
Final Environmental Impact Statement
Thacker Pass Lithium Mine Project

Appendix P, Part 7 of 8

Water Information

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APPENDIX L
Geochemical sensitivity analyses

North Sub-Pit

Appendix L - Sensitivity Analysis

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North Sub-Pit

Appendix L - Sensitivity Analysis

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North Sub-Pit
Open Pit Scenario

Appendix L - Sensitivity Analysis

Open Pit Alternative

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South Sub-Pit

Partially Backfilled Pit Scenario

Appendix L - Sensitivity Analysis

Partially Backfilled South Sub-pit Alternative

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Appendix L - Sensitivity Analysis

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Partially Backfilled Pit Scenario

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Partially Backfilled South Sub-pit Alternative

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Appendix L - Sensitivity Analysis

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South Sub-Pit

Appendix L - Sensitivity Analysis

		75 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.69	7.60	8.52	7.84	7.66	7.70	7.68	7.73	7.42
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	251	228	2,126	326	237	253	244	275	103
Aluminum	4.47	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.286	0.754	0.286	0.302	0.336	0.288	0.281	0.291	0.019
Arsenic	0.2	0.393	0.899	0.423	0.449	0.442	0.405	0.362	0.483	0.024
Barium	23.1	0.01	0.01	0.49	0.02	0.01	0.01	0.01	0.01	0.03
Beryllium	2.83	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	4.18	7.69	4.18	4.38	4.60	4.46	3.40	6.61	0.16
Cadmium	0.05	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.000
Calcium	----	370	633	940	146	474	369	381	330	50
Chloride	----	1,258	3,321	1,258	728	1,526	1,292	1,167	1,541	60
Chromium	1	0.005	0.003	0.009	0.009	0.004	0.006	0.003	0.010	0.000
Copper	0.5	0.04	0.08	0.10	0.03	0.05	0.04	0.04	0.04	0.00
Fluoride	2	4.15	4.13	45.92	4.72	4.10	4.17	4.10	4.34	2.19
Iron	----	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.004	0.003	0.007	0.005	0.003	0.004	0.003	0.006	0.000
Lithium	40.3	8.35	23.76	8.35	4.30	10.52	8.52	7.94	9.52	0.38
Magnesium	----	470	806	524	187	600	468	484	417	28
Manganese	377	0.993	1.252	0.993	0.565	1.016	1.018	0.942	1.138	0.016
Mercury	0.10	0.0004	0.0008	0.0004	0.0004	0.0005	0.0005	0.0004	0.0007	0.0000
Molybdenum	0.60	16.55	50.27	16.55	12.59	20.79	16.67	16.40	16.48	0.86
Nickel	171	0.14	0.31	0.14	0.11	0.16	0.15	0.12	0.19	0.01
Total Nitrogen	100	9.51	17.72	9.52	8.08	10.46	7.85	10.08	12.17	0.31
Phosphorus	----	2.27	4.04	2.28	2.28	2.44	2.37	2.01	3.08	0.15
Potassium	----	82.2	221.7	82.2	56.9	99.5	83.7	78.6	91.7	4.6
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.010	0.016	0.010	0.012	0.011	0.011	0.009	0.016	0.001
Sodium	2000	820	1,643	820	645	926	871	683	1,252	34
Strontium	1127	11.8	30.6	11.8	7.1	14.2	12.2	10.9	14.6	0.6
Sulfate	----	2,734	3,924	2,734	1,304	3,401	2,778	2,649	2,958	143
Thallium	0.032	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.003	0.000
Tin	29.2	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.0
TDS	7000	6,044	10,919	8,588	3,439	7,334	6,172	5,744	6,934	427
TSS	-----									
Uranium	6.995	0.005	0.015	0.005	0.003	0.006	0.005	0.005	0.005	0.000
Vanadium	0.1	0.33	0.61	0.34	0.30	0.36	0.34	0.31	0.40	0.02
Zinc	25	0.10	0.21	0.11	0.08	0.12	0.11	0.10	0.13	0.00
Profile III Exceedance										

South Sub-Pit

Appendix L - Sensitivity Analysis

		100 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.69	7.60	8.57	7.84	7.65	7.69	7.67	7.73	7.42
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	250	229	2,495	330	237	252	242	277	104
Aluminum	4.47	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.320	0.838	0.320	0.337	0.369	0.323	0.314	0.325	0.019
Arsenic	0.2	0.446	1.011	0.477	0.509	0.495	0.461	0.410	0.551	0.023
Barium	23.1	0.01	0.01	0.56	0.02	0.01	0.01	0.01	0.01	0.03
Beryllium	2.83	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	4.80	8.64	4.80	5.02	5.23	5.16	3.86	7.69	0.16
Cadmium	0.05	0.002	0.004	0.002	0.002	0.003	0.003	0.002	0.004	0.000
Calcium	----	399	641	1,052	152	502	396	412	348	51
Chloride	----	1,409	3,672	1,409	829	1,675	1,449	1,299	1,740	62
Chromium	1	0.007	0.005	0.010	0.010	0.005	0.007	0.005	0.013	0.000
Copper	0.5	0.04	0.11	0.11	0.03	0.05	0.04	0.04	0.05	0.00
Fluoride	2	4.16	4.15	52.15	4.75	4.11	4.18	4.10	4.36	2.11
Iron	----	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.004	0.004	0.008	0.007	0.004	0.005	0.004	0.007	0.000
Lithium	40.3	9.18	25.89	9.18	4.79	11.32	9.38	8.69	10.53	0.38
Magnesium	----	506	817	587	194	634	502	523	440	29
Manganese	377	1.042	1.334	1.043	0.600	1.065	1.072	0.980	1.212	0.015
Mercury	0.10	0.0005	0.0009	0.0005	0.0004	0.0006	0.0006	0.0004	0.0008	0.0000
Molybdenum	0.60	18.03	54.91	18.03	13.66	22.23	18.15	17.88	17.86	0.86
Nickel	171	0.16	0.35	0.16	0.12	0.18	0.17	0.14	0.22	0.01
Total Nitrogen	100	11.25	20.33	11.25	9.67	12.19	9.17	11.96	14.34	0.31
Phosphorus	----	2.60	4.60	2.62	2.61	2.77	2.73	2.28	3.56	0.12
Potassium	----	91.5	244.5	91.6	63.9	108.7	93.4	87.3	102.5	4.6
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.012	0.019	0.012	0.014	0.013	0.013	0.010	0.019	0.001
Sodium	2000	941	1,839	941	749	1,046	1,004	774	1,452	34
Strontium	1127	13.3	33.9	13.3	8.1	15.6	13.7	12.1	16.6	0.6
Sulfate	----	3,013	3,970	3,014	1,440	3,674	3,064	2,913	3,265	144
Thallium	0.032	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.003	0.000
Tin	29.2	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.0
TDS	7000	6,674	11,570	9,706	3,809	7,953	6,826	6,315	7,701	432
TSS	-----									
Uranium	6.995	0.005	0.016	0.005	0.003	0.007	0.006	0.005	0.006	0.000
Vanadium	0.1	0.37	0.68	0.38	0.34	0.40	0.38	0.34	0.45	0.02
Zinc	25	0.11	0.22	0.12	0.08	0.13	0.12	0.10	0.14	0.00
Profile III Exceedance										

South Sub-Pit

Appendix L - Sensitivity Analysis

		150 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.67	7.58	8.66	7.85	7.64	7.67	7.65	7.72	7.41
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	247	227	3,412	338	238	250	238	281	102
Aluminum	4.47	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.389	1.022	0.390	0.409	0.438	0.397	0.383	0.390	0.015
Arsenic	0.2	0.567	1.275	0.599	0.648	0.616	0.593	0.516	0.703	0.020
Barium	23.1	0.01	0.01	0.71	0.02	0.01	0.01	0.01	0.01	0.03
Beryllium	2.83	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	6.38	11.02	6.38	6.62	6.79	6.96	5.02	10.28	0.16
Cadmium	0.05	0.003	0.005	0.003	0.003	0.003	0.004	0.003	0.006	0.000
Calcium	----	469	637	1,330	165	551	466	491	388	50
Chloride	----	1,778	4,518	1,779	1,072	2,037	1,848	1,625	2,206	59
Chromium	1	0.010	0.010	0.014	0.014	0.009	0.012	0.007	0.019	0.000
Copper	0.5	0.05	0.17	0.16	0.03	0.07	0.05	0.05	0.06	0.00
Fluoride	2	4.17	4.43	67.07	4.84	4.14	4.19	4.11	4.41	1.91
Iron	----	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.006	0.006	0.011	0.009	0.005	0.007	0.005	0.009	0.000
Lithium	40.3	11.23	31.16	11.23	6.00	13.32	11.58	10.57	12.91	0.37
Magnesium	----	592	916	742	210	694	588	620	488	28
Manganese	377	1.154	1.527	1.155	0.682	1.176	1.206	1.065	1.376	0.015
Mercury	0.10	0.0007	0.0012	0.0007	0.0006	0.0007	0.0008	0.0005	0.0011	0.0000
Molybdenum	0.60	21.65	66.32	21.66	16.24	25.74	21.93	21.54	21.03	0.83
Nickel	171	0.21	0.44	0.21	0.16	0.23	0.22	0.18	0.29	0.01
Total Nitrogen	100	15.54	26.77	15.54	13.60	16.45	12.54	16.61	19.52	0.31
Phosphorus	----	3.43	5.99	3.45	3.43	3.59	3.65	2.97	4.70	0.12
Potassium	----	113.9	298.8	113.9	80.1	130.6	117.2	108.2	127.0	4.2
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.016	0.025	0.016	0.019	0.017	0.018	0.013	0.025	0.000
Sodium	2000	1,240	2,322	1,240	1,005	1,343	1,343	1,000	1,930	32
Strontium	1127	16.9	42.0	16.9	10.6	19.2	17.7	15.3	21.2	0.6
Sulfate	----	3,703	4,339	3,705	1,774	4,212	3,797	3,572	3,982	139
Thallium	0.032	0.003	0.005	0.003	0.003	0.003	0.003	0.003	0.005	0.000
Tin	29.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.3	0.0
TDS	7000	8,225	13,452	12,470	4,708	9,298	8,491	7,733	9,501	418
TSS	-----									
Uranium	6.995	0.007	0.020	0.007	0.004	0.008	0.007	0.007	0.007	0.000
Vanadium	0.1	0.47	0.85	0.48	0.43	0.50	0.49	0.43	0.57	0.02
Zinc	25	0.13	0.26	0.14	0.10	0.15	0.14	0.12	0.18	0.00

South Sub-Pit

Partially Backfilled Pit Scenario

Appendix L - Sensitivity Analysis

Partially Backfilled South Sub-pit Alternative

		175 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.66	7.57	8.70	7.84	7.65	7.66	7.64	7.72	7.40
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	245	224	3,976	341	242	248	235	283	100
Aluminum	4.47	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.431	1.134	0.431	0.452	0.478	0.440	0.425	0.423	0.015
Arsenic	0.2	0.646	1.444	0.678	0.737	0.694	0.678	0.586	0.789	0.021
Barium	23.1	0.01	0.01	0.81	0.02	0.01	0.01	0.01	0.01	0.04
Beryllium	2.83	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	7.37	12.53	7.38	7.64	7.78	8.09	5.76	11.75	0.16
Cadmium	0.05	0.004	0.006	0.004	0.004	0.004	0.004	0.003	0.006	0.000
Calcium	----	514	632	1,505	173	551	512	543	410	52
Chloride	----	2,016	5,063	2,017	1,228	2,272	2,106	1,841	2,469	64
Chromium	1	0.013	0.013	0.017	0.017	0.012	0.015	0.009	0.023	0.000
Copper	0.5	0.06	0.21	0.19	0.03	0.07	0.06	0.06	0.07	0.00
Fluoride	2	4.18	4.64	76.41	4.88	4.17	4.20	4.11	4.43	1.93
Iron	----	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.007	0.007	0.012	0.010	0.006	0.008	0.006	0.011	0.000
Lithium	40.3	12.55	34.53	12.55	6.77	14.61	13.02	11.81	14.24	0.40
Magnesium	----	648	990	841	220	694	645	685	515	29
Manganese	377	1.223	1.646	1.223	0.739	1.244	1.283	1.118	1.457	0.014
Mercury	0.10	0.0008	0.0014	0.0008	0.0007	0.0009	0.0009	0.0006	0.0013	0.0000
Molybdenum	0.60	23.96	73.59	23.97	17.88	27.99	24.38	23.96	22.78	0.89
Nickel	171	0.24	0.50	0.24	0.19	0.26	0.26	0.20	0.33	0.01
Total Nitrogen	100	18.30	30.86	18.31	16.13	19.20	14.69	19.64	22.50	0.31
Phosphorus	----	3.96	6.88	3.98	3.96	4.12	4.23	3.42	5.35	0.12
Potassium	----	127.9	333.4	127.9	90.2	144.3	132.3	121.6	140.5	4.4
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.019	0.029	0.019	0.021	0.019	0.020	0.015	0.028	0.000
Sodium	2000	1,430	2,628	1,431	1,167	1,531	1,558	1,146	2,199	33
Strontium	1127	19.3	47.3	19.3	12.2	21.6	20.3	17.5	23.8	0.6
Sulfate	----	4,144	4,597	4,146	1,984	4,322	4,268	4,005	4,379	147
Thallium	0.032	0.004	0.006	0.004	0.003	0.004	0.004	0.003	0.005	0.000
Tin	29.2	0.2	0.5	0.2	0.2	0.3	0.3	0.2	0.3	0.0
TDS	7000	9,218	14,685	14,211	5,276	9,859	9,563	8,666	10,504	433
TSS	-----									
Uranium	6.995	0.008	0.022	0.008	0.004	0.009	0.008	0.007	0.008	0.000
Vanadium	0.1	0.52	0.95	0.54	0.48	0.55	0.55	0.48	0.63	0.01
Zinc	25	0.15	0.28	0.15	0.11	0.17	0.16	0.13	0.19	0.0

