borehole Recovery
Grab Recovery = 75%
Total Recovery = 75%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K$_i$
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6195/001 (03/10)


IFRC Well 399-2-18 (C6196)
Coordinates [NAD83(91)]
E: 594,254.15 m
N: 116,066.13 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.= Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.862 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
110
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/11/08
105
104.3 m
4 in. dia. 20-slot PVC Screen
100
Centralizer
95
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
10'
gS
sG
Rip-up Clast
24.8'
sG
34.6'
sG
sG
gS
57'
G
Oxidized
Reduced
M
Total Depth = 65' bgs
Borehole Recovery
Grab Recovery = 95%
Total Recovery = 95%
50 750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
0 0.1 0.2 0.3
Normalized K_i
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6196/001 (03/10)

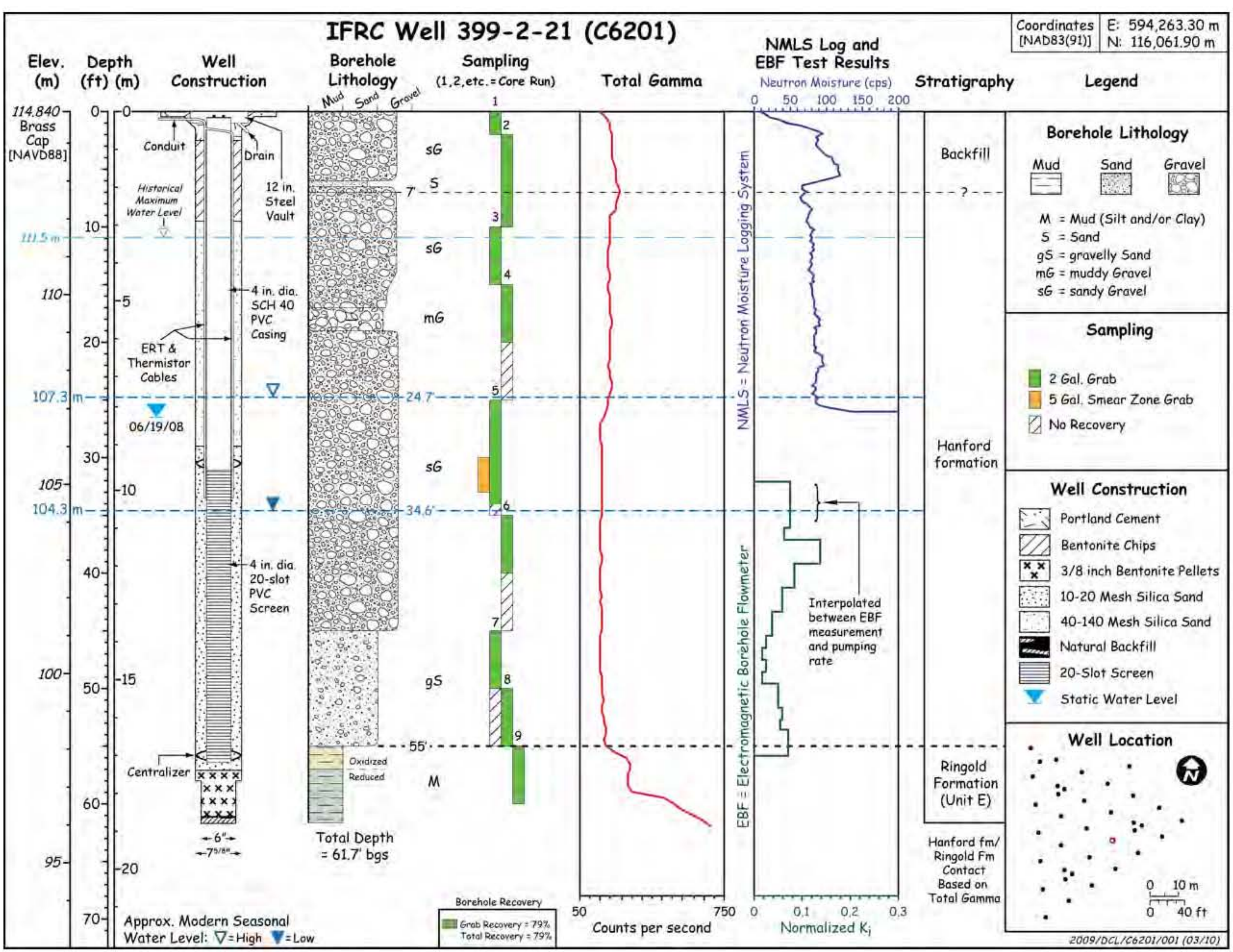

IFRC Well 399-2-19 (C6197)
Coordinates [NAD83(91)]
E: 594,262.72 m
N: 116,071.76 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.866 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
05/20/08
107.3 m
24.8'
104.3 m
34.6'
8'
54'
Rip-up Clast
4 in. dia. 20-slot PVC Screen
Centralizer
Oxidized
Reduced
6"
7 5/8"
Total Depth = 60.8' bgs
sG
sG
gS
M
sG
gS
M
gS
M
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Core Recovery = 66.5%
Total Recovery = 66.5%
50 750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
0 0.1 0.2 0.3
Normalized K_i
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
G = Gravel
Sampling
Intact Core
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6197/001 (03/10)

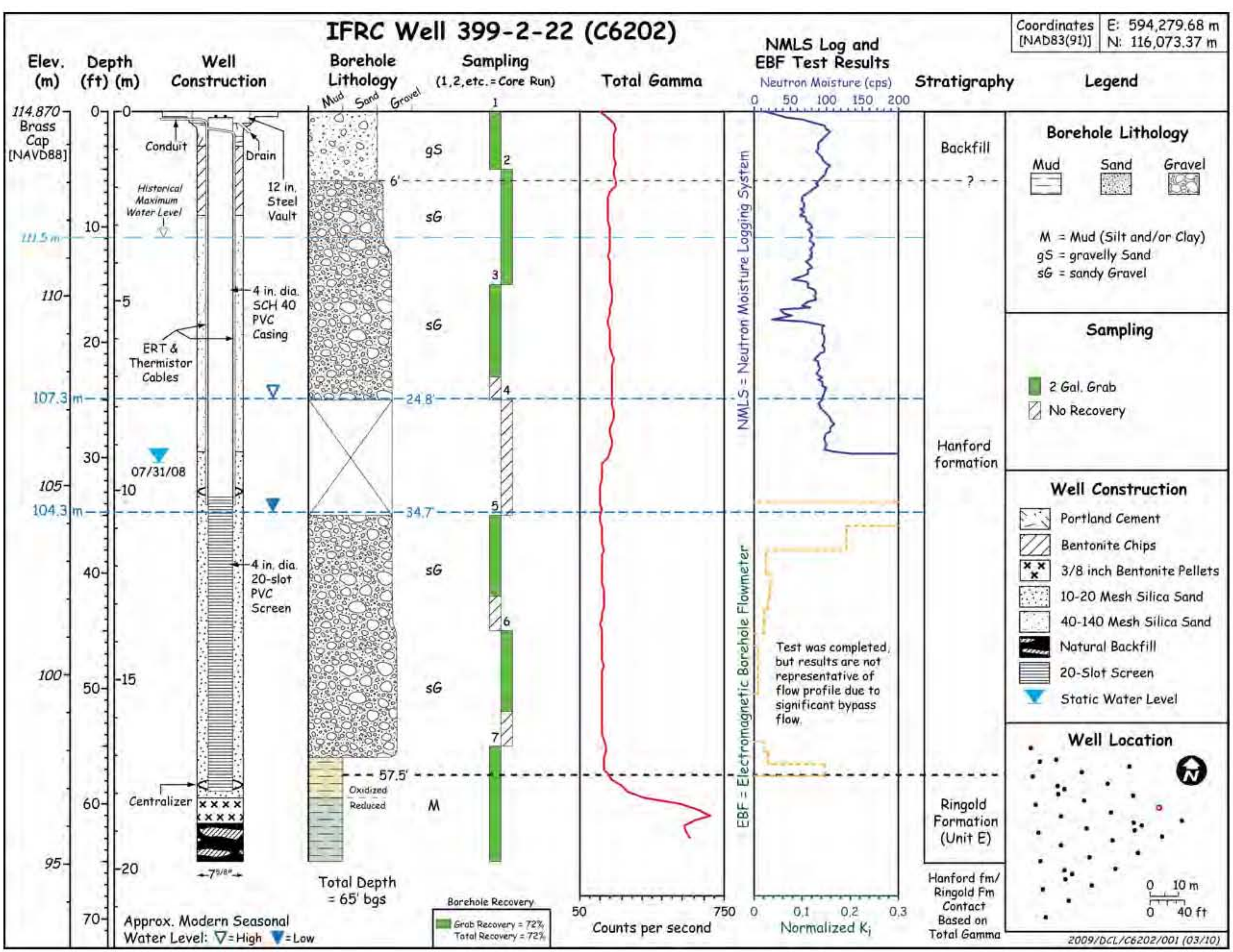

IFRC Well 399-2-20 (C6198)
Coordinates [NAD83(91)]
E: 594,270.58 m
N: 116,077.64 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.886 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.9'
07/17/08
104.3 m
34.7'
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
gS
mG
G
sG
sG
G
M
6'
56'
Oxidized
Reduced
Total Depth = 62' bgs
Borehole Recovery
Grab Recovery = 81%
Total Recovery = 81%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
Normalized Ki
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6198/001 (03/10)

