NORTHWEST
Land & Water, INC.
Consulting in Hydrogeology

6556 37th Ave. NE
Seattle, WA 98115
206-525-0049 p
206-374-2575 f
www.nlwinc.com

Memorandum

Date: June 30, 2013

To: Rick Noll, Project Manager, Spokane Conservation District

From: Jim Mathieu, LG, LHg, Northwest Land & Water, Inc. (NLW)

Re: Addendum 1 to June 2012 West Plains and Lower Hangman Creek Hydro-geologic Study

Introduction

This memorandum documents the work conducted to complete Tasks 6, 7, and 8 of Amendment 1 to Ecology Grant G1200416:

- Task 6: Whole Rock Analysis
- Task 7: Install Well 2nd Well at Marshall Pit (MW-11)
- Task 8: Write Memorandum

It serves as an addendum to the report dated June 30, 2012, entitled *West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling Final Report,* referred to herein as the 2012 report. The 2012 report was an addendum to an earlier report (NLW, 2011).

The results of Tasks 6 and 7 are summarized below. The Task 8 work product is this memorandum.

Task 6: Whole Rock Analysis

NLW logged and collected drill cuttings in 2010 and 2012 from eleven boreholes located in the Hangman Creek watershed (WRIA 56) and West Plains area of WRIA 54. In an effort to better understand the Colombia River Basalt Group stratigraphy from these boreholes, select basalt samples where analyzed for whole rock geochemistry at Peter Hooper GeoAnalytical Laboratory, Washington State University, Pullman. The samples consisted of air rotary drill cuttings that were collected from five-foot sections of drilled basalt.

Under this task, basalt drill cuttings were selected, stored, and submitted by geologists Robert Derkey (well MW-6 samples) and Michael Hamilton (wells MW-7, -8, and-9 samples) for whole rock geochemistry. Note that basalt samples from wells MW-1 through -5 were analyze under previous work (NLW, 2011); MW-10 drilling did not encounter basalt; and samples from the small MW-11 basalt section were not analyze because MW-11 is adjacent to the analyzed basalt section of MW-7.

The laboratory results for Task 6 are shown in **Table A1-1** for MW-6 and for **Tables A1-2a and b** for MW-7, -8, and -9. Basalt flow / formation or member / formation associated with each sample are also listed in these tables.

Task 7: Install Well 2nd Well at Marshall Pit (MW-11)

The borehole for well MW-11 was drilled to a depth of 262 feet below ground in April 2012. A basalt aquifer was encountered from 233 – 240 feet. In November 2012, a monitoring well was completed in this "shallow" basalt aquifer at the Marshall pit. Note that in spring 2012 a monitoring well (nearby well MW-7) was completed in a "deep" basalt aquifer (NLW, 2012).

The well log and as-built for MW-11 is shown on **Figures A1-1 and A1-2**.

References

Northwest Land & Water, 2011. Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling. Prepared for Spokane County Conservation District, June 1, 2011.

Northwest Land & Water, 2012. West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling Final Report, An Addendum to: Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling Final Report, June 30, 2012.

Table A1-1 Whole Rock Analysis Results
Borehole Samples from MW-6

Sample ID	BH6-90	BH6-190	BH6-250	BH6-285	BH6-335	BH6-380
Flow Identity*	PR	PR	SF	SF	CC	CC
Unnormalized Major Elements (Weight %):						
SiO2	48.63	49.65	54.67	54.35	54.00	53.89
TiO2	3.53	3.61	1.97	1.96	1.93	1.92
Al2O3	12.42	12.76	14.99	14.88	14.01	13.73
FeO*	15.45	15.10	9.70	10.37	11.63	12.09
MnO	0.27	0.24	0.17	0.18	0.21	0.19
MgO	4.24	4.29	3.73	3.97	4.37	4.44
CaO	8.35	8.42	8.52	8.88	8.52	8.20
Na2O	2.71	2.89	2.98	2.95	2.98	3.13
K2O	1.31	1.22	1.26	1.15	1.42	1.20
P2O5	0.79	0.79	0.30	0.29	0.44	0.42
sum	97.69	98.97	98.28	98.99	99.52	99.23
Unnormalized Trace Elements (ppm):						
Ni	19.50	18.71	17.42	15.44	15.15	14.75
Cr	10.49	12.28	44.45	43.56	36.53	32.57
Sc	37.92	40.10	37.72	37.92	36.04	34.75
V	416.69	428.37	343.93	344.52	282.35	276.21
Ba	565.39	578.95	604.59	583.11	539.85	541.13
Rb	32.47	31.68	35.44	32.18	33.86	31.09
Sr	285.81	289.48	338.58	334.72	318.38	310.56
Zr	221.96	229.09	170.08	168.30	173.45	173.94
Y	48.91	49.80	36.43	38.51	37.22	37.62
Nb	17.13	18.51	11.68	11.19	12.28	12.18
Ga	21.58	20.99	21.09	20.89	20.69	20.89
Cu	22.08	24.16	38.41	38.21	29.90	29.21
Zn	152.66	159.98	129.10	128.21	125.93	124.44
Pb	4.75	5.35	6.63	5.25	6.24	5.05
La	29.70	30.79	20.00	25.25	25.64	20.30
Ce	67.82	68.41	49.01	50.19	46.33	44.15
Th	3.37	3.66	4.06	3.96	4.06	5.64
Nd	37.62	42.17	25.84	27.03	25.15	25.54
U	1.78	1.68	0.99	1.58	1.19	2.38