South Sub-Pit

Appendix L - Sensitivity Analysis

		200 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.65	7.56	8.74	7.84	7.65	7.66	7.64	7.71	7.39
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	246	222	4,611	345	246	251	237	285	96
Aluminum	4.47	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.476	1.258	0.476	0.498	0.522	0.492	0.471	0.462	0.014
Arsenic	0.2	0.737	1.644	0.780	0.840	0.784	0.783	0.667	0.896	0.020
Barium	23.1	0.01	0.01	0.97	0.01	0.01	0.01	0.01	0.01	0.05
Beryllium	2.83	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	8.58	14.46	8.59	8.86	8.98	9.53	6.67	13.58	0.17
Cadmium	0.05	0.005	0.007	0.005	0.005	0.005	0.005	0.004	0.008	0.000
Calcium	----	541	626	1,706	183	551	536	558	436	49
Chloride	----	2,300	5,714	2,301	1,417	2,550	2,431	2,097	2,796	62
Chromium	1	0.014	0.013	0.020	0.018	0.013	0.017	0.010	0.026	0.000
Copper	0.5	0.07	0.24	0.22	0.04	0.08	0.08	0.07	0.08	0.00
Fluoride	2	4.20	4.89	87.29	4.91	4.20	4.23	4.13	4.45	1.89
Iron	----	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.007	0.007	0.014	0.009	0.007	0.008	0.006	0.011	0.000
Lithium	40.3	14.24	38.99	14.24	7.82	16.26	14.94	13.42	15.99	0.42
Magnesium	----	681	1,079	956	232	695	674	704	546	28
Manganese	377	1.295	1.765	1.295	0.808	1.315	1.377	1.170	1.560	0.012
Mercury	0.10	0.0010	0.0016	0.0010	0.0008	0.0010	0.0011	0.0007	0.0015	0.0000
Molybdenum	0.60	26.59	81.86	26.60	19.72	30.54	27.36	26.72	24.86	0.82
Nickel	171	0.27	0.56	0.28	0.22	0.29	0.30	0.23	0.38	0.01
Total Nitrogen	100	21.40	35.42	21.41	18.94	22.29	17.24	23.02	26.00	0.30
Phosphorus	----	4.57	7.87	4.59	4.56	4.72	4.93	3.93	6.12	0.12
Potassium	----	144.8	376.2	144.9	102.5	160.9	151.5	137.8	157.6	4.4
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.022	0.033	0.022	0.025	0.022	0.024	0.018	0.033	0.000
Sodium	2000	1,651	2,986	1,652	1,355	1,751	1,822	1,316	2,527	32
Strontium	1127	22.0	53.3	22.0	14.1	24.3	23.5	19.9	27.0	0.6
Sulfate	----	4,460	4,899	4,651	2,221	4,444	4,594	4,161	4,854	138
Thallium	0.032	0.004	0.007	0.004	0.004	0.004	0.005	0.003	0.006	0.000
Tin	29.2	0.3	0.5	0.3	0.3	0.3	0.3	0.2	0.4	0.0
TDS	7000	10,131	16,145	16,213	5,937	10,513	10,564	9,311	11,724	413
TSS	-----									
Uranium	6.995	0.008	0.025	0.008	0.004	0.010	0.009	0.008	0.008	0.000
Vanadium	0.1	0.59	1.07	0.61	0.54	0.61	0.62	0.54	0.70	0.02
Zinc	25	0.17	0.33	0.17	0.13	0.19	0.18	0.15	0.22	0.00
Profile III Exceedance										

South Sub-Pit

Appendix L - Sensitivity Analysis

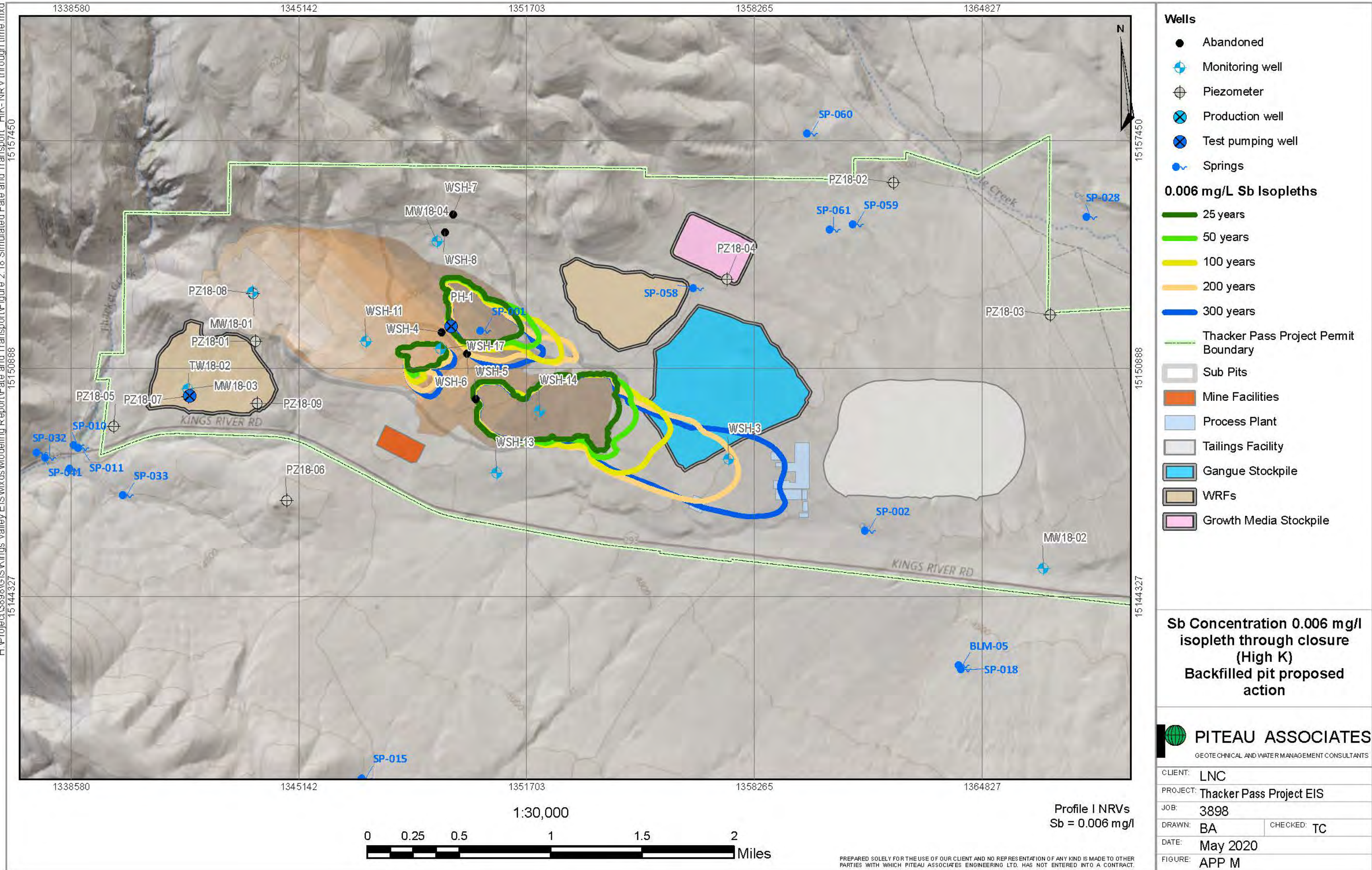
		250 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.66	7.54	8.78	7.84	7.65	7.66	7.64	7.71	7.39
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	251	219	5,312	348	250	256	240	287	96
Aluminum	4.47	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.525	1.393	0.525	0.549	0.570	0.550	0.521	0.496	0.014
Arsenic	0.2	0.839	1.867	0.895	0.953	0.885	0.903	0.759	0.997	0.020
Barium	23.1	0.01	0.01	1.15	0.01	0.01	0.01	0.01	0.01	0.05
Beryllium	2.83	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	9.93	16.60	9.94	10.21	10.32	11.18	7.70	15.34	0.17
Cadmium	0.05	0.006	0.008	0.006	0.006	0.006	0.006	0.004	0.009	0.000
Calcium	----	542	619	1,928	193	551	536	562	460	49
Chloride	----	2,615	6,430	2,616	1,626	2,858	2,802	2,384	3,110	63
Chromium	1	0.016	0.012	0.023	0.020	0.015	0.019	0.011	0.029	0.000
Copper	0.5	0.08	0.28	0.26	0.04	0.10	0.09	0.08	0.09	0.00
Fluoride	2	4.23	5.16	99.37	4.94	4.23	4.27	4.16	4.47	1.90
Iron	----	0.00	0.00	1.65	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.008	0.007	0.016	0.009	0.007	0.008	0.006	0.012	0.000
Lithium	40.3	16.12	43.92	16.12	8.99	18.07	17.15	15.21	17.69	0.42
Magnesium	----	682	1,176	1,083	245	695	673	709	576	28
Manganese	377	1.370	1.890	1.370	0.888	1.390	1.479	1.224	1.645	0.012
Mercury	0.10	0.0011	0.0018	0.0011	0.0010	0.0012	0.0013	0.0009	0.0017	0.0000
Molybdenum	0.60	29.48	90.88	29.48	21.72	33.30	30.74	29.75	26.78	0.83
Nickel	171	0.31	0.63	0.32	0.25	0.33	0.34	0.27	0.42	0.01
Total Nitrogen	100	24.90	40.49	24.90	22.11	25.75	20.19	26.87	29.43	0.30
Phosphorus	----	5.24	8.96	5.28	5.22	5.39	5.73	4.50	6.87	0.12
Potassium	----	163.6	423.3	163.6	116.1	179.2	173.5	155.9	173.8	4.4
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.025	0.038	0.025	0.028	0.026	0.028	0.020	0.037	0.000
Sodium	2000	1,898	3,379	1,898	1,563	1,994	2,123	1,505	2,843	32
Strontium	1127	25.1	59.9	25.1	16.1	27.2	27.1	22.6	30.1	0.6
Sulfate	----	4,598	5,224	5,207	2,481	4,579	4,766	4,246	5,305	138
Thallium	0.032	0.005	0.008	0.005	0.005	0.005	0.005	0.004	0.007	0.000
Tin	29.2	0.3	0.6	0.3	0.3	0.3	0.4	0.3	0.4	0.0
TDS	7000	10,868	17,745	18,426	6,665	11,234	11,451	9,916	12,891	415
TSS	-----									
Uranium	6.995	0.009	0.028	0.009	0.005	0.011	0.010	0.009	0.009	0.000
Vanadium	0.1	0.66	1.20	0.69	0.60	0.69	0.71	0.60	0.77	0.02
Zinc	25	0.19	0.38	0.20	0.15	0.21	0.21	0.17	0.24	0.00
Profile III Exceedance										