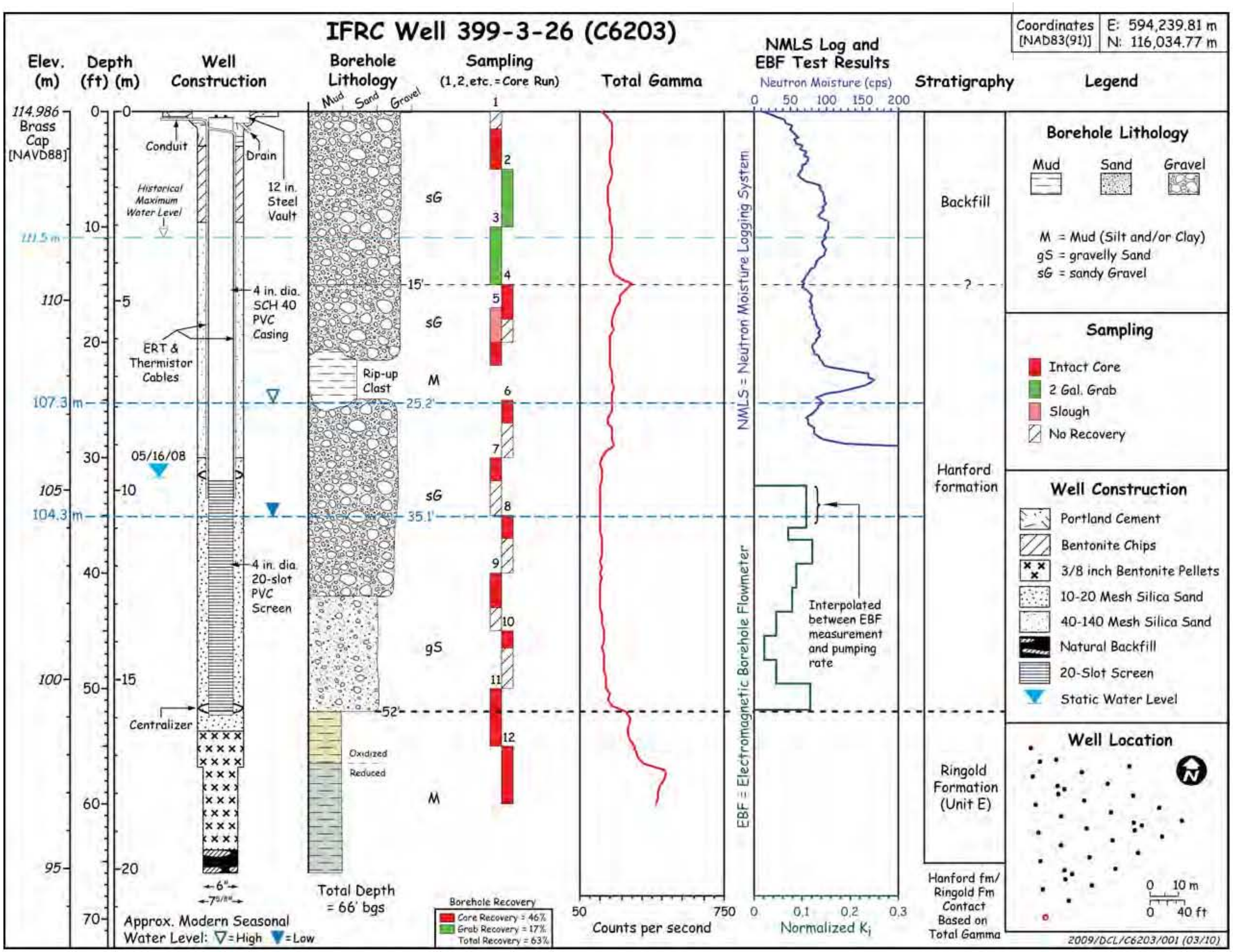

IFRC Well 399-3-24 (C6199)
Coordinates [NAD83(91)]
E: 594,238.80 m
N: 116,044.60 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.978 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
25.2'
08/01/08
104.3 m
35.0'
16'
4 in. dia. 20-slot PVC Screen
Centralizer
53'
Oxidized
Reduced
7 5/8"
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
gS
S
sG
sG
gS
M
Borehole Recovery
Grab Recovery = 70%
Total Recovery = 70%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K$_i$
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
sG = sandy Gravel
Sampling
2 Gal. Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6199/001 (03/10)

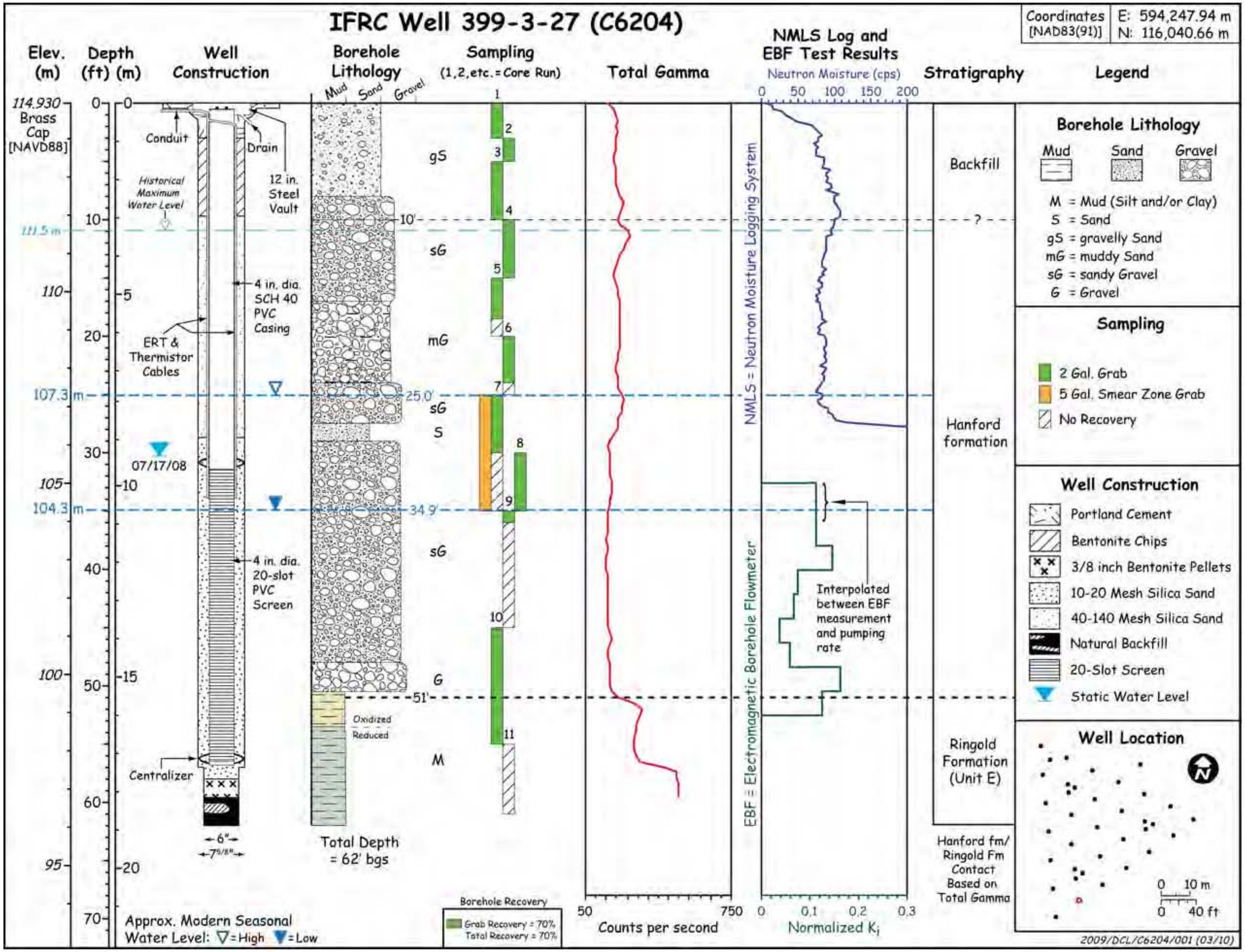


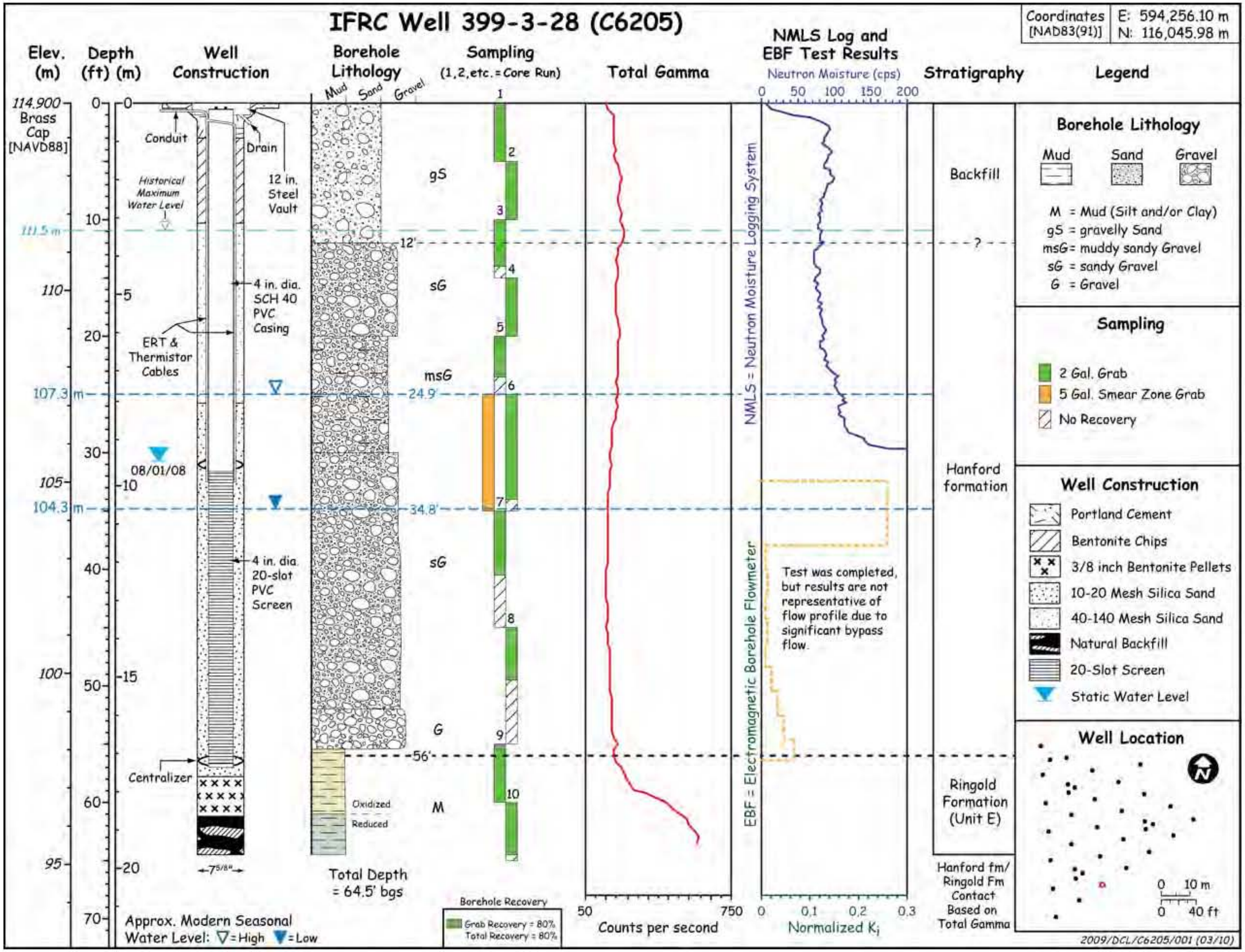
IFRC Well 399-3-25 (C6200)
Coordinates [NAD83(91)]
E: 594,255.11 m
N: 116,056.03 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.875
Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/16/08
105
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
Rip-up Clast
Oxidized
Reduced
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
10'
24.9'
34.7'
57'
sG
mG
gS
M
G
Borehole Recovery
Core Recovery = 64%
Grab Recovery = 8%
Total Recovery = 72%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K$_i$
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
G = Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6200/001 (03/10)