*** Flow Identity Nomemclature:**

PR = Preist Rapids Member, Wanapum Basalt Formation

SF = Spokane Falls Flow, Grande Ronde Basalt Formation

CC = California Creek Flow, Grande Ronde Basalt Formation

Table A1-2a Whole Rock Analysis Results
Borehole Samples from MW-7,-8, and -9

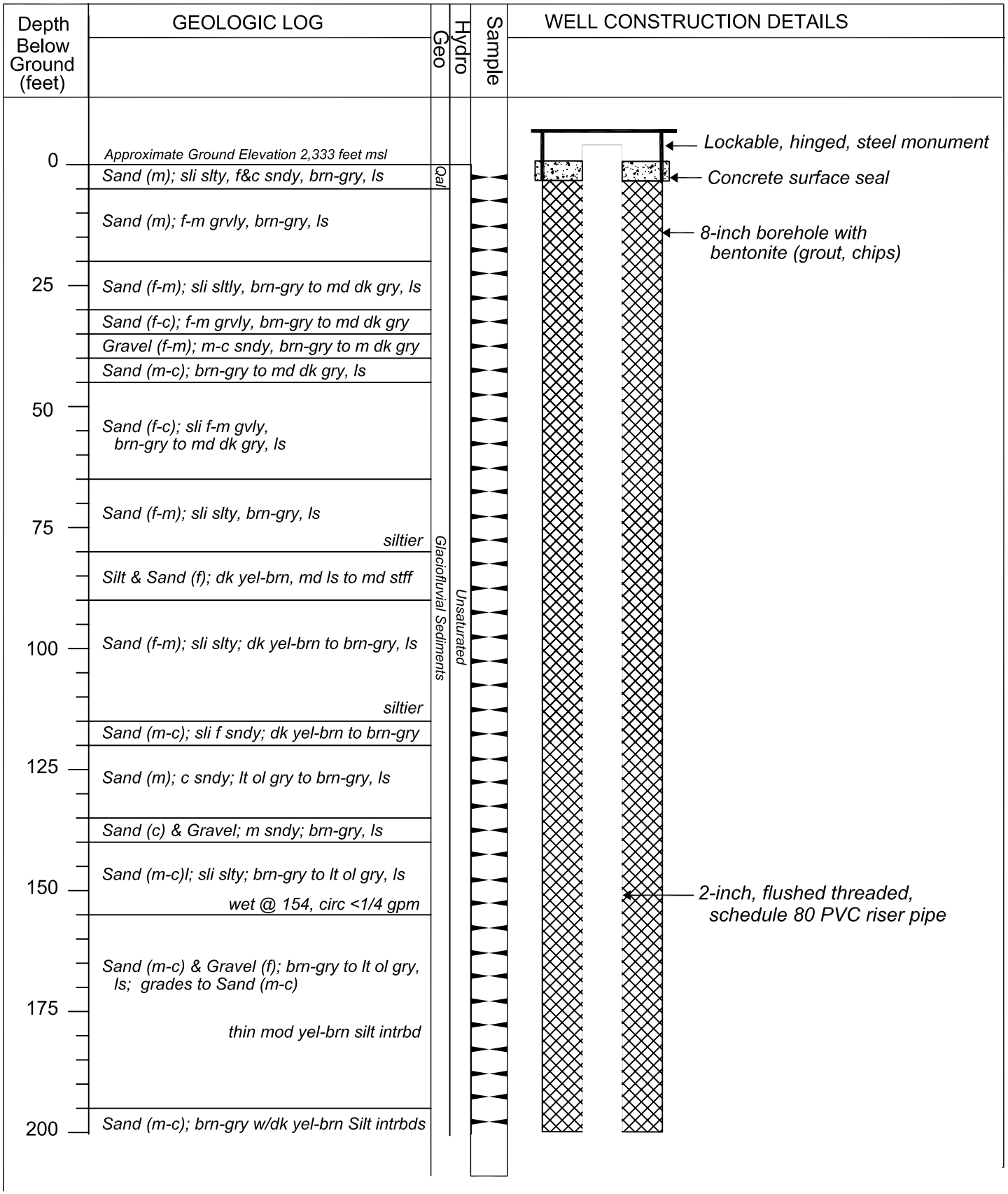
Sample ID	B8-30	B8-50	B8-70	B8-90	B8-120	B8-220	B8-250	B8-305	B8-335	B8-355	B8-375	B7-260	B7-280	B7-310	B7-325	B7-345	B9-245	B9-260	B9-295
Flow Identity*	PR	PR	PR	PR	PR	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	WR	WR	WR
Unnormalized Major Elements (Weight %):																			
SiO2	49.51	49.99	49.04	48.99	49.63	53.56	53.44	53.80	54.25	53.91	53.71	54.07	53.87	54.05	53.84	53.81	54.51	55.40	54.56
TiO2	3.595	3.696	3.608	3.673	3.597	1.842	1.827	1.884	1.894	1.881	1.888	1.883	1.859	1.845	1.847	1.848	2.416	2.434	2.439
Al2O3	12.67	12.81	12.60	12.75	12.78	14.25	14.00	13.94	14.03	13.94	13.85	14.18	14.07	14.12	14.12	14.08	13.35	13.67	13.31
FeO*	14.95	14.77	15.27	14.72	14.82	10.84	11.31	11.62	11.38	11.69	11.62	11.10	11.19	11.08	11.01	11.32	12.43	11.83	12.47
MnO	0.246	0.245	0.253	0.238	0.243	0.183	0.191	0.207	0.195	0.207	0.207	0.194	0.193	0.194	0.192	0.197	0.210	0.209	0.202
MgO	4.50	4.55	4.30	4.20	4.57	4.35	4.33	4.83	4.18	4.86	4.74	4.53	4.66	4.85	4.83	4.80	3.35	3.10	3.16
CaO	8.40	8.53	8.41	8.50	8.48	8.81	8.68	8.52	8.41	8.53	8.40	8.76	8.66	8.67	8.67	8.68	7.05	6.90	6.88
Na2O	2.77	2.84	2.78	2.75	2.77	2.75	2.83	2.96	3.10	3.00	2.92	2.89	2.89	2.90	2.89	2.81	3.19	3.51	3.41
K2O	1.25	1.33	1.35	1.27	1.31	1.12	1.19	1.23	1.13	1.17	1.31	1.29	1.25	1.26	1.26	1.33	1.87	1.73	1.67