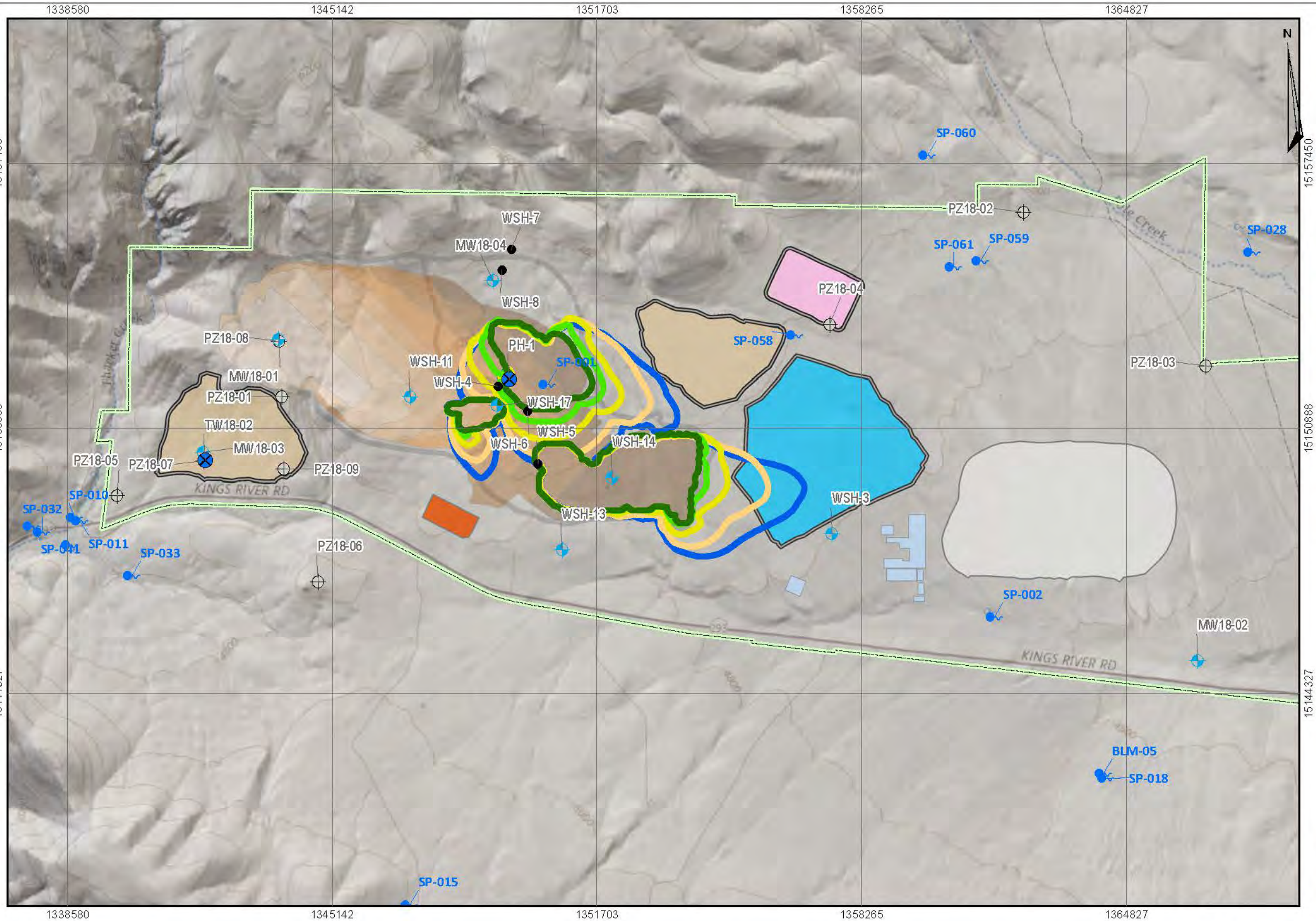
South Sub-Pit

Appendix L - Sensitivity Analysis

		300 Year								
Concentration (mg/L)	Profile III	Partial Base Case	Partial Scale Factor	Partial No Mineral	Partial Week 1 Flush	Partial 5 Pore Flush	Partial +15% ET	Partial -15% ET	Minus 25K	Plus 25K
Time (yr)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	6.5-8.5	7.66	7.53	8.81	7.84	7.65	7.67	7.64	7.70	7.39
pe	-----	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Alkalinity Total	-----	255	217	6,019	352	255	262	242	289	97
Aluminum	4.47	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.29	0.573	1.526	0.573	0.597	0.616	0.609	0.571	0.524	0.014
Arsenic	0.2	0.942	2.091	1.010	1.067	0.985	1.029	0.851	1.086	0.021
Barium	23.1	0.01	0.01	1.33	0.01	0.01	0.01	0.01	0.01	0.05
Beryllium	2.83	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Boron	5	11.31	18.76	11.31	11.58	11.67	12.92	8.75	16.91	0.17
Cadmium	0.05	0.006	0.010	0.006	0.006	0.007	0.007	0.005	0.010	0.000
Calcium	----	542	611	2,150	202	551	535	565	480	50
Chloride	----	2,933	7,147	2,933	1,835	3,164	3,190	2,673	3,386	65
Chromium	1	0.018	0.011	0.027	0.022	0.016	0.021	0.012	0.031	0.000
Copper	0.5	0.10	0.32	0.30	0.04	0.11	0.10	0.09	0.10	0.00
Fluoride	2	4.26	5.43	111.48	4.97	4.26	4.31	4.18	4.48	1.94
Iron	----	0.00	0.00	2.06	0.00	0.00	0.00	0.00	0.00	0.00
Lead	0.1	0.008	0.007	0.019	0.008	0.007	0.009	0.006	0.012	0.000
Lithium	40.3	18.00	48.85	18.00	10.17	19.87	19.46	17.01	19.18	0.44
Magnesium	----	682	1,271	1,210	256	694	672	714	600	29
Manganese	377	1.434	2.003	1.434	0.966	1.453	1.576	1.268	1.702	0.012
Mercury	0.10	0.0013	0.0021	0.0013	0.0011	0.0013	0.0015	0.0010	0.0019	0.0000
Molybdenum	0.60	32.31	99.77	32.31	23.64	35.96	34.19	32.77	28.36	0.86
Nickel	171	0.35	0.70	0.36	0.28	0.37	0.39	0.30	0.46	0.01
Total Nitrogen	100	28.47	45.60	28.47	25.32	29.28	23.31	30.85	32.50	0.30
Phosphorus	----	5.92	10.05	5.97	5.89	6.06	6.57	5.07	7.52	0.12
Potassium	----	182.3	470.4	182.3	129.6	197.3	196.3	174.1	187.9	4.5
Selenium	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Silver	----	0.028	0.043	0.028	0.032	0.029	0.032	0.023	0.040	0.000
Sodium	2000	2,147	3,774	2,147	1,773	2,239	2,440	1,698	3,123	33
Strontium	1127	28.1	66.4	28.1	18.2	30.2	30.8	25.4	32.8	0.6
Sulfate	----	4,735	5,542	5,760	2,736	4,714	4,947	4,330	5,696	143
Thallium	0.032	0.006	0.009	0.006	0.005	0.006	0.006	0.005	0.008	0.000
Tin	29.2	0.4	0.7	0.4	0.4	0.4	0.4	0.3	0.5	0.0
TDS	7000	11,610	19,336	20,647	7,388	11,955	12,378	10,525	13,909	426
TSS	-----									
Uranium	6.995	0.011	0.031	0.011	0.006	0.012	0.011	0.010	0.010	0.000
Vanadium	0.1	0.73	1.34	0.76	0.67	0.76	0.80	0.66	0.83	0.02
Zinc	25	0.22	0.43	0.22	0.17	0.23	0.24	0.19	0.27	0.00
Profile III Exceedance										

APPENDIX M
Fate and transport sensitivity analysis results





- Wells**
- Abandoned
 - Monitoring well
 - Piezometer
 - Production well
 - Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary
- Sub Pits
 - Mine Facilities
 - Process Plant
 - Tailings Facility
 - Gangue Stockpile
 - WRFs
 - Growth Media Stockpile

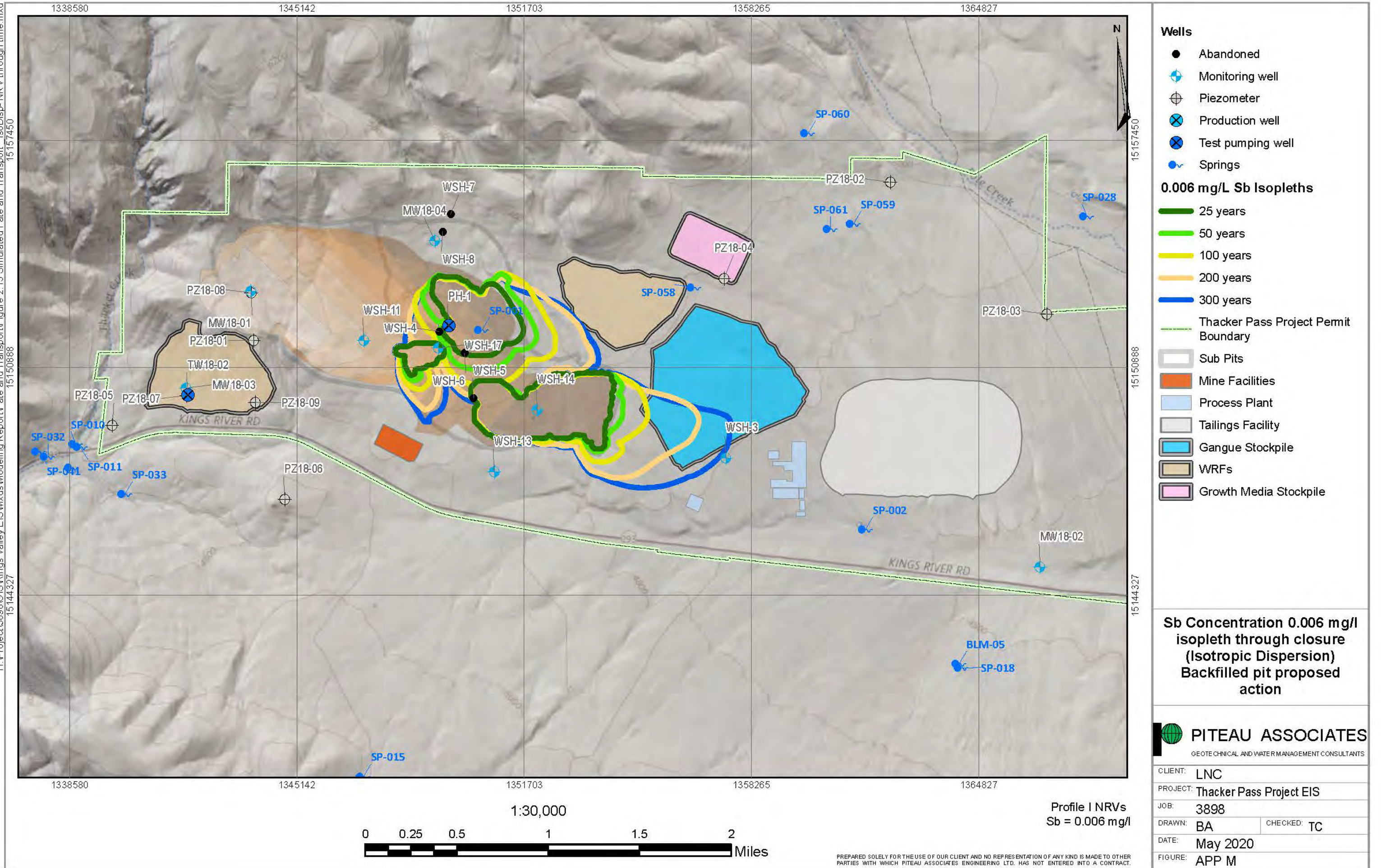
**Sb Concentration 0.006 mg/l
isopleth through closure
(High Porosity)
Backfilled pit proposed
action**

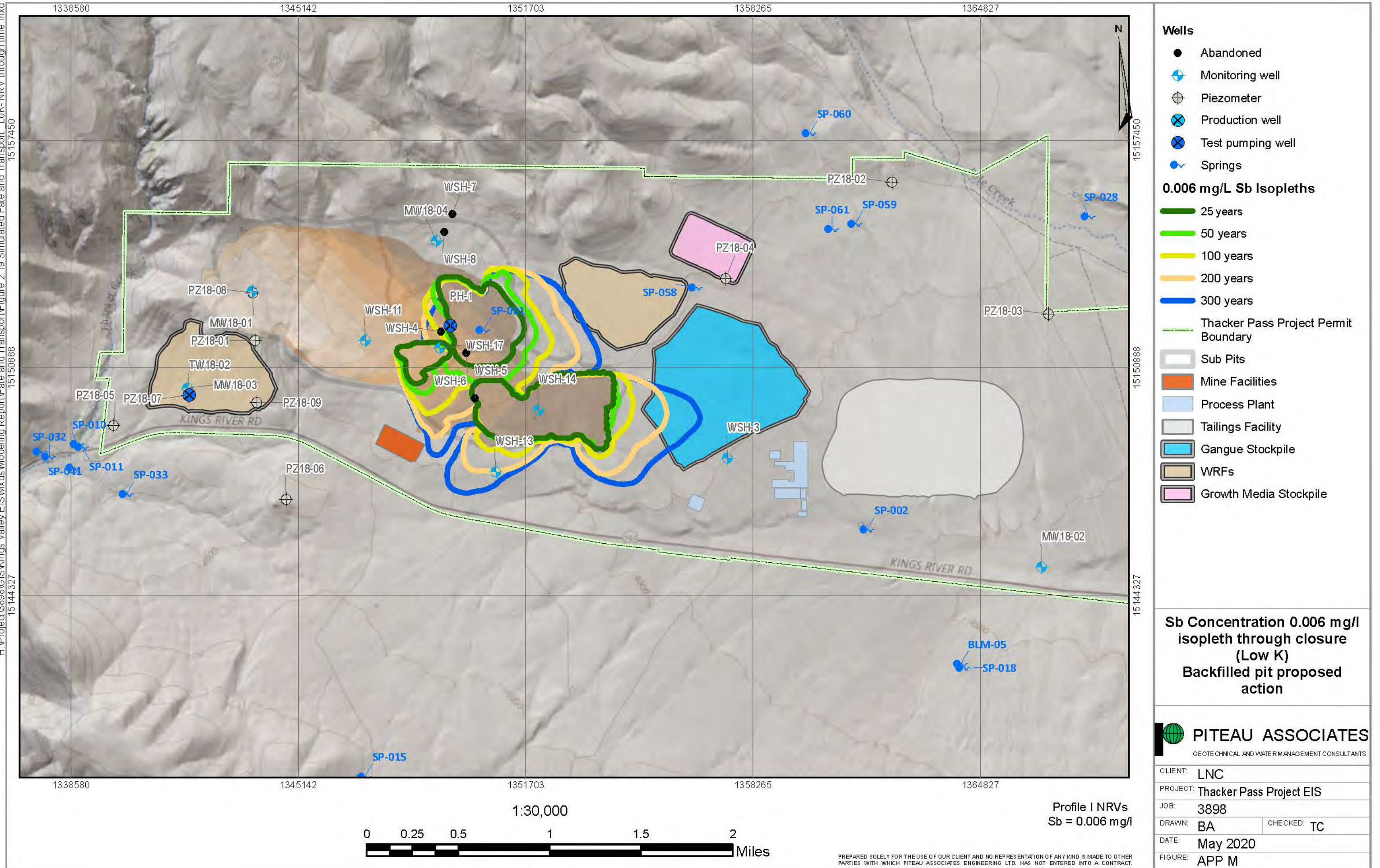
PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

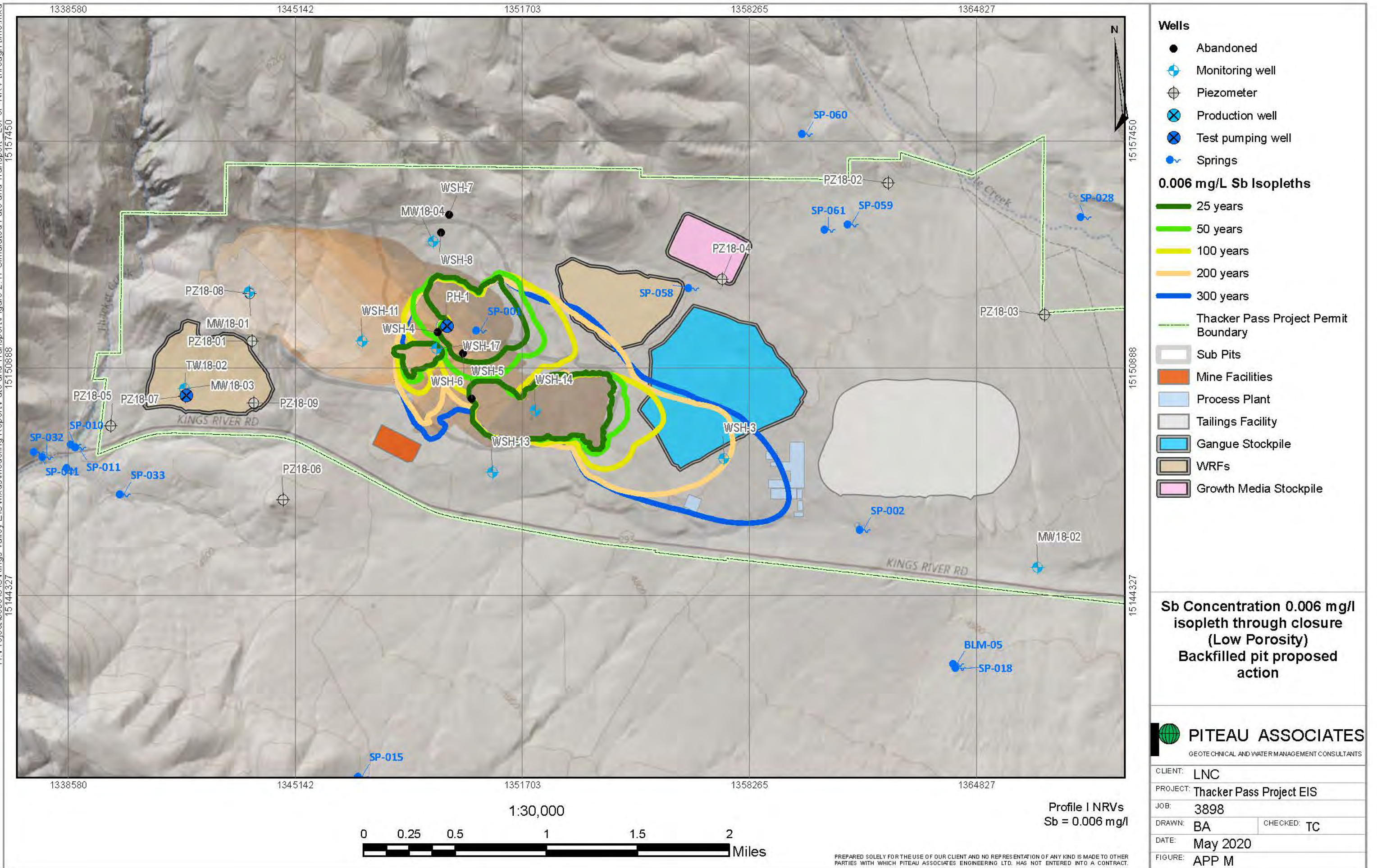
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PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		