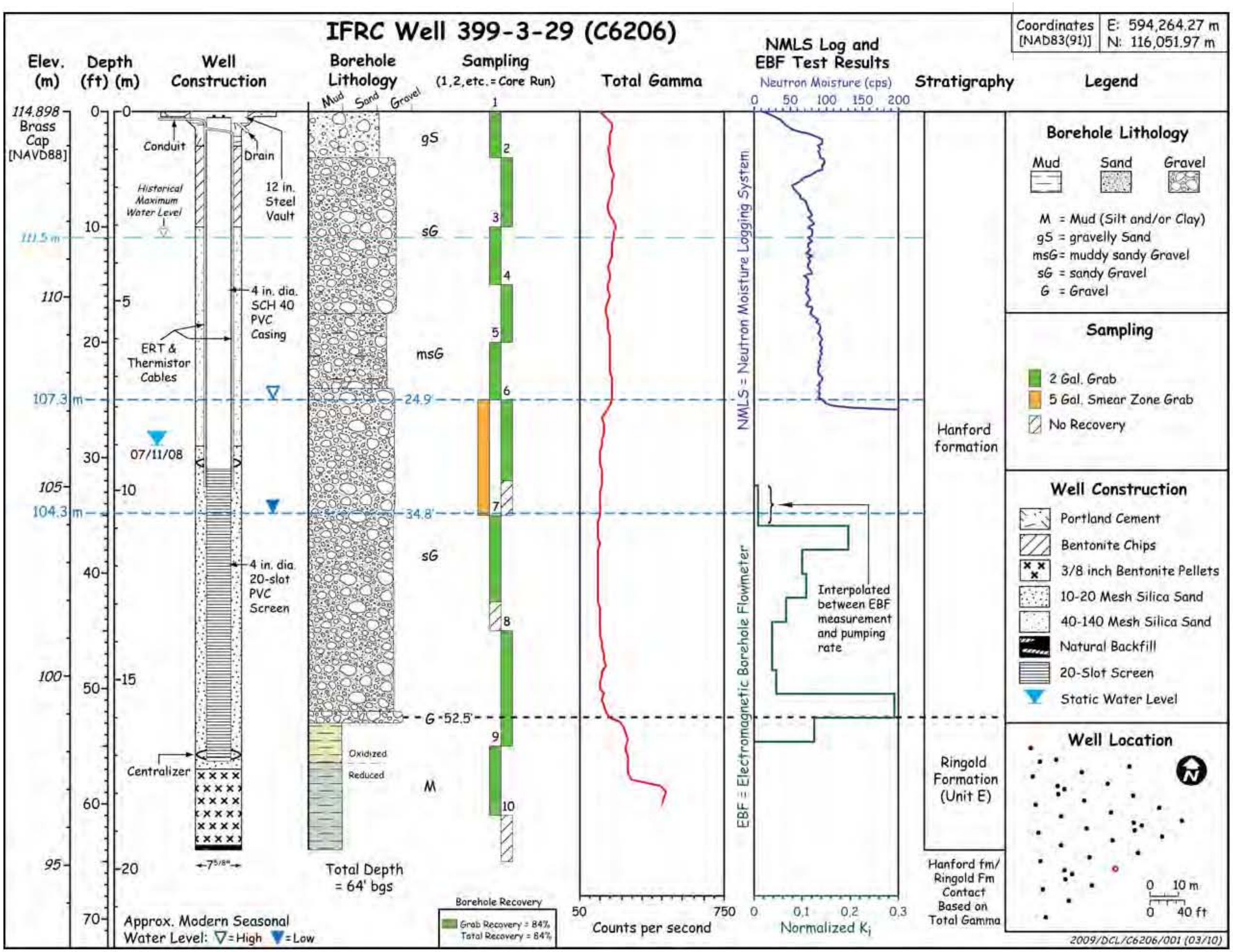

IFRC Well 399-2-21 (C6201)
Coordinates [NAD83(91)]
E: 594,263.30 m
N: 116,061.90 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.840 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/19/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
S
7'
sG
mG
24.7'
sG
34.6'
gS
55'
Oxidized
Reduced
M
Total Depth = 61.7' bgs
Borehole Recovery
Grab Recovery = 79%
Total Recovery = 79%
50
750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
0 0.1 0.2 0.3
Normalized K$_i$
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6201/001 (03/10)

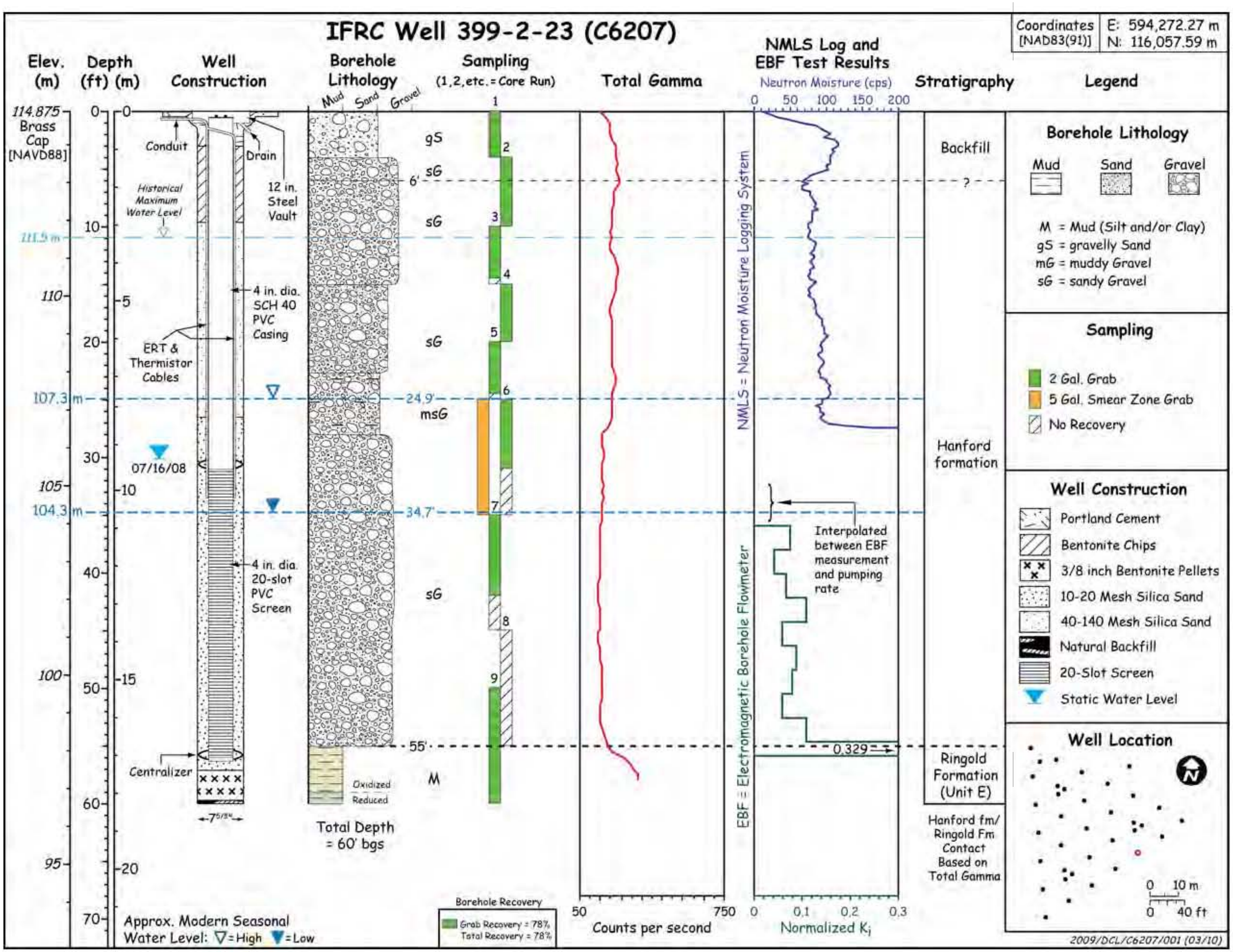

IFRC Well 399-2-22 (C6202)
Coordinates [NAD83(91)]
E: 594,279.68 m
N: 116,073.37 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud
Sand
Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.870 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.8'
07/31/08
104.3 m
34.7'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
57.5'
Oxidized
Reduced
gS
sG
M
6'
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 72%
Total Recovery = 72%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
Normalized K_i
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
Sampling
2 Gal. Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6202/001 (03/10)


IFRC Well 399-3-26 (C6203)
Coordinates [NAD83(91)]
E: 594,239.81 m
N: 116,034.77 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.986 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
Rip-up Clast
107.3 m
25.2'
05/16/08
104.3 m
35.1'
4 in. dia. 20-slot PVC Screen
Centralizer
15'
52'
Oxidized
Reduced
sG
M
gS
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
6"
7 5/8"
Total Depth = 66' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Core Recovery = 46%
Grab Recovery = 17%
Total Recovery = 63%
Counts per second
Normalized K_i
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
sG = sandy Gravel
Sampling
Intact Core
2 Gal. Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6203/001 (03/10)

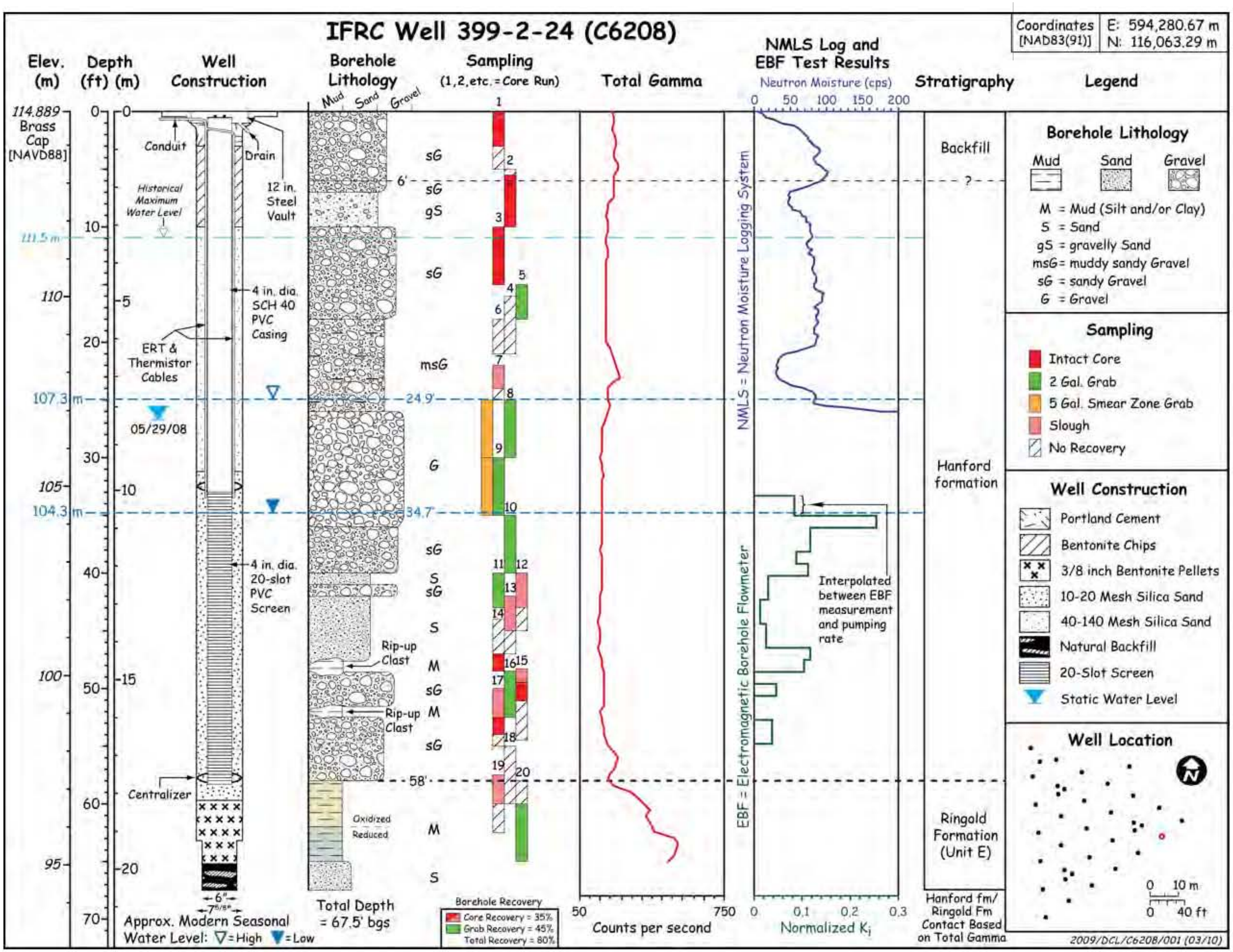

IFRC Well 399-3-27 (C6204)
Coordinates [NAD83(91)]
E: 594,247.94 m
N: 116,040.66 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.= Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.930 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
07/17/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
6"
7 5/8"
gS
sG
mG
S
G
M
10'
25.0'
34.9'
51'
Oxidized
Reduced
Total Depth = 62' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 70%
Total Recovery = 70%
50
750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K_i
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
mG = muddy Sand
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6204/001 (03/10)