P2O5	0.784	0.804	0.799	0.800	0.786	0.293	0.292	0.372	0.388	0.366	0.380	0.301	0.298	0.298	0.298	0.298	0.418	0.435	0.418
Sum	98.68	99.55	98.41	97.89	98.98	98.00	98.09	99.36	98.97	99.55	99.03	99.19	98.93	99.28	98.96	99.18	98.78	99.21	98.53
Unnormalized Trace Elements (ppm):																			
Ni	19	19	21	20	19	14	15	17	13	16	15	16	16	19	18	18	8	7	7
Cr	8	10	8	10	13	44	42	39	38	39	37	40	42	42	41	41	0	0	0
Sc	40	38	39	41	38	36	36	36	35	35	36	36	37	36	36	36	34	35	35
V	418	430	421	426	422	332	330	297	287	299	291	337	334	331	333	334	359	355	358
Ba	580	586	589	592	578	489	540	512	528	511	521	503	502	502	500	492	723	759	713
Rb	34	34	33	32	33	30	33	31	28	31	32	33	33	32	33	32	46	48	45
Sr	289	294	289	296	290	317	315	308	311	310	307	313	311	312	311	311	330	335	325
Zr	225	230	228	228	224	158	158	166	167	165	168	162	162	159	158	161	191	197	191
Y	49	51	50	51	50	33	33	35	35	35	36	34	34	34	33	33	39	39	39
Nb	18.3	17.8	18.9	17.9	17.6	11.6	11.3	11.9	11.6	11.8	11.5	11.4	12.0	11.3	10.4	11.4	13.8	13.7	13.1
Ga	24	22	22	23	22	21	18	20	21	20	20	23	21	20	22	20	23	22	20
Cu	23	24	25	23	24	35	35	35	32	33	35	37	37	37	36	36	13	12	13
Zn	156	161	160	159	157	117	115	118	120	120	122	116	116	114	116	117	138	144	140
Pb	6	6	6	6	5	5	6	6	5	6	7	6	6	6	7	7	8	9	8
La	28	35	28	26	28	22	18	20	21	17	19	20	20	22	18	20	25	25	27
Ce	70	69	66	67	73	41	46	47	48	48	46	46	44	47	43	46	55	56	59
Th	5	4	5	4	3	4	3	4	4	4	4	4	5	4	3	5	5	6	5
Nd	39	40	38	41	39	23	24	26	27	26	27	23	21	24	24	24	29	31	31
U	3	3	1	2	2	4	2	2	3	1	2	2	2	2	2	1	4	1	2	1
sum tr.	2034	2073	2048	2065	2037	1737	1779	1732	1736	1727	1736	1764	1754	1753	1742	1749	2041	2096	2030