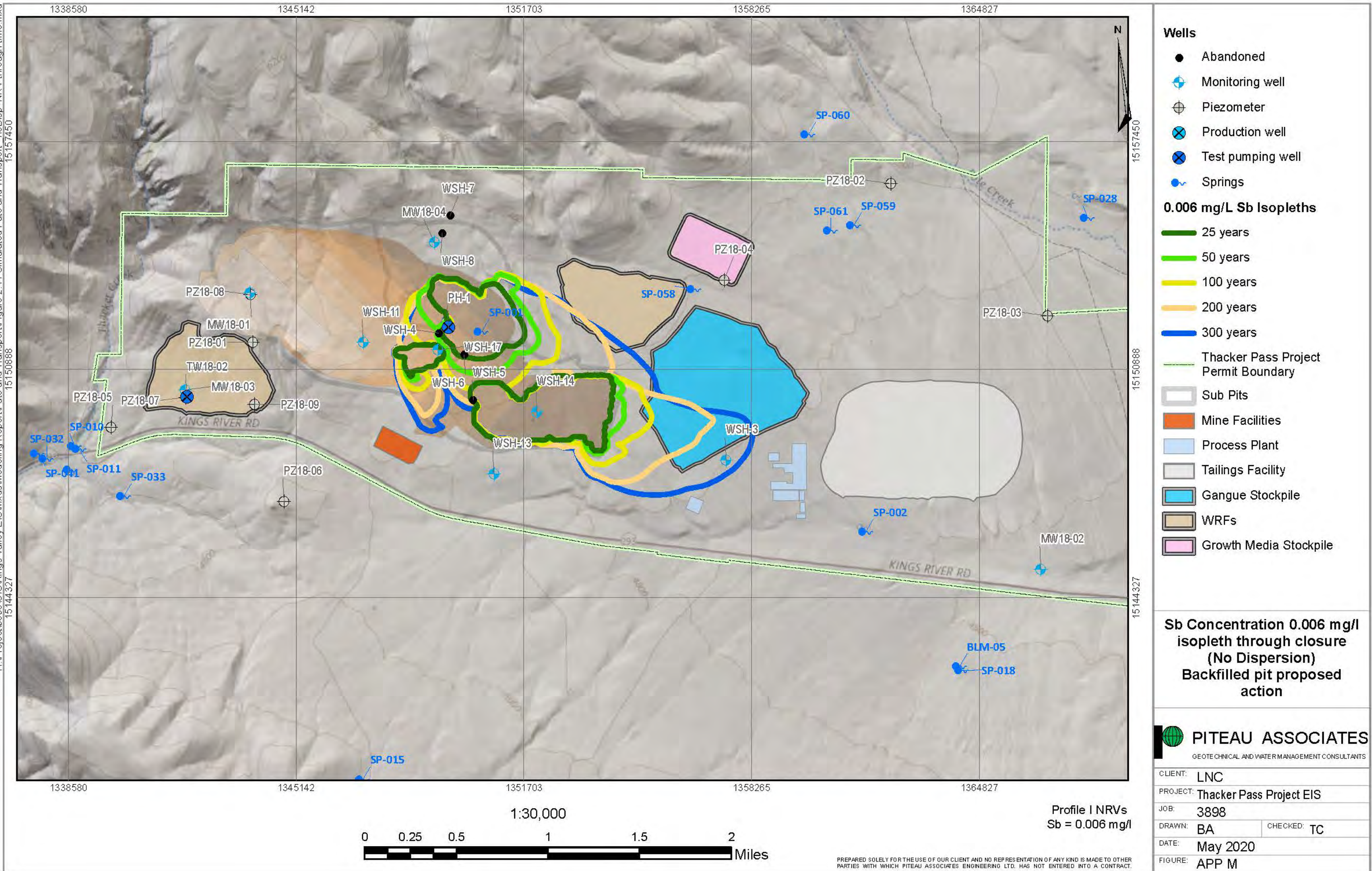
Profile I NRVs
Sb = 0.006 mg/l

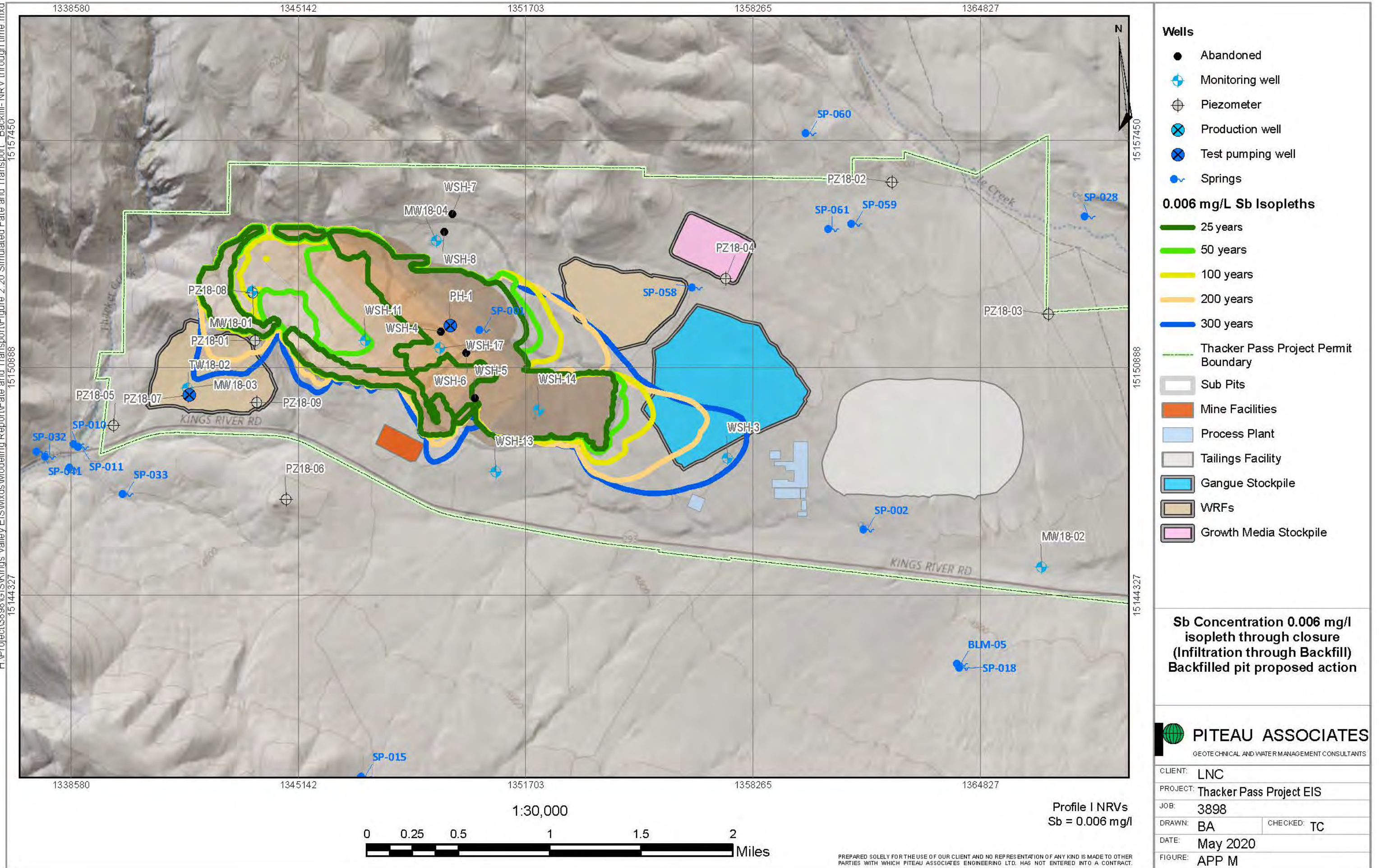
PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