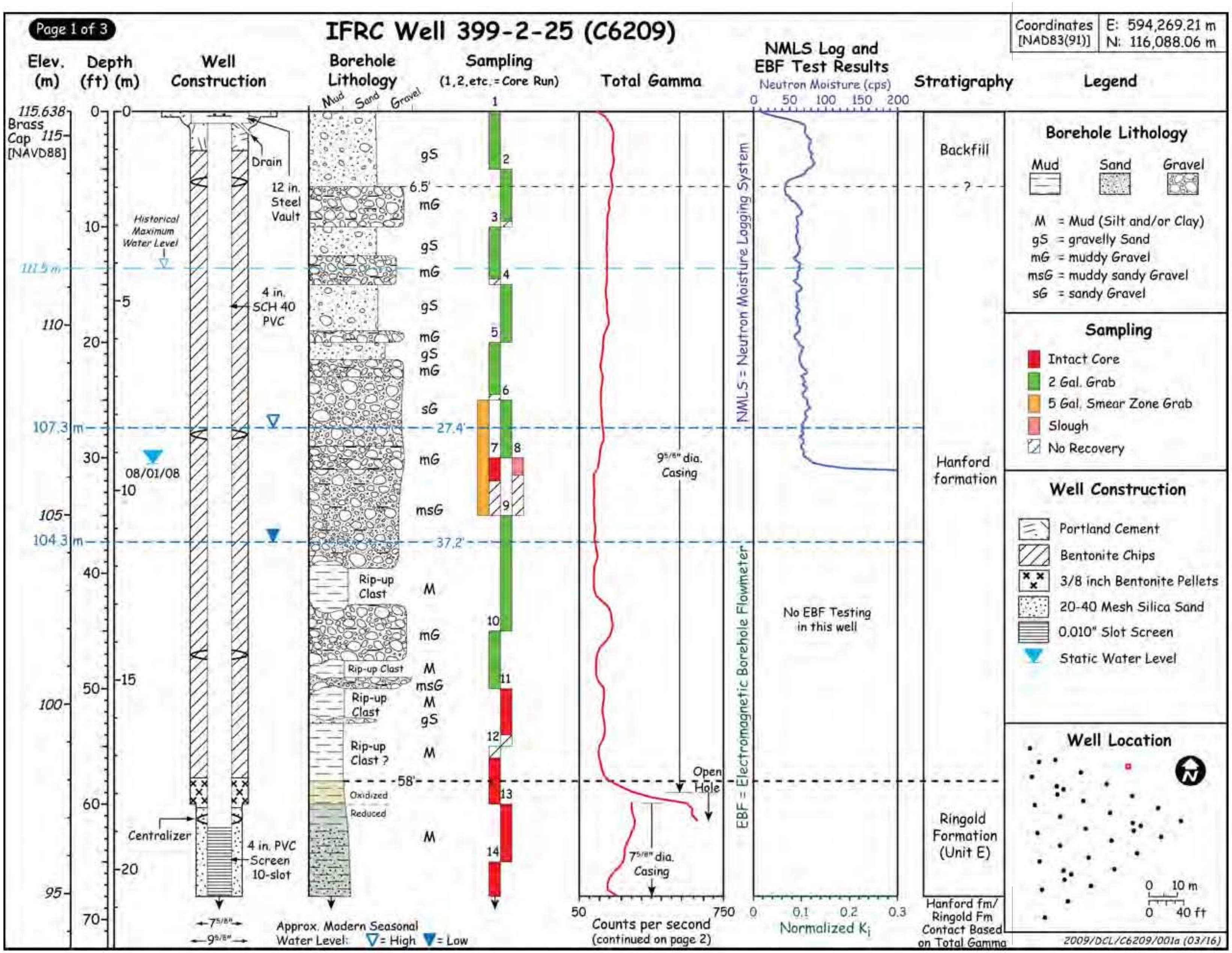

IFRC Well 399-3-28 (C6205)
Coordinates [NAD83(91)]
E: 594,256.10 m
N: 116,045.98 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.900 Brass Cap [NAVD88]
Conduit
Drain
Historical Maximum Water Level
12 in. Steel Vault
111.5 m
12'
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.9'
08/01/08
104.3 m
34.8'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
56'
Oxidized
Reduced
gS
sG
msG
sG
G
M
Total Depth = 64.5' bgs
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Test was completed, but results are not representative of flow profile due to significant bypass flow.
Counts per second
Normalized K_i
Borehole Recovery
Grab Recovery = 80%
Total Recovery = 80%
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
msG= muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6205/001 (03/10)


IFRC Well 399-3-29 (C6206)
Coordinates [NAD83(91)]
E: 594,264.27 m
N: 116,051.97 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.= Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.898 Brass Cap [NAVD88]
Conduit
Drain
Historical Maximum Water Level
12 in. Steel Vault
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.9'
07/11/08
104.3 m
34.8'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
gS
sG
msG
sG
G 52.5'
Oxidized
Reduced
M
Total Depth = 64' bgs
Borehole Recovery
Grab Recovery = 84%
Total Recovery = 84%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
Normalized K_i
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
msG= muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6206/001 (03/10)

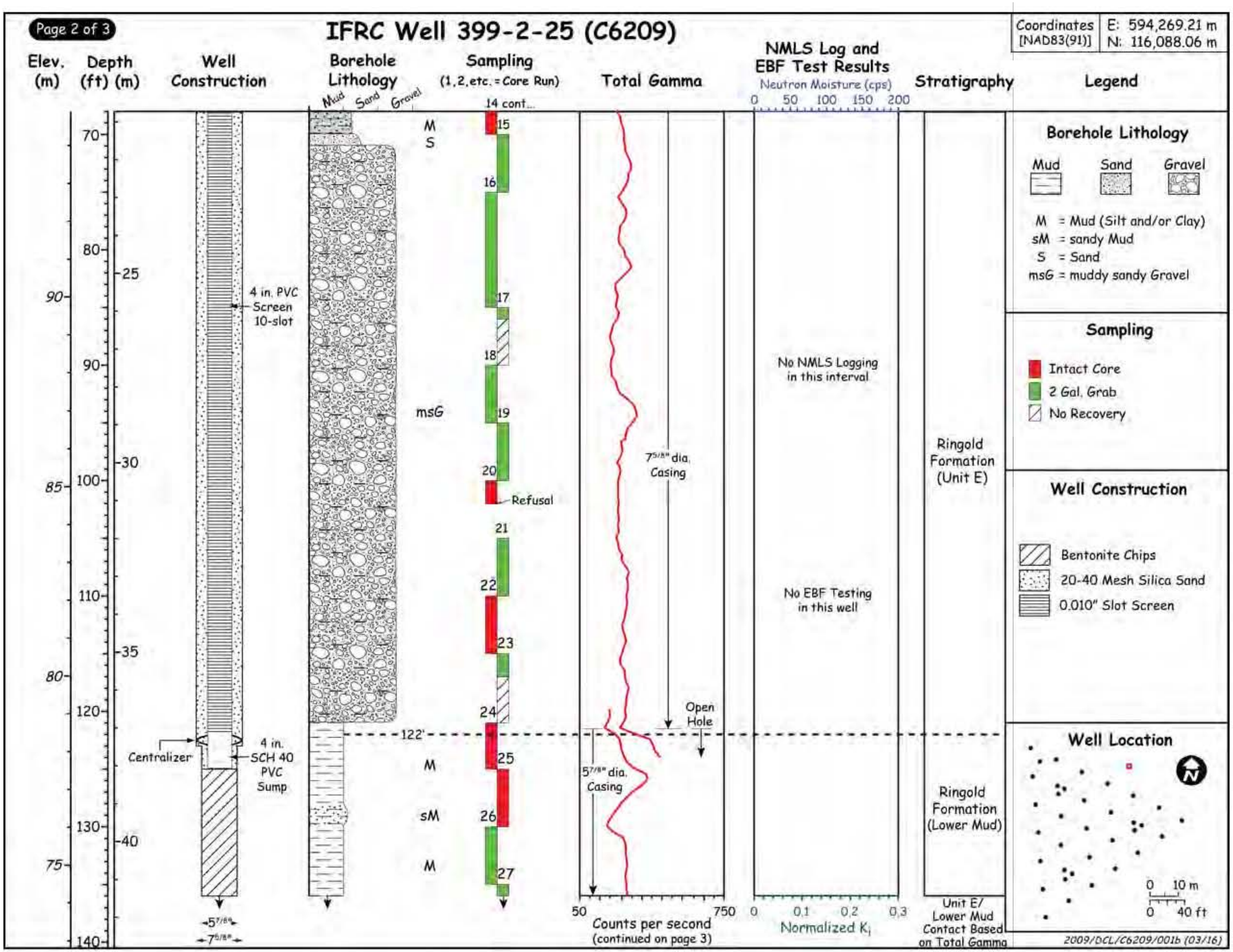


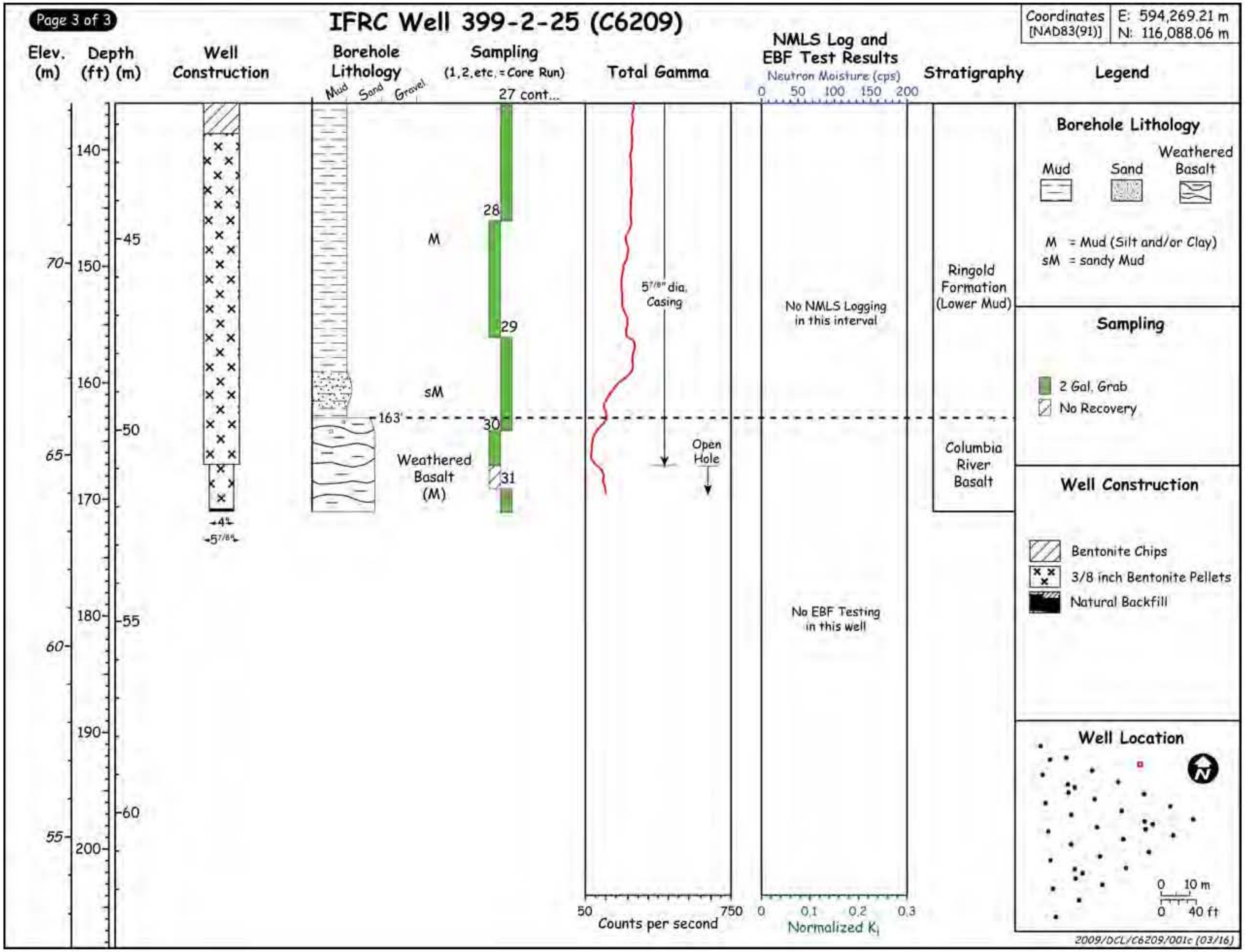
IFRC Well 399-2-23 (C6207)
Coordinates [NAD83(91)]
E: 594,272.27 m
N: 116,057.59 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.875 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.9 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.9'
07/16/08
104.3 m
34.7'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
gS
sG
msG
M
6'
55'
Oxidized
Reduced
Total Depth = 60' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 78%
Total Recovery = 78%
Counts per second
50
750
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
0.329
Normalized K_i
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6207/001 (03/10)