*** Flow Identity Nomemclature:**
PR = Preist Rapids Member, Wanapum Basalt Formation
SB = Sentinel Bluffs Member, Grande Ronde Basalt Formation
WR = Wapshilla Ridge Member, Grande Ronde Basalt Formation

Table A1-2b Whole Rock Analysis Results
Borehole Sample from MW-9

Sample ID	NLW BH9 230-235	NLW BH9 245-250	NLW BH9 270-275	NLW BH9 280-285	NLW BH9 285-290	NLW BH9 295-300
Flow ID	WR	WR	WR	WR	WR	WR
	Unnormalized Major Elements (Weight %):					
SiO2	55.78	54.25	55.18	54.77	54.46	54.72
TiO2	2.613	2.402	2.471	2.452	2.418	2.430
Al2O3	14.21	13.25	13.58	13.54	13.34	13.33
FeO*	9.77	12.65	11.72	12.13	12.58	12.89
MnO	0.187	0.213	0.198	0.190	0.200	0.205
MgO	3.08	3.33	3.15	3.11	3.21	3.20
CaO	7.26	7.04	7.21	6.83	6.84	6.95
Na2O	3.46	3.20	3.25	3.46	3.40	3.44
K2O	1.82	1.88	1.90	1.71	1.72	1.68
P2O5	0.461	0.420	0.425	0.425	0.421	0.420
Sum	98.65	98.64	99.09	98.63	98.58	99.26
	Unnormalized Trace Elements (ppm):					
Ni	6	6	7	8	7	7
Cr	0	0	0	0	0	0
Sc	37	35	35	34	33	34
V	384	355	366	361	358	358
Ba	962	716	817	741	720	714
Rb	44	46	47	46	47	46
Sr	368	330	343	330	323	325
Zr	202	192	196	197	199	193
Y	42	40	40	39	39	40
Nb	13.9	14.1	13.7	13.8	14.1	13.5
Ga	23	21	22	23	23	22
Cu	13	13	13	14	14	12
Zn	151	140	141	141	143	139
Pb	9	9	9	8	8	7
La	30	29	28	23	30	25
Ce	61	60	62	56	60	59
Th	6	6	5	7	7	5
Nd	32	31	31	30	32	32
U	2	2	3	2	2	3
sum tr.	2386	2046	2177	2075	2059	2035