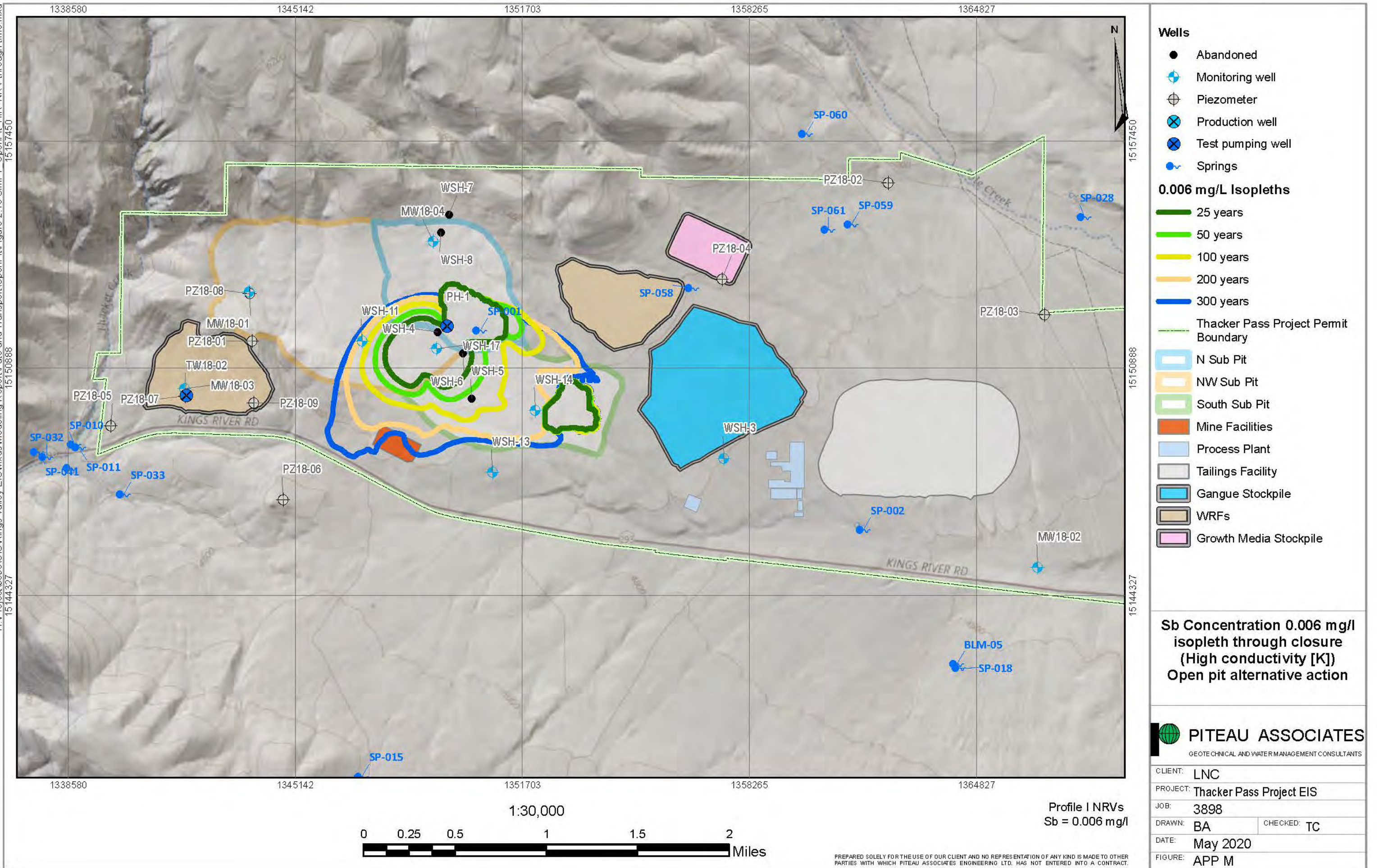




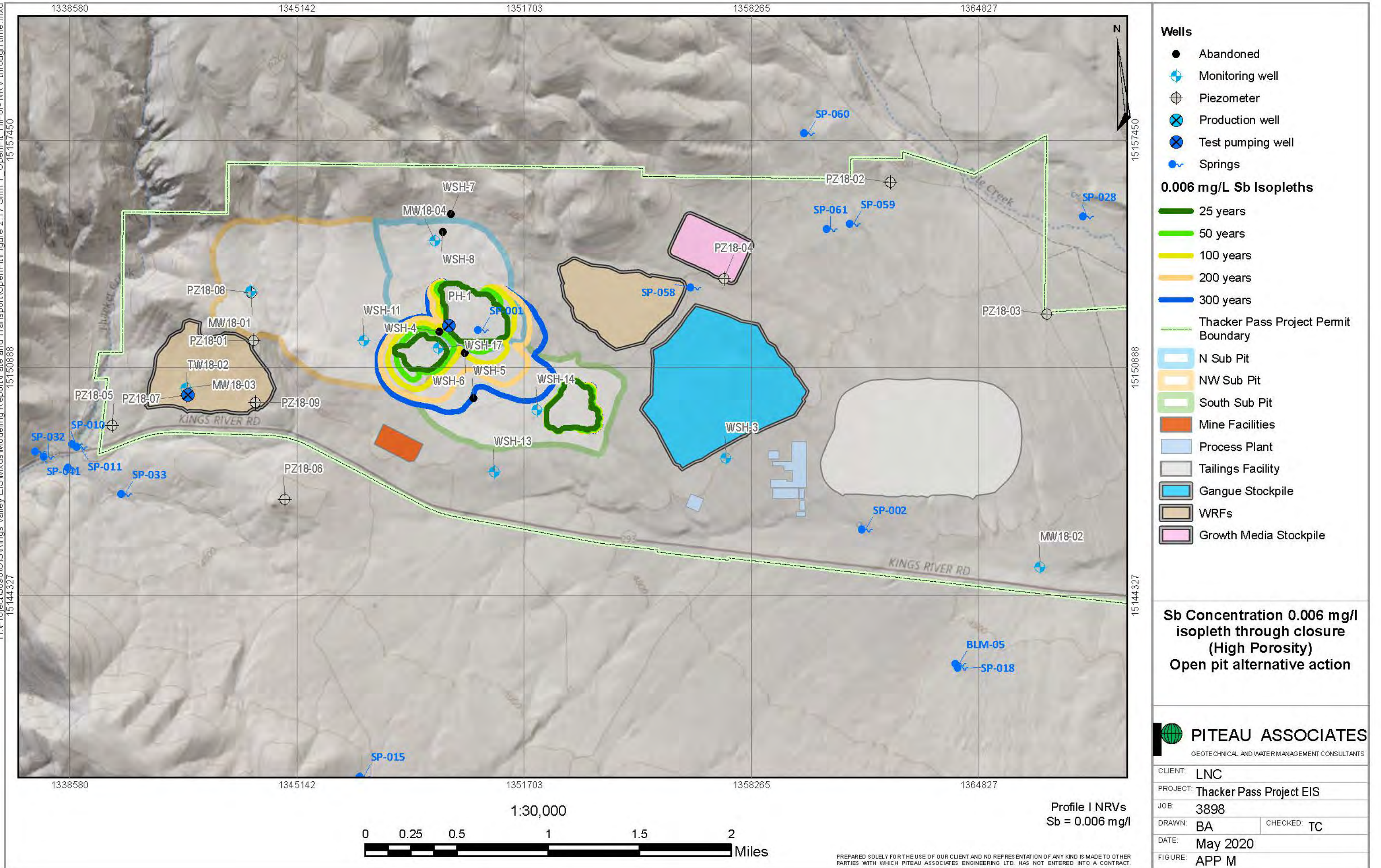


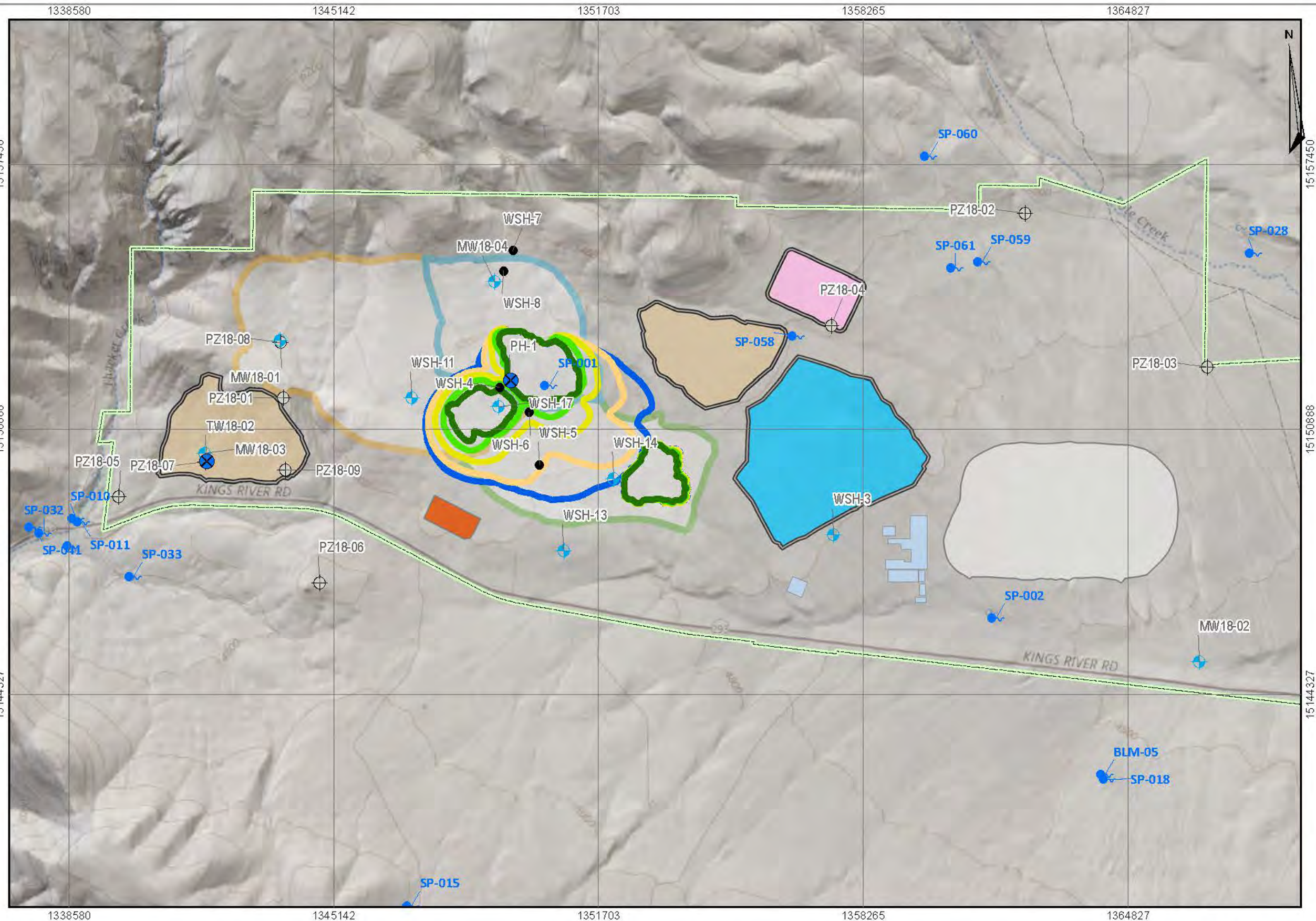






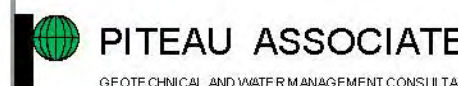
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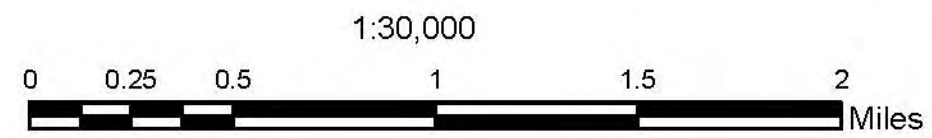


- Wells**
- Abandoned
 - Monitoring well
 - Piezometer
 - Production well
 - Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary
- N Sub Pit
 - NW Sub Pit
 - South Sub Pit
- Mine Facilities
- Process Plant
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- Gangue Stockpile
- WRFs
- Growth Media Stockpile

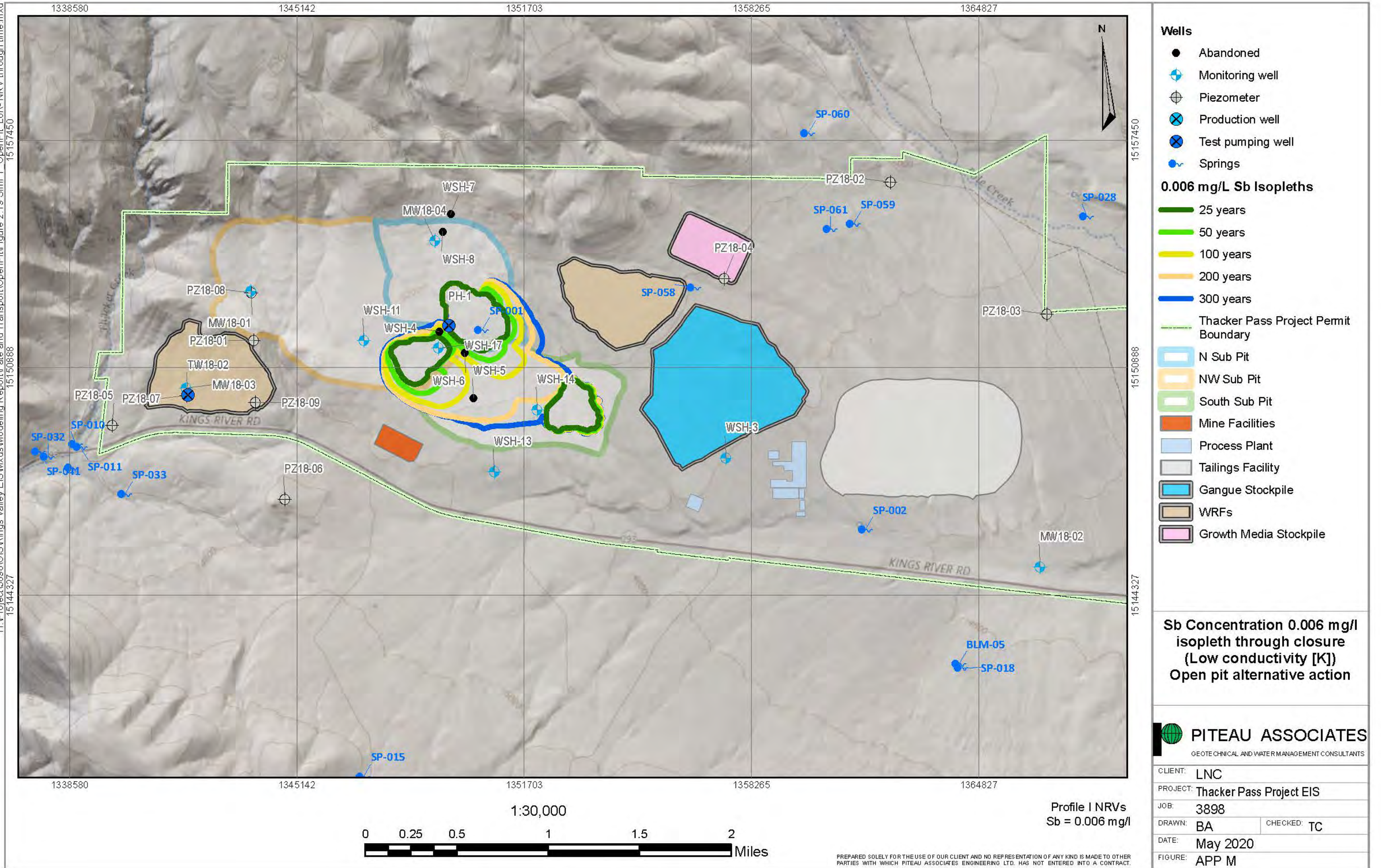
Sb Concentration 0.006 mg/l isopleth through closure (Isotropic Dispersion) Open pit alternative action



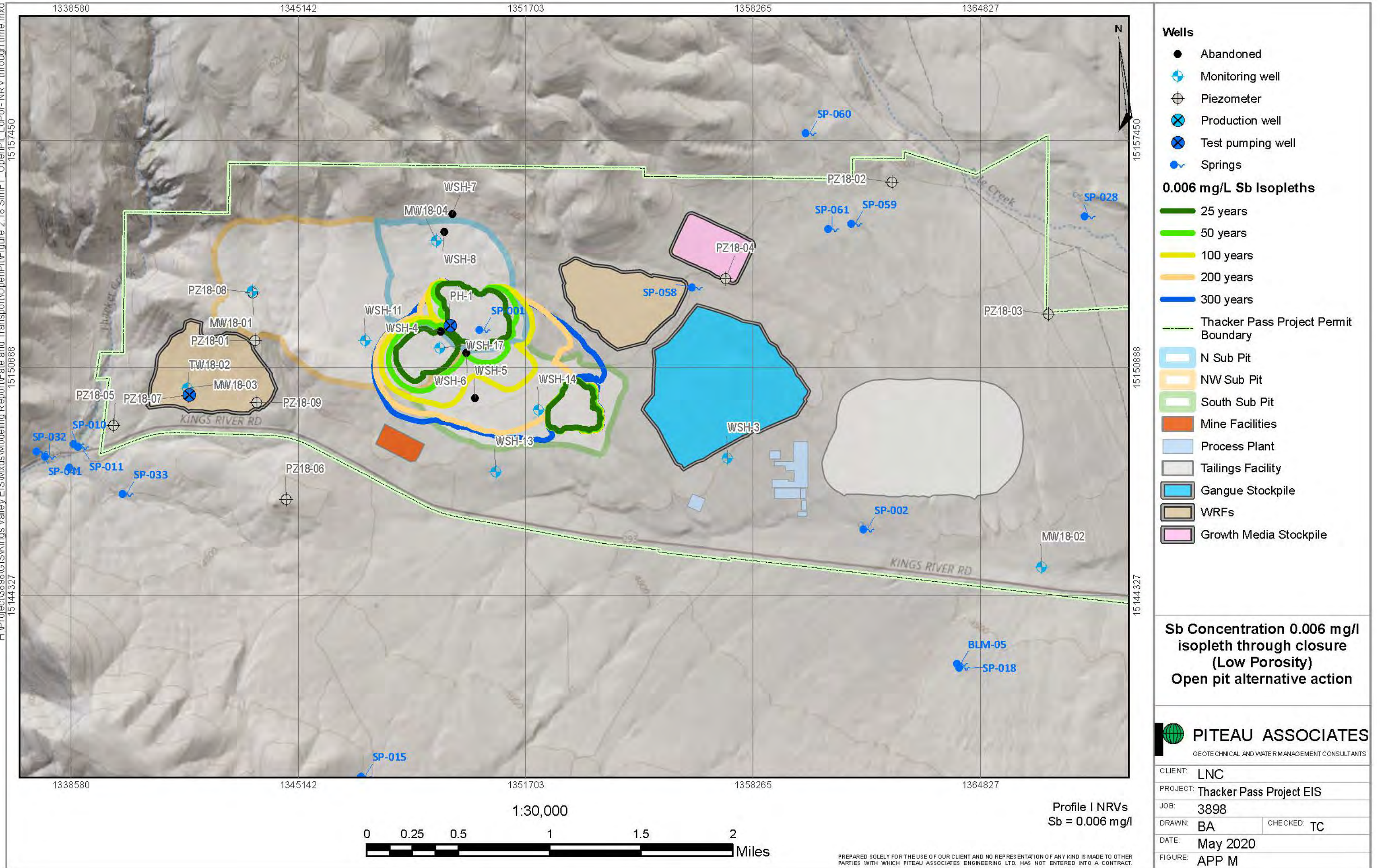
CLIENT:	LNC		
PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		