IFRC Well 399-2-24 (C6208)
Coordinates [NAD83(91)]
E: 594,280.67 m
N: 116,063.29 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.889 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
05/29/08
24.9'
104.3 m
34.7'
4 in. dia. 20-slot PVC Screen
Rip-up Clast
Centralizer
58'
6'
Oxidized
Reduced
sG
gS
msG
G
S
M
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Total Depth = 67.5' bgs
Borehole Recovery
Core Recovery = 35%
Grab Recovery = 45%
Total Recovery = 80%
50
750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
Interpolated between EBF measurement and pumping rate
0 0.1 0.2 0.3
Normalized K_i
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6208/001 (03/10)

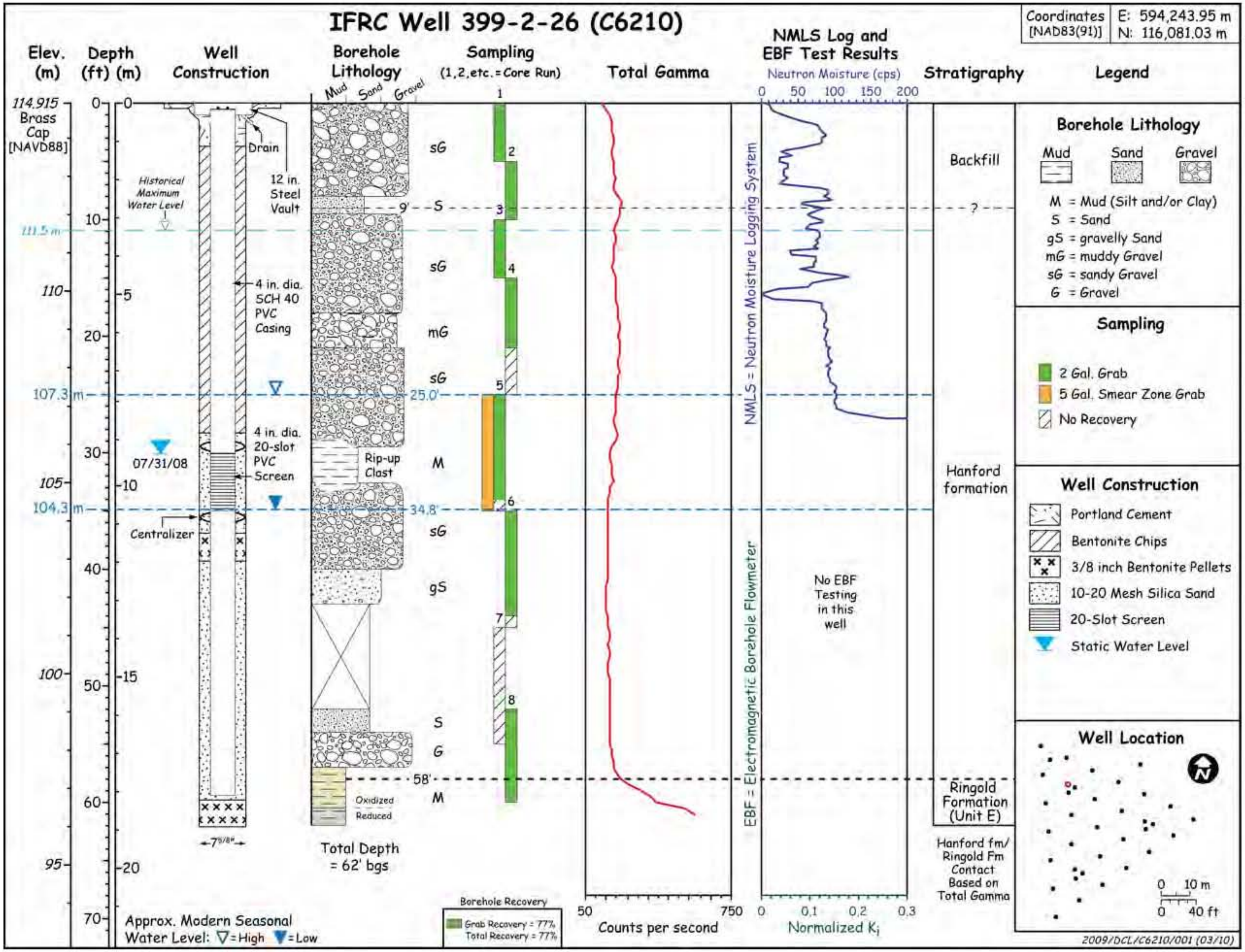


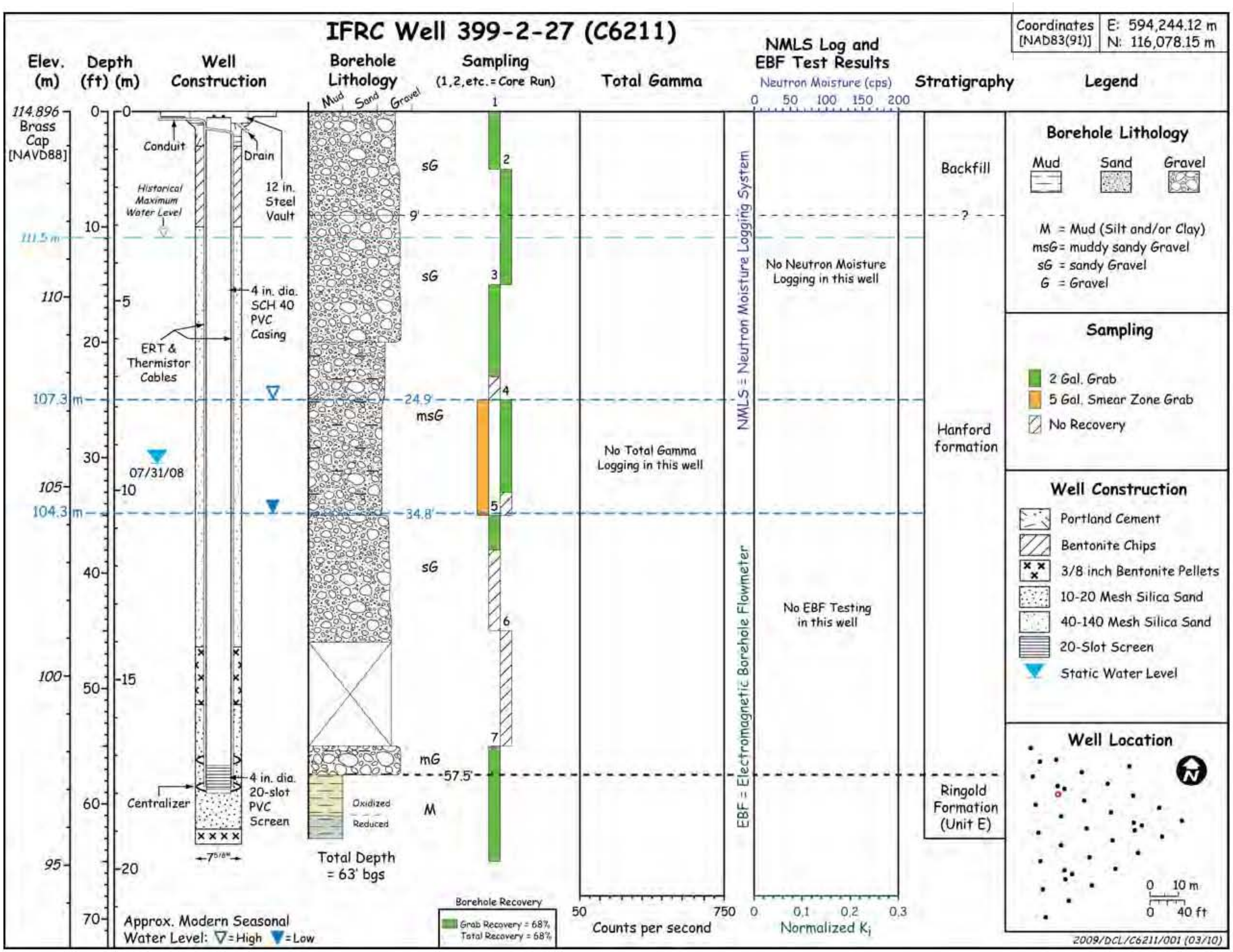
Page 1 of 3
IFRC Well 399-2-25 (C6209)
Coordinates [NAD83(91)]
E: 594,269.21 m
N: 116,088.06 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
115.638 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. SCH 40 PVC
107.3 m
27.4'
08/01/08
104.3 m
37.2'
6.5'
58'
Rip-up Clast
Rip-up Clast ?
Oxidized
Reduced
Centralizer
4 in. PVC Screen 10-slot
9 5/8" dia. Casing
7 5/8" dia. Casing
Open Hole
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Backfill
Hanford formation
Ringold Formation (Unit E)
Approx. Modern Seasonal Water Level: ▽ = High ▼ = Low
Counts per second
(continued on page 2)
Normalized K_i
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
Sampling
Intact Core
2 Gal. Grab
5 Gal. Smear Zone Grab
Slough
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
20-40 Mesh Silica Sand
0.010" Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6209/001a (03/16)