*** Flow Identity Nomemclature:**
WR = Wapshilla Rigde Member, Grande Ronde Basalt Formation



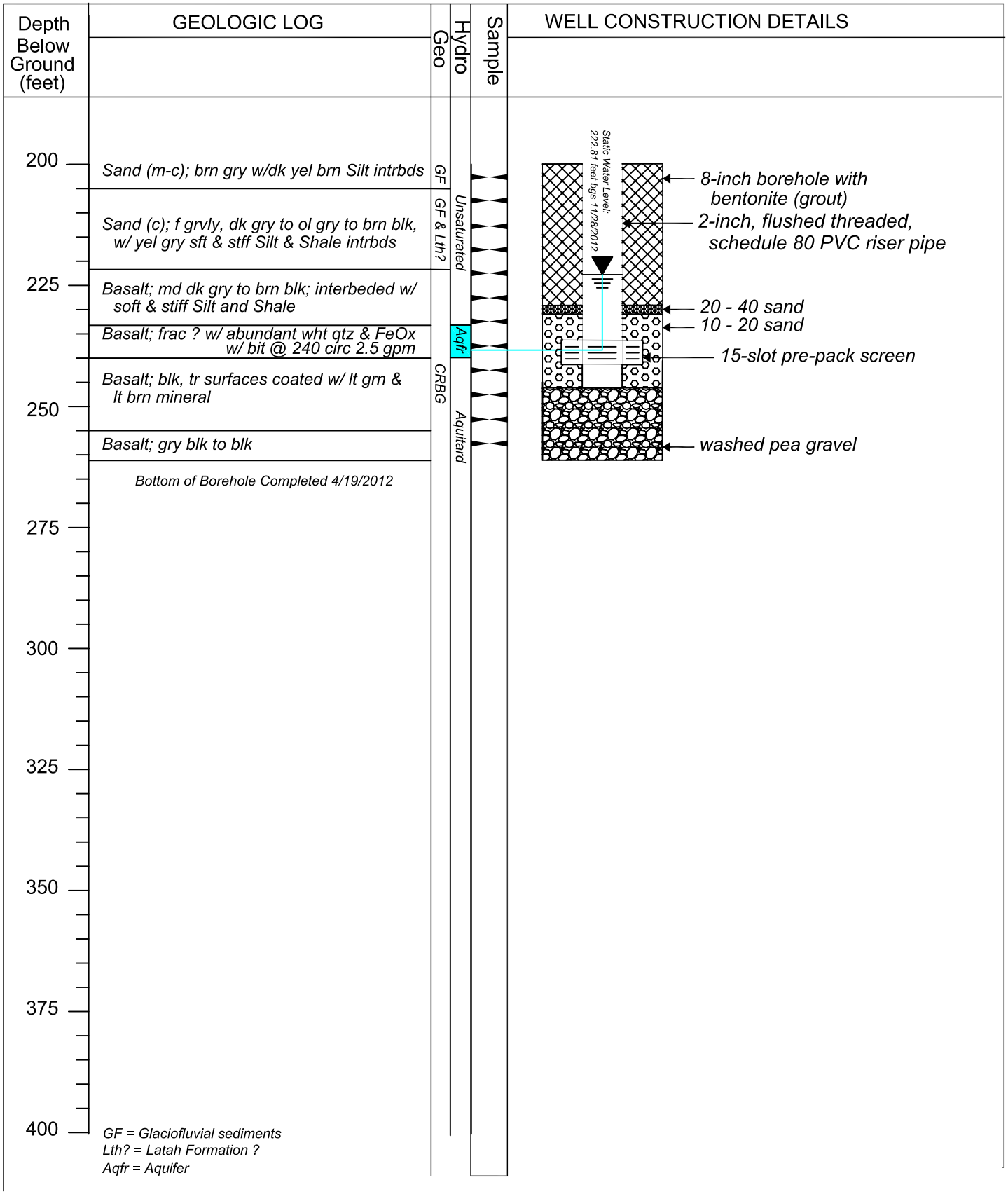
PROJECT NAME: West Plains and L Hangman Ck Study
DRILLING METHOD: Air Rotary
DRILLER: Jim McLeslie, Kevin Young (helper)
FIRM: H2O Well Services, Inc
CONSULTING FIRM: Northwest Land & Water, Inc
REPRESENTATIVE: Jim Mathieu, Hydrogeologist
LOCATION: NE 1/4 SE 1/4 Sec 16, T24N, R42E
WELL NAME: MW-11
WELL TAG ID: BCL 666

Figure A1-1 (pg 1/2)
MW-11 Geologic Log and Well Construction Details

NORTHWEST Land & Water, INC.

West Plains and L Hangman Ck Hydrogeologic Study
Addendum to Hangman Ck Hydrogeologic Study
Spokane County Conservation District

D:\Projects\WRIA_54_56\Log&AsBuilts\Asbuilt and GeoLog_ MW11(aka Marshall Pit)_pg1of2 version 06/28/13



PROJECT NAME: West Plains and L Hangman Ck Study
DRILLING METHOD: Air Rotary
DRILLER: Jim McLeslie, Kevin Young (helper)
FIRM: H2O Well Services, Inc
CONSULTING FIRM: Northwest Land & Water, Inc
REPRESENTATIVE: Jim Mathieu, Hydrogeologist
LOCATION: NE 1/4 SE 1/4 Sec 16, T24N, R42E
WELL NAME: MW-11
WELL TAG ID: BCL 666

Figure A1-1 (pg 2/2)

MW-11 Geologic Log and Well Construction Details

NORTHWEST Land & Water, INC.

West Plains and L Hangman Ck Hydrogeologic Study
Addendum to Hangman Ck Hydrogeologic Study
Spokane County Conservation District

D:\Projects\WRIA_54_56\Log&AsBuilts\Asbuilt and GeoLog_ MW11(aka Marshall Pit)_pg2of2.dwg version 06/28/13