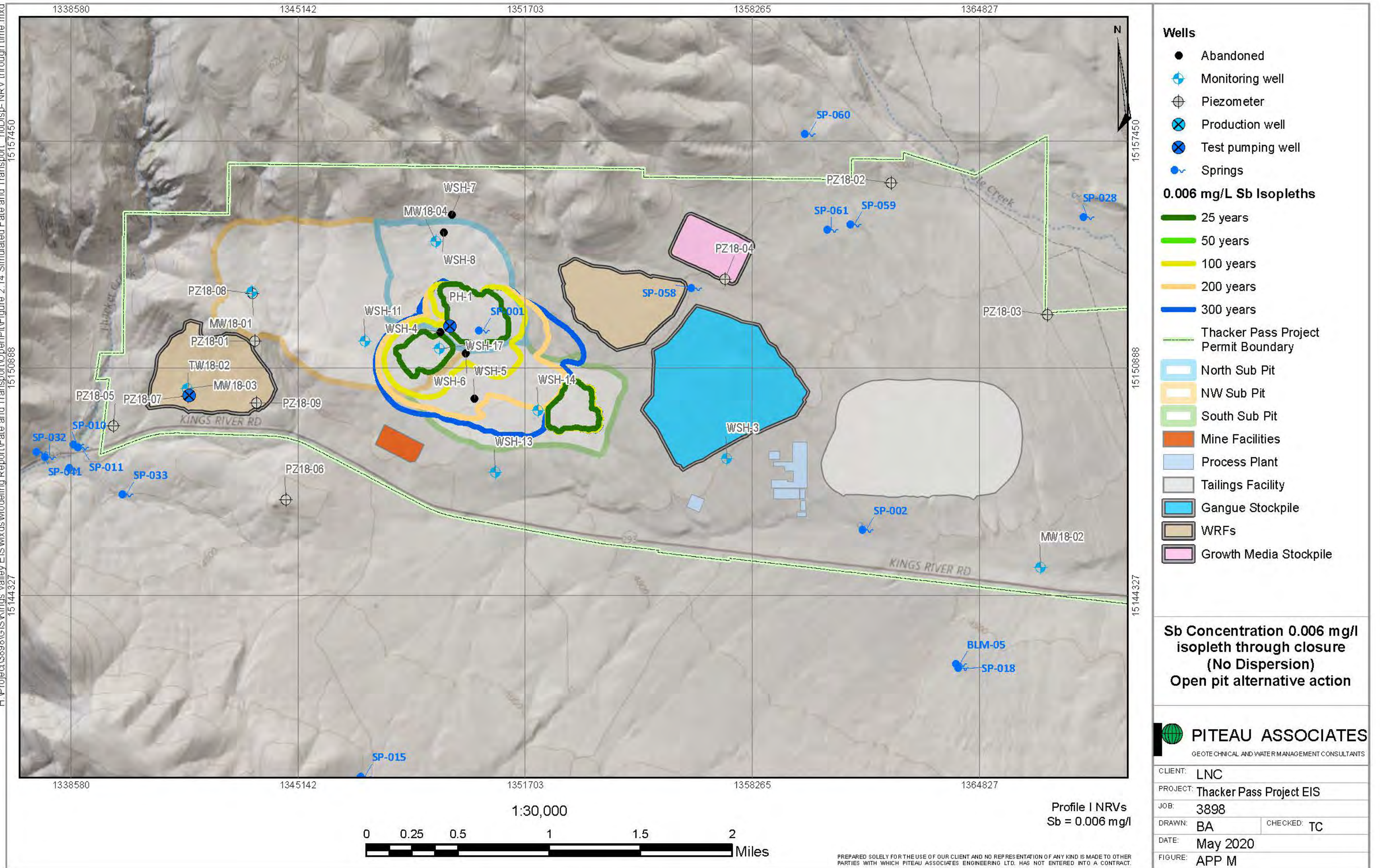


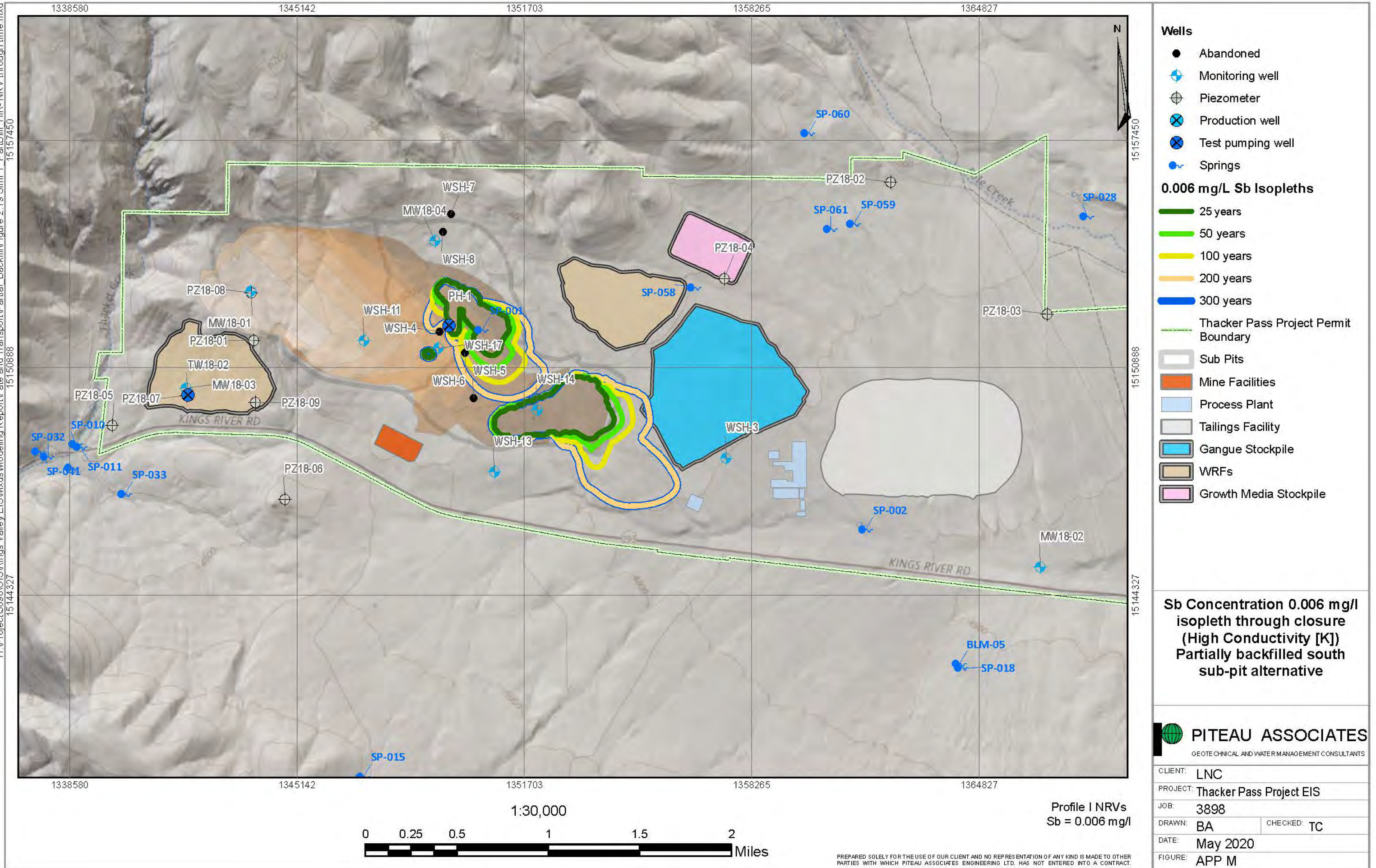
PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

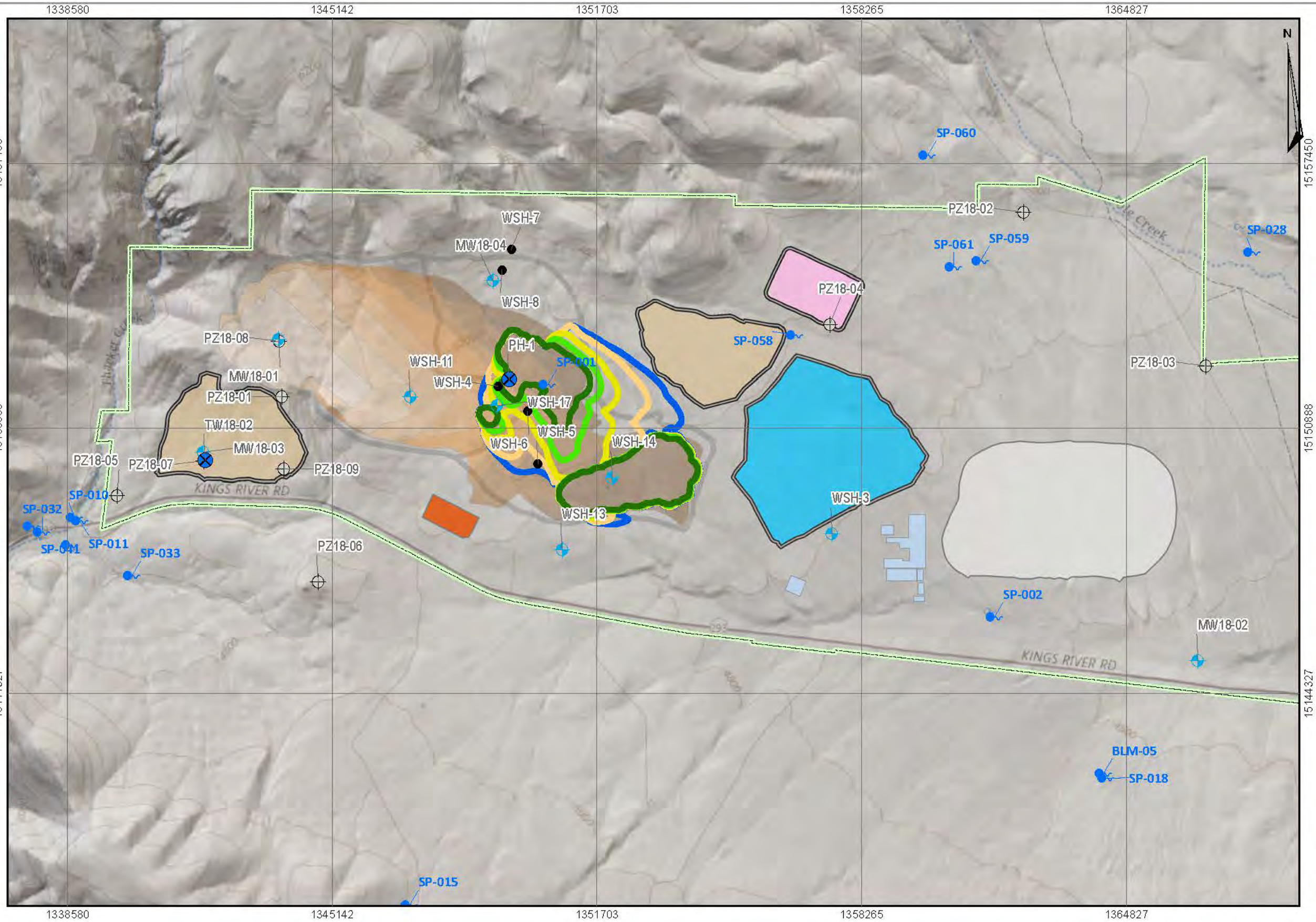


H:\Project\3898\GIS\Kings Valley EIS\Mxds\Modelling\Report\Fate and Transport\OpenPit\Figure 2.18 SimFT_OpenPit_LoPor_NRV through time.mxd









- Wells**
- Abandoned
 - Monitoring well
 - Piezometer
 - Production well
 - Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary
- Sub Pits
 - Mine Facilities
 - Process Plant
 - Tailings Facility
 - Gangue Stockpile
 - WRFs
 - Growth Media Stockpile

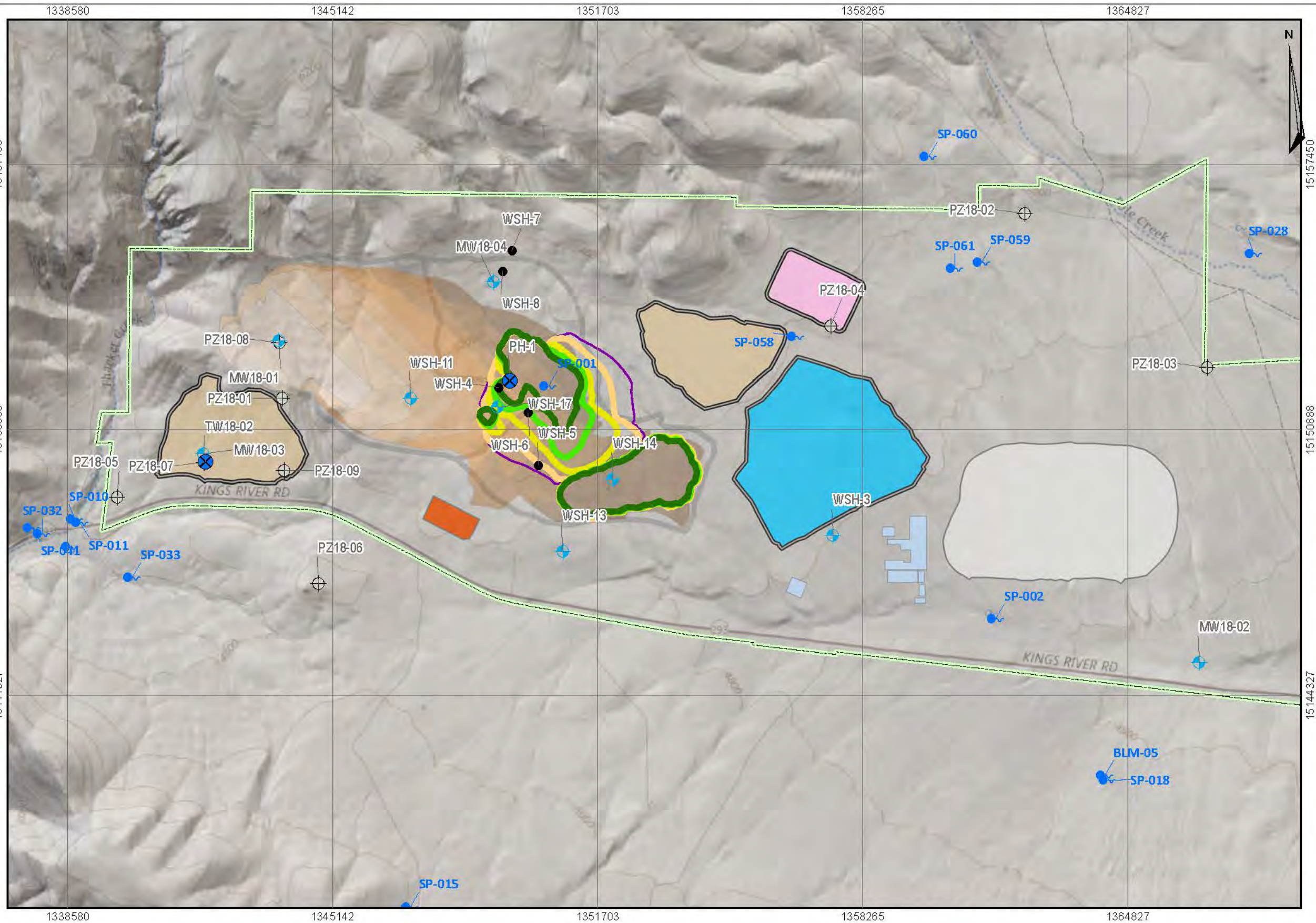
Sb Concentration 0.006 mg/l isopleth through closure (High Porosity) Partially backfilled south sub-pit alternative

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CLIENT:	LNC		
PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		

Profile I NRVs
Sb = 0.006 mg/l

H:\Project\3898\GIS\Kings Valley EIS\MapDocs\Modeling Report\Fate and Transport\Partial Backfill\Figure 2.14 SimFT PartBfill IsoDisp- NRV through time.mxd



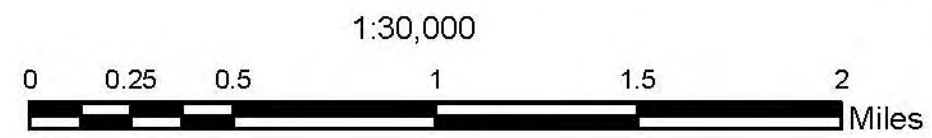
- Wells**
- Abandoned
 - Monitoring well
 - Piezometer
 - Production well
 - Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary**
- Sub Pits
 - Mine Facilities
 - Process Plant
 - Tailings Facility
 - Gangue Stockpile
 - WRFs
 - Growth Media Stockpile

Sb Concentration 0.006 mg/l isopleth through closure (Isotropic Dispersion) Partially backfilled south sub-pit alternative