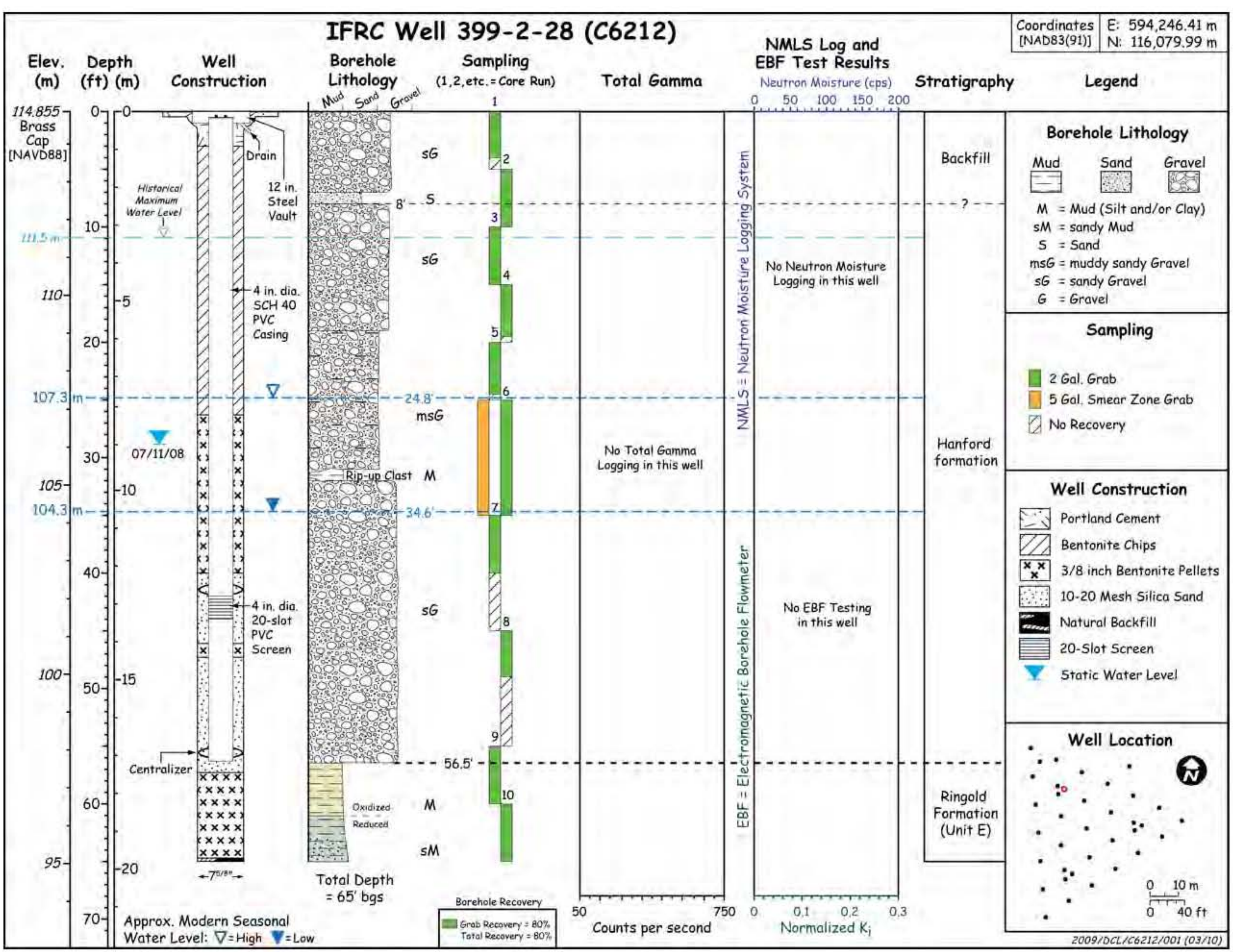

Page 2 of 3
IFRC Well 399-2-25 (C6209)
Coordinates [NAD83(91)]
E: 594,269.21 m
N: 116,088.06 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
14 cont...
M
S
msG
sM
M
4 in. PVC Screen 10-slot
Centralizer
4 in. SCH 40 PVC Sump
Refusal
122'
7⁵/⁸" dia. Casing
Open Hole
5⁷/⁸" dia. Casing
No NMLS Logging in this interval
No EBF Testing in this well
Ringold Formation (Unit E)
Ringold Formation (Lower Mud)
Unit E/ Lower Mud Contact Based on Total Gamma
50 750
Counts per second
(continued on page 3)
0 0.1 0.2 0.3
Normalized Kᵢ
Borehole Lithology
Mud Sand Gravel
M = Mud (Silt and/or Clay)
sM = sandy Mud
S = Sand
msG = muddy sandy Gravel
Sampling
Intact Core
2 Gal. Grab
No Recovery
Well Construction
Bentonite Chips
20-40 Mesh Silica Sand
0.010" Slot Screen
Well Location
0 10 m
0 40 ft
2009/DCL/C6209/001b (03/16)

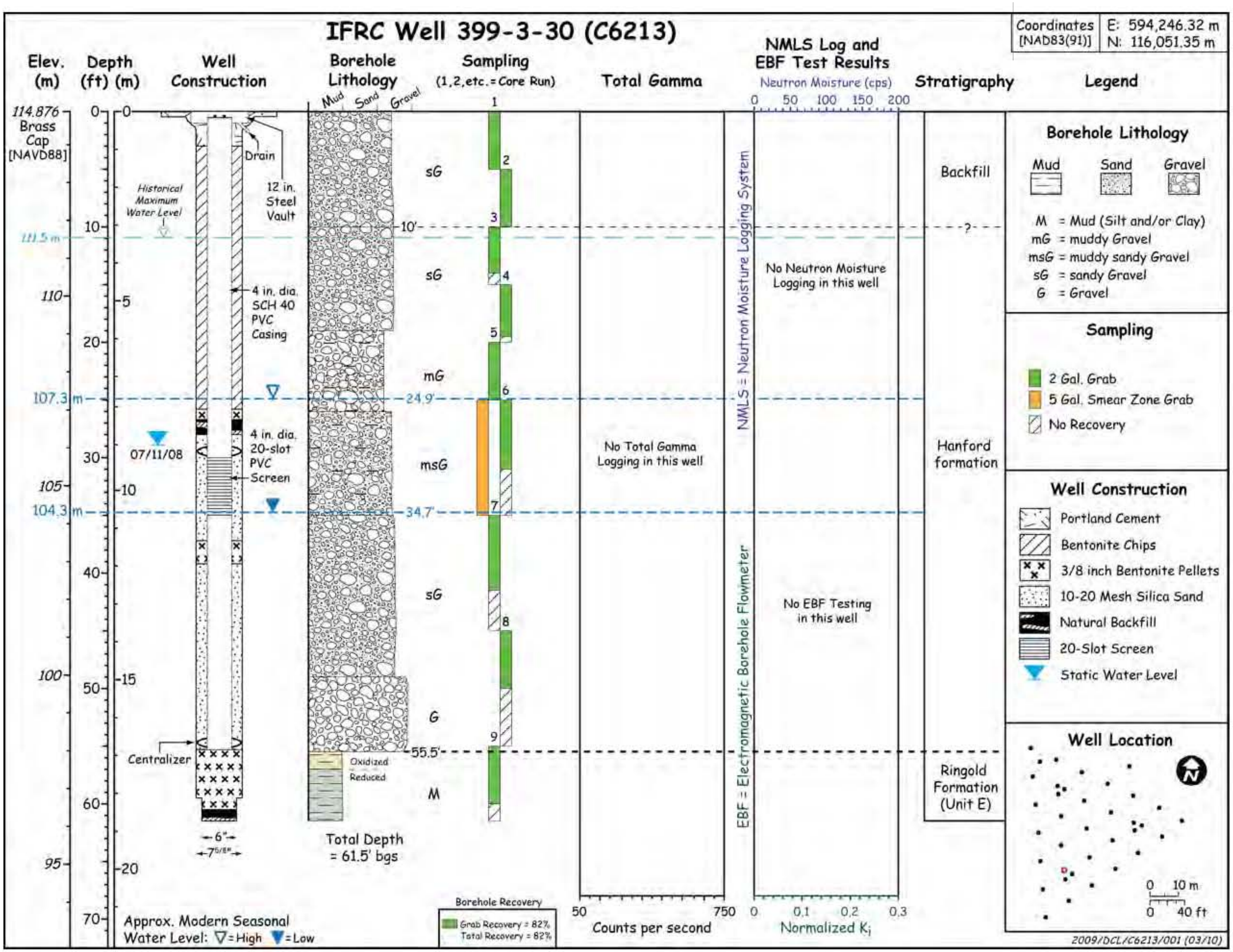


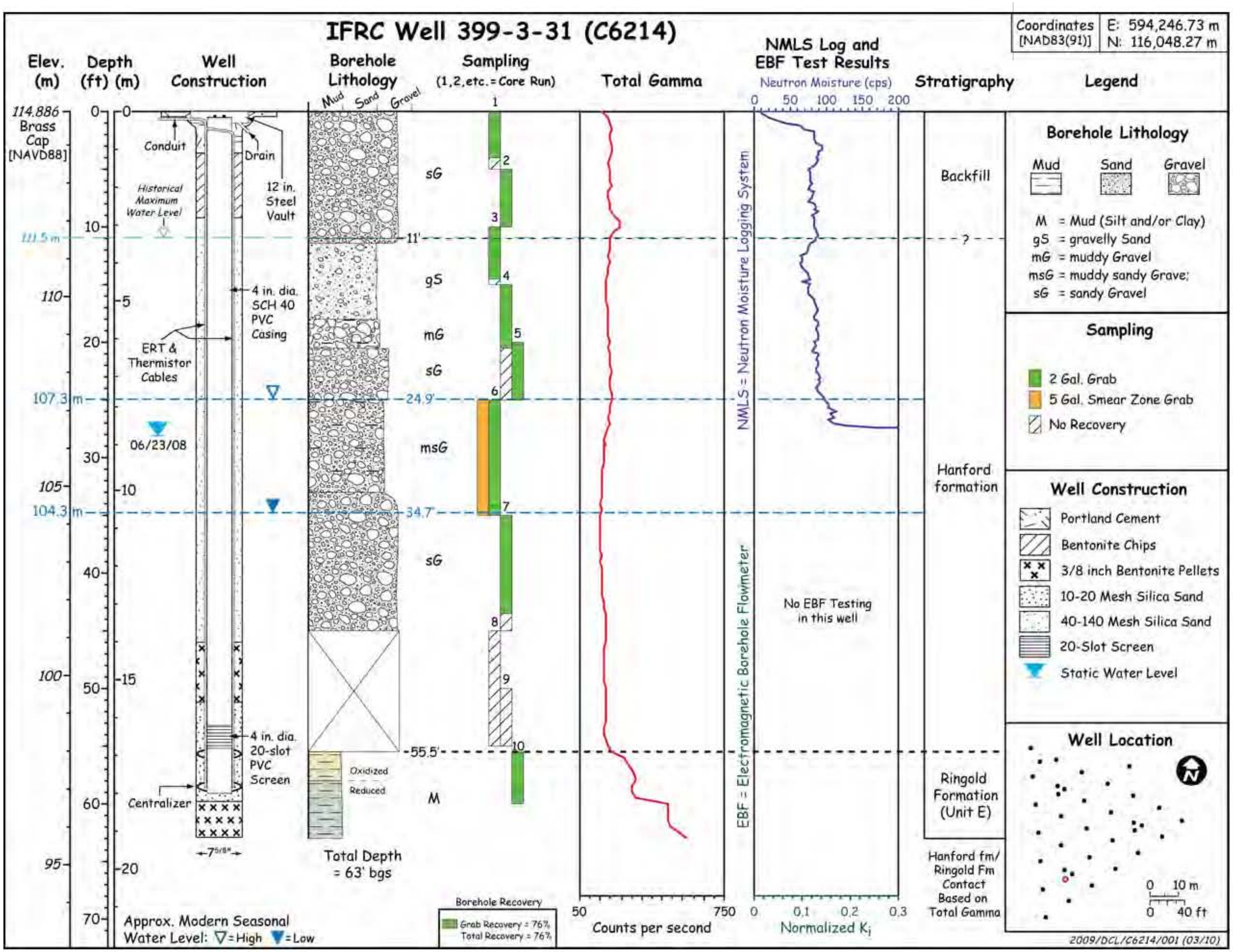
Page 3 of 3
IFRC Well 399-2-25 (C6209)
Coordinates [NAD83(91)]
E: 594,269.21 m
N: 116,088.06 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1, 2, etc. = Core Run)
27 cont...
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
140
150
160
170
180
190
200
45
50
55
60
70
65
60
55
28
29
30
31
M
sM
163'
Weathered Basalt (M)
5 7/8" dia. Casing
Open Hole
4 1/2
5 7/8
No NMLS Logging in this interval
No EBF Testing in this well
Ringold Formation (Lower Mud)
Columbia River Basalt
50
750
Counts per second
0 0.1 0.2 0.3
Normalized K_i
Borehole Lithology
Mud
Sand
Weathered Basalt
M = Mud (Silt and/or Clay)
sM = sandy Mud
Sampling
2 Gal. Grab
No Recovery
Well Construction
Bentonite Chips
3/8 inch Bentonite Pellets
Natural Backfill
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6209/001c (03/16)


IFRC Well 399-2-26 (C6210)
Coordinates [NAD83(91)]
E: 594,243.95 m
N: 116,081.03 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.915 Brass Cap [NAVD88]
111.5 m
110
107.3 m
105
104.3 m
100
95
Drain
12 in. Steel Vault
Historical Maximum Water Level
4 in. dia. SCH 40 PVC Casing
4 in. dia. 20-slot PVC Screen
07/31/08
Centralizer
7 5/8"
Rip-up Clast
9'
25.0'
34.8'
58'
Oxidized
Reduced
Total Depth = 62' bgs
sG
S
sG
mG
sG
M
sG
gS
S
G
M
Borehole Recovery
Grab Recovery = 77%
Total Recovery = 77%
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
50
750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
0 0.1 0.2 0.3
Normalized Ki
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud Sand Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6210/001 (03/10)

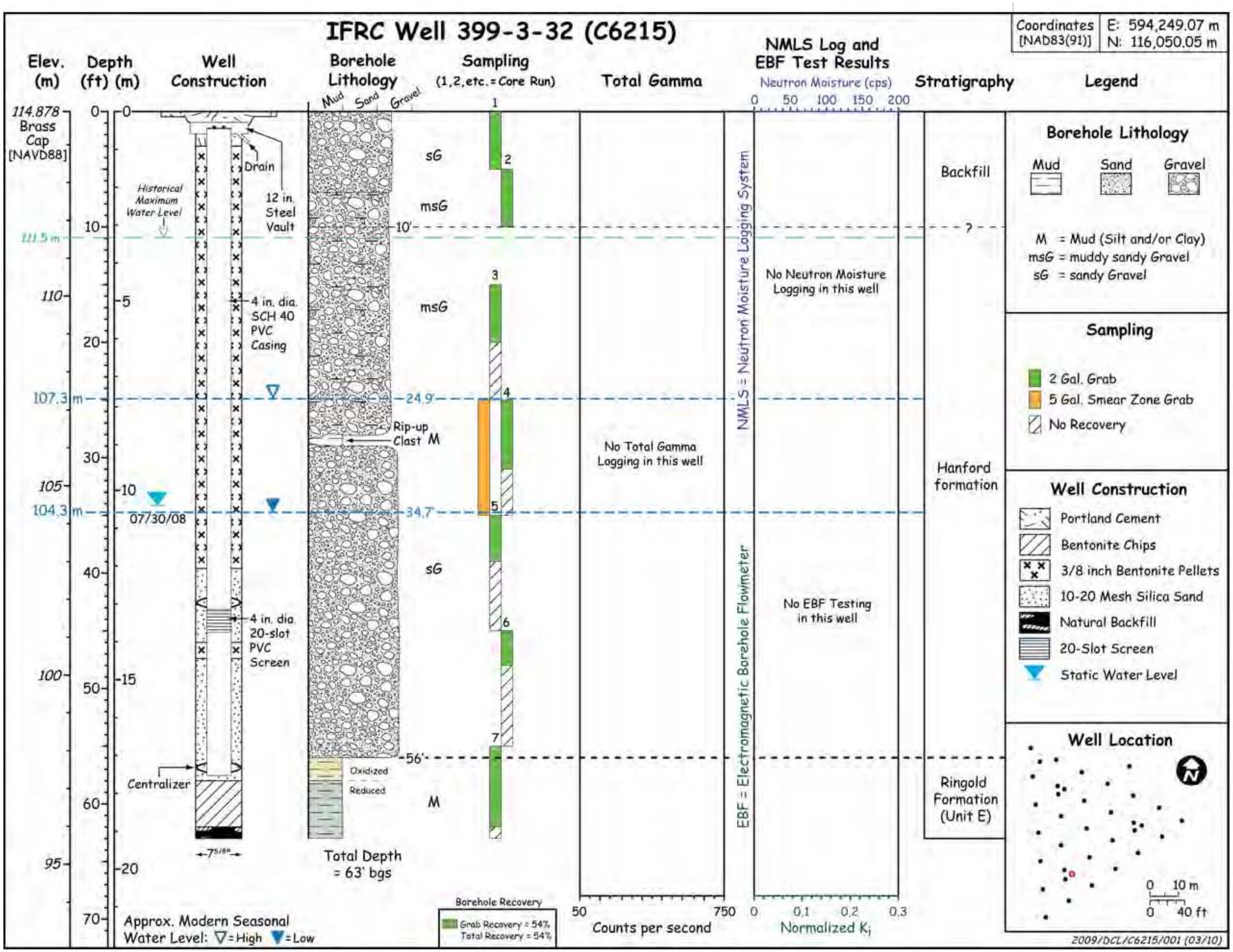

IFRC Well 399-2-27 (C6211)
Coordinates [NAD83(91)]
E: 594,244.12 m
N: 116,078.15 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.= Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.896 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
24.9'
07/31/08
104.3 m
34.8'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
Total Depth = 63' bgs
Oxidized
Reduced
sG
msG
mG
M
9'
57.5'
Borehole Recovery
Grab Recovery = 68%
Total Recovery = 68%
No Total Gamma Logging in this well
Counts per second
NMLS = Neutron Moisture Logging System
No Neutron Moisture Logging in this well
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Normalized K_i
Backfill
Hanford formation
Ringold Formation (Unit E)
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
2009/DCL/C6211/001 (03/10)

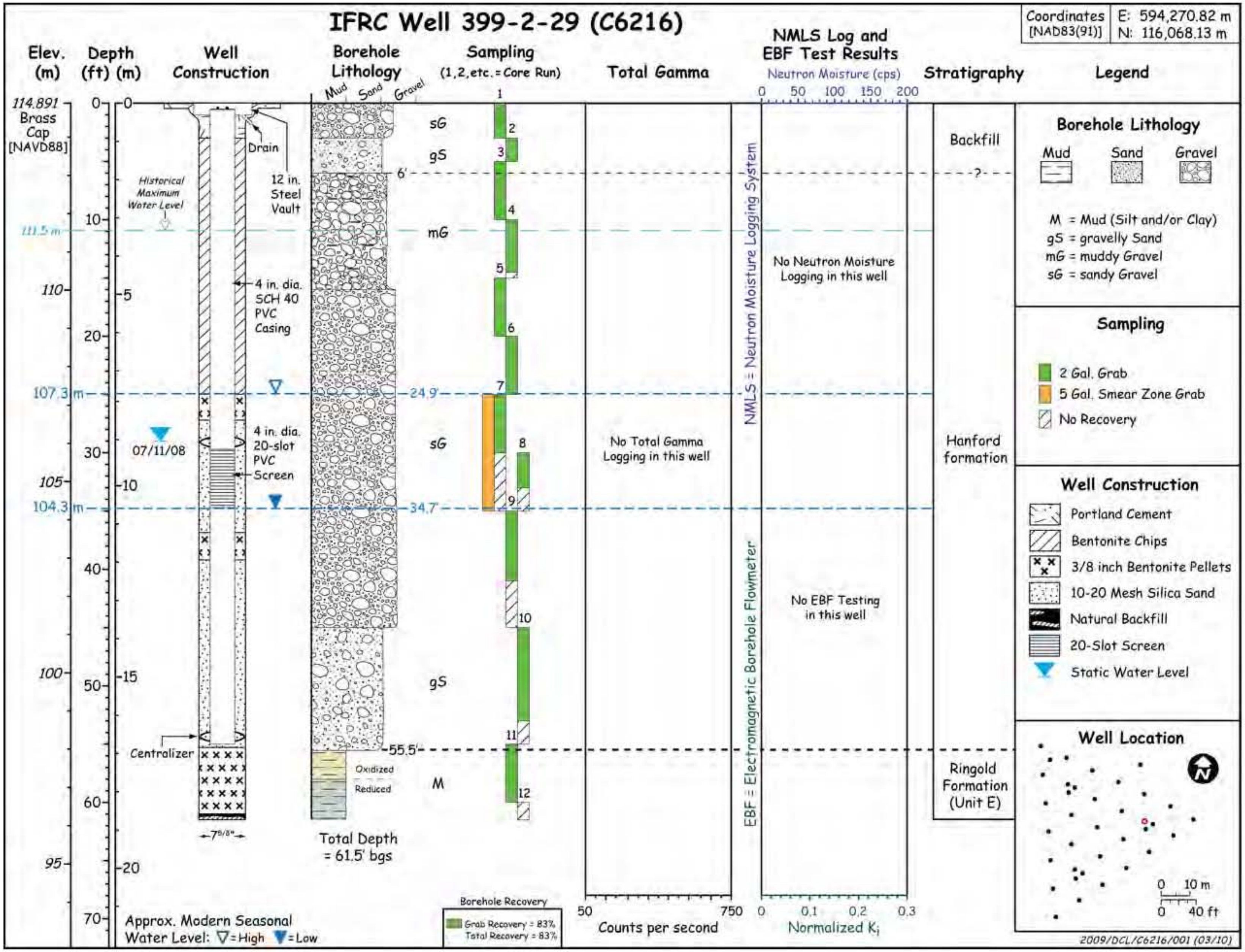

IFRC Well 399-2-28 (C6212)
Coordinates [NAD83(91)]
E: 594,246.41 m
N: 116,079.99 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.855 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
110
4 in. dia. SCH 40 PVC Casing
107.3 m
24.8'
07/11/08
105
104.3 m
34.6'
Rip-up Clast
4 in. dia. 20-slot PVC Screen
100
Centralizer
56.5'
8'
Oxidized
Reduced
95
7 5/8"
Total Depth = 65' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
S
sG
msG
M
sG
M
sM
No Total Gamma Logging in this well
Counts per second
50
750
NMLS = Neutron Moisture Logging System
No Neutron Moisture Logging in this well
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Normalized K_i
0 0.1 0.2 0.3
Backfill
Hanford formation
Ringold Formation (Unit E)
Borehole Recovery
Grab Recovery = 80%
Total Recovery = 80%
Borehole Lithology
Mud Sand Gravel
M = Mud (Silt and/or Clay)
sM = sandy Mud
S = Sand
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6212/001 (03/10)