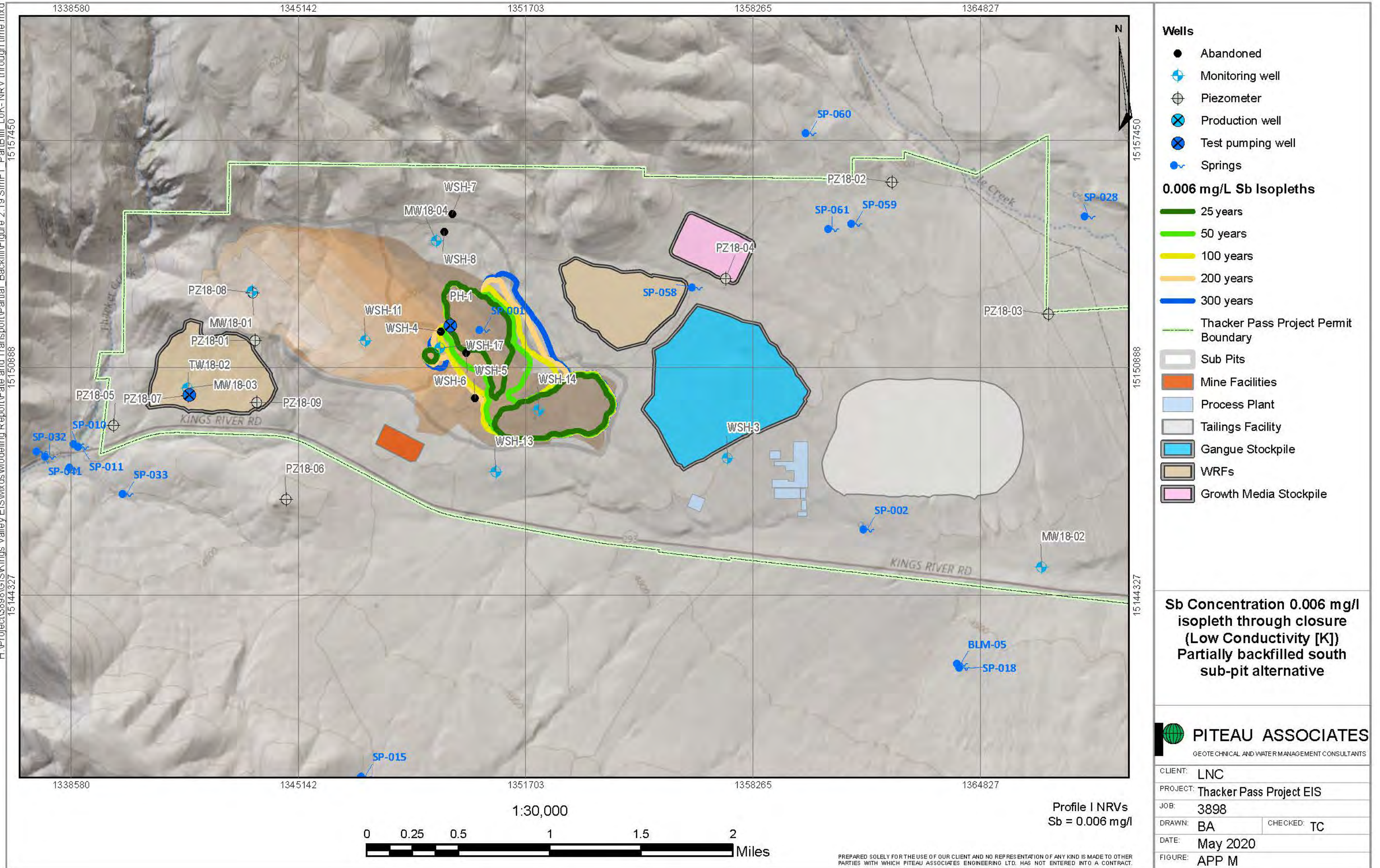
PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

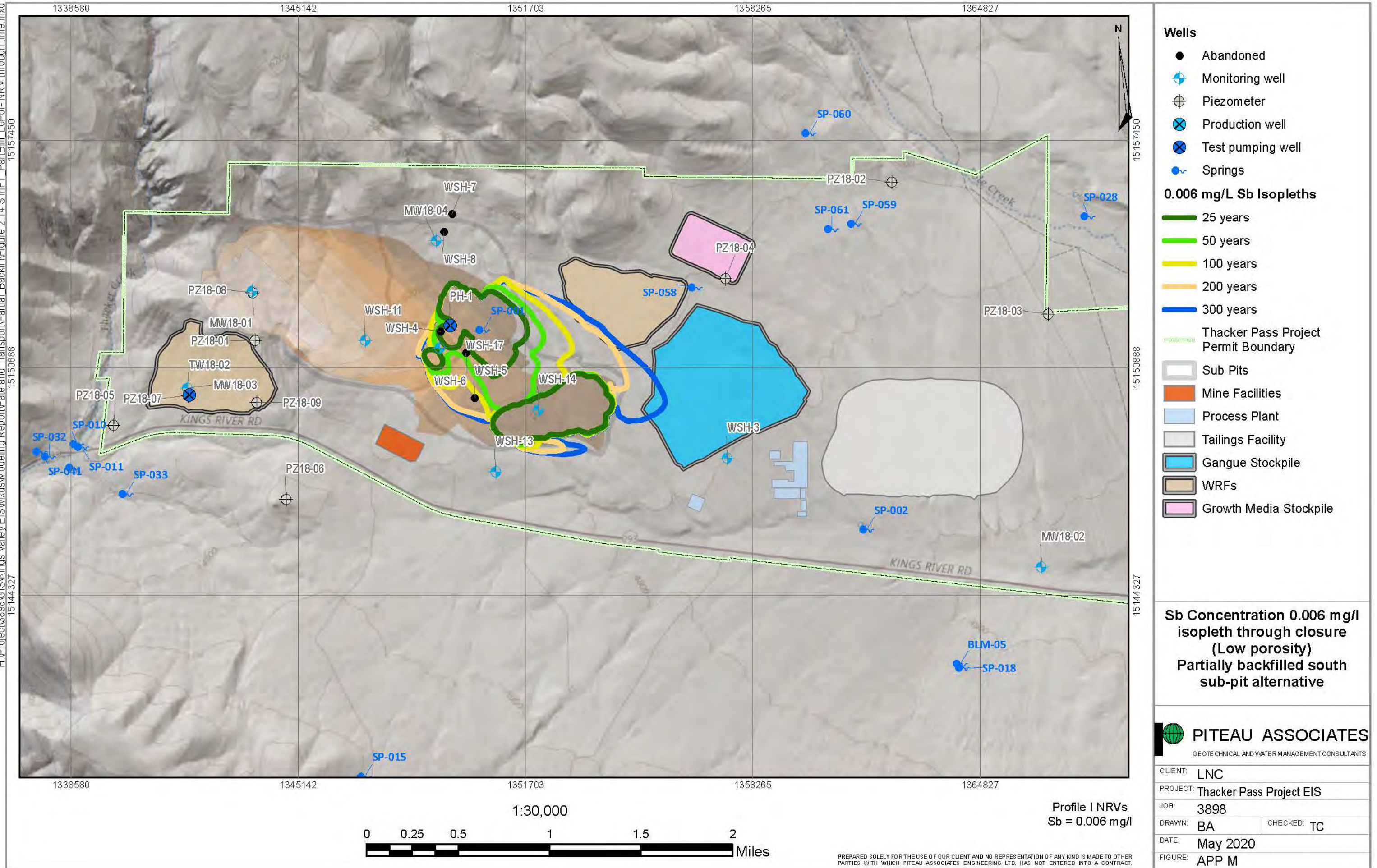
CLIENT:	LNC		
PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		

Profile I NRVs
Sb = 0.006 mg/l

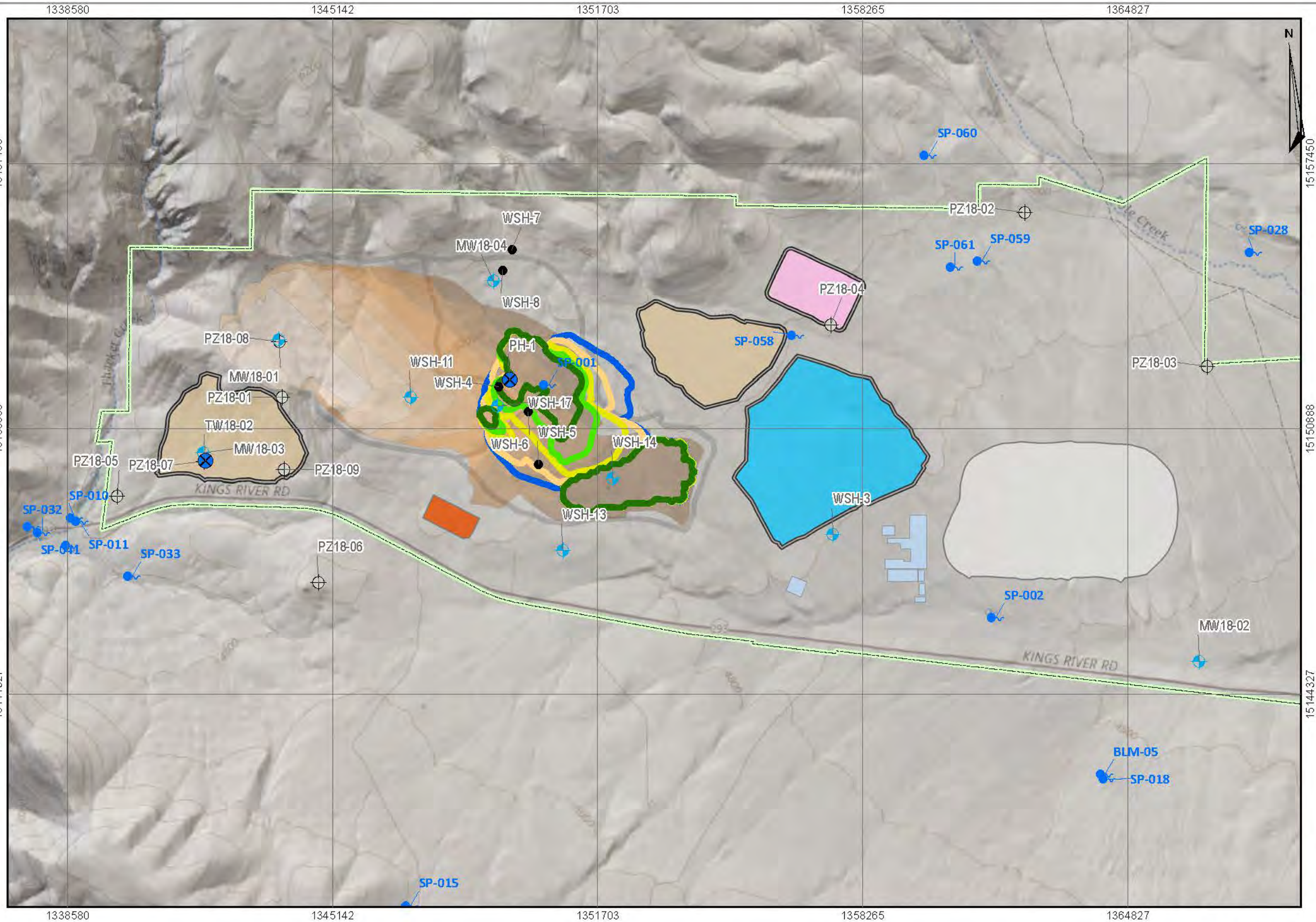


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H:\Project\3898\Kings Valley EIS\Map\Partial Backfill\Figure 2.14 SimFT_ParBil_NoDisp_NRV through time.mxd

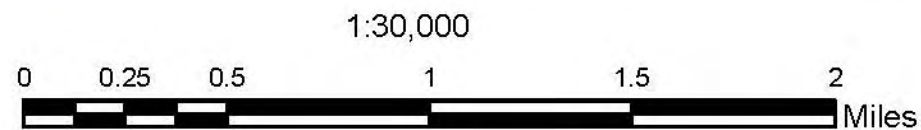


- Wells**
- Abandoned
 - ⊕ Monitoring well
 - ⊕ Piezometer
 - ⊕ Production well
 - ⊕ Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary
- Sub Pits
 - Mine Facilities
 - Process Plant
 - Tailings Facility
 - Gangue Stockpile
 - WRFs
 - Growth Media Stockpile

Sb Concentration 0.006 mg/l isopleth through closure (No Dispersion)
Partially backfilled south sub-pit alternative

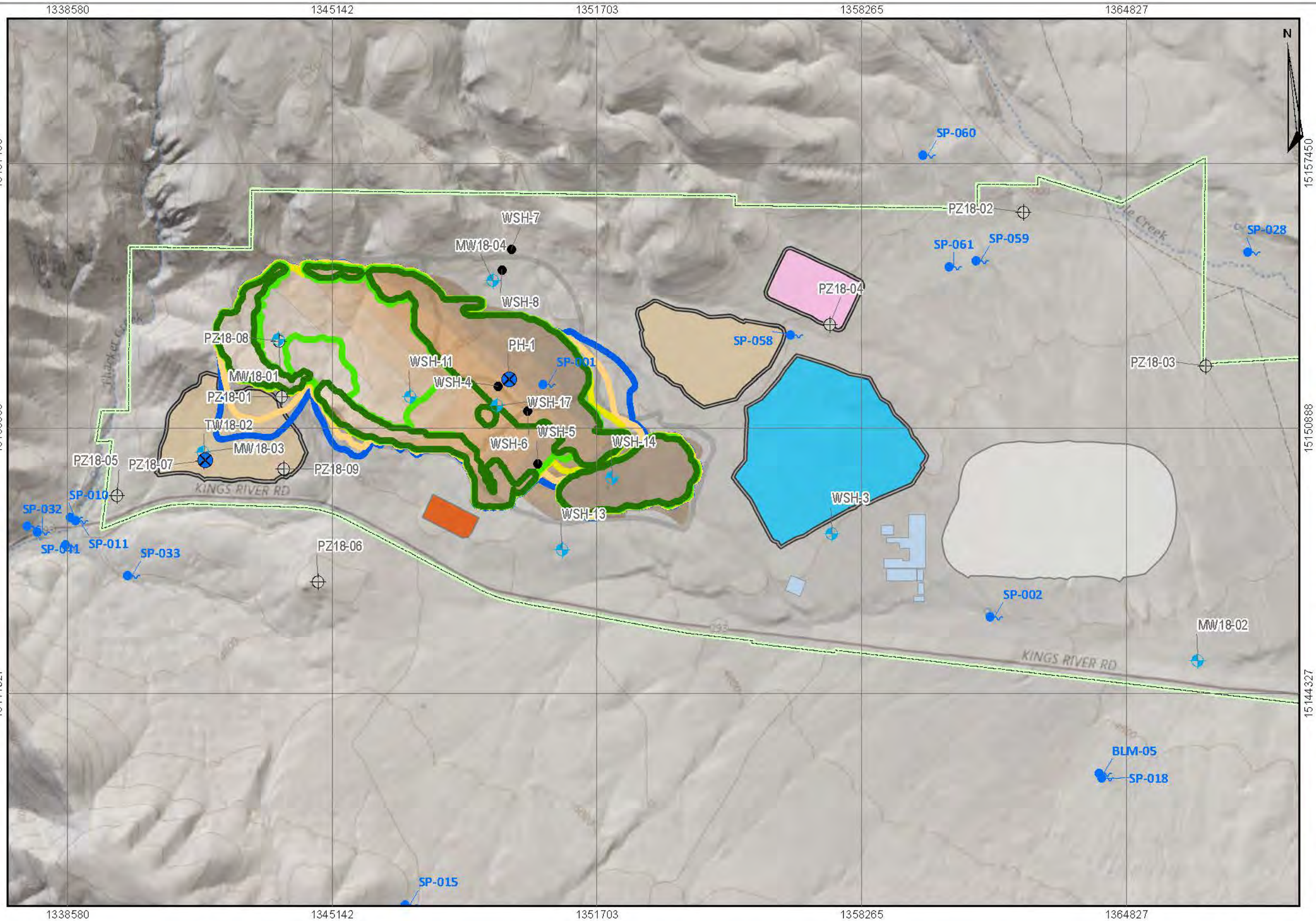
PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