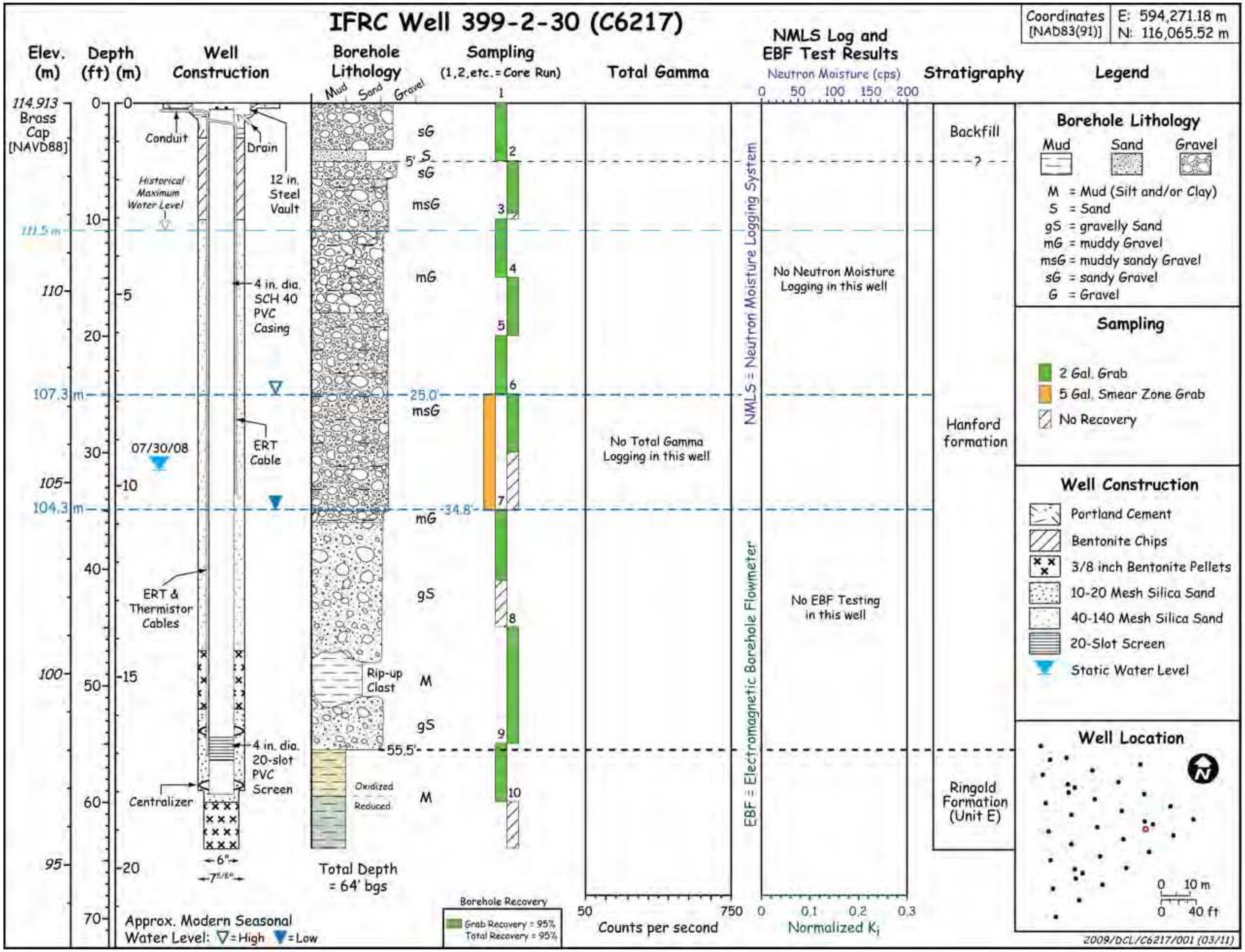

IFRC Well 399-3-30 (C6213)
Coordinates [NAD83(91)]
E: 594,246.32 m
N: 116,051.35 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.876 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
107.3 m
24.9'
07/11/08
4 in. dia. 20-slot PVC Screen
104.3 m
34.7'
10'
55.5'
Centralizer
Oxidized
Reduced
6"
7 5/8"
Total Depth = 61.5' bgs
sG
sG
mG
msG
sG
G
M
No Total Gamma Logging in this well
NMLS = Neutron Moisture Logging System
No Neutron Moisture Logging in this well
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Backfill
Hanford formation
Ringold Formation (Unit E)
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 82%
Total Recovery = 82%
Counts per second
Normalized K_i
2009/DCL/C6213/001 (03/10)

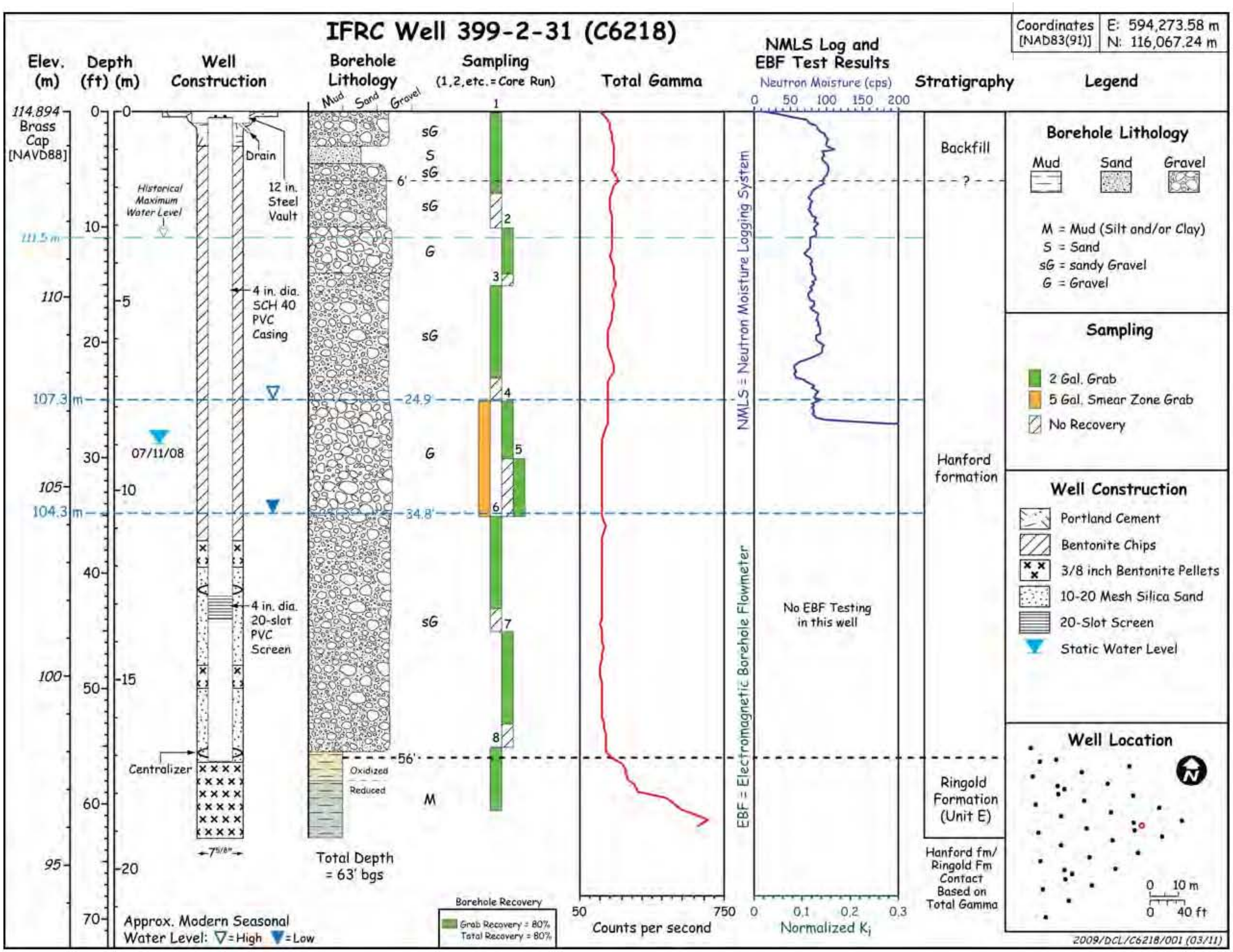


IFRC Well 399-3-31 (C6214)
Coordinates [NAD83(91)]
E: 594,246.73 m
N: 116,048.27 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.886 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
ERT & Thermistor Cables
107.3 m
06/23/08
104.3 m
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
11'
24.9'
34.7'
55.5'
sG
gS
mG
sG
msG
sG
M
Oxidized
Reduced
Total Depth = 63' bgs
Borehole Recovery
Grab Recovery = 76%
Total Recovery = 76%
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Normalized K$_i$
Backfill
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6214/001 (03/10)


IFRC Well 399-3-32 (C6215)
Coordinates [NAD83(91)]
E: 594,249.07 m
N: 116,050.05 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.878 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
107.3 m
105
104.3 m
07/30/08
100
95
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
sG
msG
msG
Rip-up Clast M
sG
M
10'
24.9'
34.7'
56'
Oxidized
Reduced
Total Depth = 63' bgs
No Total Gamma Logging in this well
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No Neutron Moisture Logging in this well
No EBF Testing in this well
Backfill
Hanford formation
Ringold Formation (Unit E)
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
msG = muddy sandy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
Borehole Recovery
Grab Recovery = 54%
Total Recovery = 54%
50
750
Counts per second
0 0.1 0.2 0.3
Normalized Ki
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
2009/DCL/C6215/001 (03/10)


IFRC Well 399-2-29 (C6216)
Coordinates [NAD83(91)]
E: 594,270.82 m
N: 116,068.13 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
Stratigraphy
Legend
114.891 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
107.3 m
24.9'
07/11/08
4 in. dia. 20-slot PVC Screen
104.3 m
34.7'
Centralizer
7 5/8"
sG
gS
6'
mG
sG
gS
55.5'
M
Oxidized
Reduced
Total Depth = 61.5' bgs
No Total Gamma Logging in this well
NMLS = Neutron Moisture Logging System
No Neutron Moisture Logging in this well
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
Backfill
Hanford formation
Ringold Formation (Unit E)
Borehole Recovery
Grab Recovery = 83%
Total Recovery = 83%
Counts per second
Normalized K_i
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
gS = gravelly Sand
mG = muddy Gravel
sG = sandy Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
Natural Backfill
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6216/001 (03/10)


IFRC Well 399-2-30 (C6217)
Coordinates [NAD83(91)]
E: 594,271.18 m
N: 116,065.52 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.913 Brass Cap [NAVD88]
Conduit
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
107.3 m
25.0'
07/30/08
ERT Cable
104.3 m
34.8'
ERT & Thermistor Cables
4 in. dia. 20-slot PVC Screen
Centralizer
55.5'
6"
7 5/8"
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
sG
5' S
sG
msG
mG
msG
mG
gS
Rip-up Clast
M
gS
Oxidized
Reduced
M
Total Depth = 64' bgs
Borehole Recovery
Grab Recovery = 95%
Total Recovery = 95%
No Total Gamma Logging in this well
50 750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No Neutron Moisture Logging in this well
No EBF Testing in this well
0 0.1 0.2 0.3
Normalized Ki
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Borehole Lithology
Mud Sand Gravel
M = Mud (Silt and/or Clay)
S = Sand
gS = gravelly Sand
mG = muddy Gravel
msG = muddy sandy Gravel
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
40-140 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
0 10 m
0 40 ft
2009/DCL/C6217/001 (03/11)



IFRC Well 399-2-31 (C6218)
Coordinates [NAD83(91)]
E: 594,273.58 m
N: 116,067.24 m
Elev. (m)
Depth (ft) (m)
Well Construction
Borehole Lithology
Mud Sand Gravel
Sampling (1,2,etc.=Core Run)
Total Gamma
NMLS Log and EBF Test Results
Neutron Moisture (cps)
0 50 100 150 200
Stratigraphy
Legend
114.894 Brass Cap [NAVD88]
Drain
12 in. Steel Vault
Historical Maximum Water Level
111.5 m
4 in. dia. SCH 40 PVC Casing
107.3 m
24.9'
07/11/08
104.3 m
34.8'
4 in. dia. 20-slot PVC Screen
Centralizer
7 5/8"
Oxidized
Reduced
56'
6'
sG
S
sG
sG
G
sG
G
sG
M
Total Depth = 63' bgs
Approx. Modern Seasonal Water Level: ▽=High ▼=Low
Borehole Recovery
Grab Recovery = 80%
Total Recovery = 80%
50
750
Counts per second
NMLS = Neutron Moisture Logging System
EBF = Electromagnetic Borehole Flowmeter
No EBF Testing in this well
0 0.1 0.2 0.3
Normalized Ki
Backfill
?
Hanford formation
Ringold Formation (Unit E)
Hanford fm/ Ringold Fm Contact Based on Total Gamma
Borehole Lithology
Mud
Sand
Gravel
M = Mud (Silt and/or Clay)
S = Sand
sG = sandy Gravel
G = Gravel
Sampling
2 Gal. Grab
5 Gal. Smear Zone Grab
No Recovery
Well Construction
Portland Cement
Bentonite Chips
3/8 inch Bentonite Pellets
10-20 Mesh Silica Sand
20-Slot Screen
Static Water Level
Well Location
N
0 10 m
0 40 ft
2009/DCL/C6218/001 (03/11)

Appendices B Through I

The following appendixes are provided on the compact disc bound inside the back cover of printed copies of this report:

Appendix B – Well-Site Geologist Logs

Appendix C – Sample Inventory Sheets

Appendix D – Field-Activity Reports

Appendix E – Well Development and Testing Data Sheets

Appendix F – Well Summary Sheets

Appendix G – Downhole Geophysical Logs

Appendix H – Survey Reports

Appendix I – Chip Tray Photographs

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