CLIENT:	LNC		
PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		



Profile I NRVs
Sb = 0.006 mg/l

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- Wells**
- Abandoned
 - Monitoring well
 - Piezometer
 - Production well
 - Test pumping well
 - Springs
- 0.006 mg/L Sb Isopleths**
- 25 years
 - 50 years
 - 100 years
 - 200 years
 - 300 years
- Thacker Pass Project Permit Boundary
- Sub Pits
 - Mine Facilities
 - Process Plant
 - Tailings Facility
 - Gangue Stockpile
 - WRFs
 - Growth Media Stockpile

Sb Concentration 0.006 mg/l isopleth through closure (Infiltration through backfill) Partially backfilled south sub-pit alternative



CLIENT:	LNC		
PROJECT:	Thacker Pass Project EIS		
JOB:	3898		
DRAWN:	BA	CHECKED:	TC
DATE:	May 2020		
FIGURE:	APP M		

Profile I NRVs
Sb = 0.006 mg/l



PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

APPENDIX N
Materials characterization laboratory report

Laboratory Report for Piteau Associates

Lithium Nevada Project Samples

October 29, 2019



Daniel B. Stephens & Associates, Inc.

4400 Alameda Blvd. NE, Suite C • Albuquerque, New Mexico 87113



October 29, 2019

Tyler Cluff
Piteau Associates
9090 Double Diamond Parkway, Unit 1B
Reno, NV 89521
(775) 324-8883

Re: DBS&A Laboratory Report for the Piteau Associates, Lithium Nevada Sample Testing

Dear Mr. Cluff:

Enclosed is the report for the Piteau Associates, Lithium Nevada project samples. Please review this report and provide any comments as samples will be held for a maximum of 30 days. After 30 days samples will be returned or disposed of in an appropriate manner.

All testing results were evaluated subjectively for consistency and reasonableness, and the results appear to be reasonably representative of the material tested. However, DBS&A does not assume any responsibility for interpretations or analyses based on the data enclosed, nor can we guarantee that these data are fully representative of the undisturbed materials at the field site. We recommend that careful evaluation of these laboratory results be made for your particular application.

The testing utilized to generate the enclosed report employs methods that are standard for the industry. The results do not constitute a professional opinion by DBS&A, nor can the results affect any professional or expert opinions rendered with respect thereto by DBS&A. You have acknowledged that all the testing undertaken by us, and the report provided, constitutes mere test results using standardized methods, and cannot be used to disqualify DBS&A from rendering any professional or expert opinion, having waived any claim of conflict of interest by DBS&A.

We are pleased to provide this service to Piteau Associates and look forward to future laboratory testing on other projects. If you have any questions about the enclosed data, please do not hesitate to call.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.
SOIL TESTING & RESEARCH LABORATORY

Joleen Hines
Laboratory Manager

Enclosure

Daniel B. Stephens & Associates, Inc.
Soil Testing & Research Laboratory

4400 Alameda Blvd. NE, Suite C
Albuquerque, NM 87113

505-889-7752
FAX 505-889-0258

Summaries



Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties ¹			Saturated Hydraulic Conductivity ²			Moisture Characteristics ³								Particle Size ⁴			Specific Gravity ⁵		Air Perm- eability	Atterberg Limits	Proctor Compaction
	G	VM	VD	CH	FH	FW	HC	PP	FP	DPP	RH	EP	WHC	K _{unsat}	DS	WS	H	F	C			
49-SWECO+1.0-D25B-138																X	X				X	
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	X	X		X			X	X		X	X			X								
9-SWECO+1.0-E22B-348																X	X				X	
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	X	X		X			X	X		X	X			X								
4-LFILTCAKE-E05B-315																X	X				X	
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	X	X			X		X	X			X			X								
4381-Blend																X	X				X	
4381-Blend (Firm) (970 kg/m ³)	X	X			X		X	X			X			X								
WD19-01																X	X				X	
WD19-01 (1520 kg/m ³)	X	X			X		X	X		X	X			X								
WD19-02																X	X				X	
WD19-02 (1490 kg/m ³)	X	X			X		X	X		X	X			X								
WD19-03																X	X				X	
WD19-03 (Firm) (1300 kg/m ³)	X	X		X			X	X		X	X			X								
Growth 19-01																X	X				X	

¹ G = Gravimetric Moisture Content, VM = Volume Measurement Method, VD = Volume Displacement Method

² CH = Constant Head Rigid Wall, FH = Falling Head Rigid Wall, FW = Falling Head Rising Tail Flexible Wall

³ HC = Hanging Column, PP = Pressure Plate, FP = Filter Paper, DPP = Dew Point Potentiometer, RH = Relative Humidity Box, EP = Effective Porosity, WHC = Water Holding Capacity, K_{unsat} = Calculated Unsaturated Hydraulic Conductivity

⁴ DS = Dry Sieve, WS = Wet Sieve, H = Hydrometer

⁵ F = Fine (<4.75mm), C = Coarse (>4.75mm)



Summary of Tests Performed (Continued)

Laboratory Sample Number	Initial Soil Properties ¹			Saturated Hydraulic Conductivity ²			Moisture Characteristics ³								Particle Size ⁴			Specific Gravity ⁵		Air Perm- eability	Atterberg Limits	Proctor Compaction
	G	VM	VD	CH	FH	FW	HC	PP	FP	DPP	RH	EP	WHC	K _{unsat}	DS	WS	H	F	C			
Growth 19-01 (Firm) (1480 kg/m³)	X	X		X			X	X		X	X			X								
Growth 19-02																X	X				X	
Growth 19-02 (Firm) (1490 kg/m³)	X	X		X			X	X		X	X			X								
Growth 19-03																X	X				X	
Growth 19-03 (Firm) (1390 kg/m³)	X	X		X			X	X		X	X			X								
Growth 19-04																X	X				X	
Growth 19-04 (Firm) (1410 kg/m³)	X	X		X			X	X		X	X			X								

¹ G = Gravimetric Moisture Content, VM = Volume Measurement Method, VD = Volume Displacement Method

² CH = Constant Head Rigid Wall, FH = Falling Head Rigid Wall, FW = Falling Head Rising Tail Flexible Wall

³ HC = Hanging Column, PP = Pressure Plate, FP = Filter Paper, DPP = Dew Point Potentiometer, RH = Relative Humidity Box, EP = Effective Porosity, WHC = Water Holding Capacity, K_{unsat} = Calculated Unsaturated Hydraulic Conductivity

⁴ DS = Dry Sieve, WS = Wet Sieve, H = Hydrometer

⁵ F = Fine (<4.75mm), C = Coarse (>4.75mm)



Notes

Sample Receipt:

A total of eleven samples were received on August 29, 2019. Two of the samples were received, each as loose material in a 1-gallon bag. The remaining nine samples were received, each as loose material in two 1-gallon bags. The samples were delivered in two 5-gallon buckets sealed with lids and packing tape and a 12 gallon tote sealed with a lid. All samples were received in good order.

Sample Preparation and Testing Notes:

All samples were subjected to particle size analysis and Atterberg limits testing.

A portion of each of the samples was remolded into a testing ring using either client provided dry bulk density values, or a "firm" compactive effort based on technician experience and judgement. Prior to remolding, the sub-samples were moisture adjusted to a moisture content that would facilitate compaction, and bulk target densities were reverse gravel corrected to account for coarse fraction removed (if applicable). Each of these remolded sub-samples was subjected to initial properties analysis, saturated hydraulic conductivity testing, and the hanging column and pressure chamber portions of the moisture retention testing. The actual dry bulk density achieved (in kg/m³) was added to each sub-sample ID.

Separate sub-samples were obtained for the dewpoint potentiometer and relative humidity chamber portions of the moisture retention testing. After reviewing the test results it was determined that analysis by the dewpoint potentiometer test method was not appropriate for samples 4-LFILTCAKE-E05B-315 and 4381-Blend, and the dewpoint potentiometer test results for these two samples were not included in this report.

Porosity calculations, and the particle diameter calculations in the hydrometer portion of the particle size analysis testing, are based on the use of an assumed specific gravity value of 2.65.

Material larger than either 4.75mm, 3/8" or 3/4" (as appropriate) was removed from the sample material prior to compaction and remolding. Oversize correction calculations are presented if the fraction removed was greater than 5% of the bulk sample mass.

Volumetric water contents were adjusted for changes in volume, where applicable. Due to the irregularities formed on the sample surfaces during swelling, volume measurements obtained after the initial reading should be considered estimates.



Summary of Sample Preparation/Volume Changes

Sample Number	Target Remold Parameters ¹	Actual Remold Data			Volume Change Post Saturation ²			Volume Change Post Drying Curve ³		
	Dry Bulk Density (g/cm ³)	Moisture Content (%, g/g)	Dry Bulk Density (g/cm ³)	% of Target Density (%)	Dry Bulk Density (g/cm ³)	% Volume Change (%)	% of Initial Density (%)	Dry Bulk Density (g/cm ³)	% Volume Change (%)	% of Initial Density (%)
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	1.25	20.7	1.25	100.2%	1.25	---	100%	1.25	---	100%
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	1.24	18.7	1.24	100.1%	1.24	---	100%	1.24	---	100%
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	Firm	67.8	0.93	NA	0.93	---	100%	0.93	---	100%
4381-Blend (Firm) (970 kg/m ³)	Firm	60.4	0.97	NA	0.97	---	100%	0.97	---	100%
WD19-01 (1520 kg/m ³)	1.52	19.2	1.52	99.7%	1.49	+2.0%	98%	1.49	+2.0%	98%
WD19-02 (1490 kg/m ³)	1.49	22.0	1.49	100.2%	1.49	---	100%	1.49	---	100%
WD19-03 (Firm) (1300 kg/m ³)	Firm	28.0	1.30	NA	1.25	+4.1%	96%	1.25	+4.1%	96%
Growth 19-01 (Firm) (1480 kg/m ³)	Firm	18.1	1.48	NA	1.48	---	100%	1.48	---	100%
Growth 19-02 (Firm) (1490 kg/m ³)	Firm	15.5	1.49	NA	1.49	---	100%	1.49	---	100%
Growth 19-03 (Firm) (1390 kg/m ³)	Firm	15.8	1.39	NA	1.37	+1.5%	98%	1.37	+1.5%	98%
Growth 19-04 (Firm) (1410 kg/m ³)	Firm	15.4	1.41	NA	1.41	---	100%	1.41	---	100%

¹Target Remold Parameters: Bulk target densities were reverse gravel corrected to account for coarse fraction removed prior to remolding test sample. For samples where target bulk densities were not provided, a firm compactive effort was used.

²Volume Change Post Saturation: Volume change measurements were obtained after saturated hydraulic conductivity testing.

³Volume Change Post Drying Curve: Volume change measurements were obtained throughout hanging column and pressure plate testing. The 'Volume Change Post Drying Curve' values represent the final sample dimensions after the last pressure plate point.

Notes: "+" indicates sample swelling, "-" indicates sample settling, and "---" indicates no volume change occurred.



**Summary of Initial Moisture Content, Dry Bulk Density
Wet Bulk Density and Calculated Porosity**

Sample Number	As Remolded Moisture Content				Dry Bulk Density		Wet Bulk Density		Calculated Porosity	
	Test Sample		Oversize Corrected		Test Sample	Oversize Corrected	Test Sample	Oversize Corrected	Test Sample	Oversize Corrected
	Gravimetric (%, g/g)	Volumetric (%, cm ³ /cm ³)	Gravimetric (%, g/g)	Volumetric (%, cm ³ /cm ³)						
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	20.7	25.9	19.2	25.0	1.25	1.30	1.51	1.49	52.7	50.9
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	18.7	23.1	16.9	22.1	1.24	1.30	1.47	1.45	53.2	50.8
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	67.8	63.1	NA	NA	0.93	NA	1.56	NA	64.9	NA
4381-Blend (Firm) (970 kg/m ³)	60.4	58.5	---	---	0.97	---	1.55	---	63.4	---
WD19-01 (1520 kg/m ³)	19.2	29.0	16.9	27.0	1.52	1.60	1.81	1.77	42.8	39.8
WD19-02 (1490 kg/m ³)	22.0	32.9	18.4	29.7	1.49	1.61	1.82	1.77	43.6	39.3
WD19-03 (Firm) (1300 kg/m ³)	28.0	36.5	---	---	1.30	---	1.67	---	50.8	---
Growth 19-01 (Firm) (1480 kg/m ³)	18.1	26.8	---	---	1.48	---	1.75	---	44.0	---
Growth 19-02 (Firm) (1490 kg/m ³)	15.5	23.1	11.8	19.6	1.49	1.66	1.72	1.66	43.8	37.2
Growth 19-03 (Firm) (1390 kg/m ³)	15.8	22.1	---	---	1.39	---	1.62	---	47.4	---
Growth 19-04 (Firm) (1410 kg/m ³)	15.4	21.6	NA	NA	1.41	NA	1.63	NA	46.8	NA

NA = Not applicable

'---' = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Oversize Corrected K_{sat} (cm/sec)	Method of Analysis	
			Constant Head	Falling Head
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	6.1E-04	5.6E-04	X	
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	4.1E-04	3.7E-04	X	
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	8.3E-07	NA		X
4381-Blend (Firm) (970 kg/m ³)	4.8E-06	---		X
WD19-01 (1520 kg/m ³)	1.8E-05	1.6E-05		X
WD19-02 (1490 kg/m ³)	8.4E-06	7.1E-06		X
WD19-03 (Firm) (1300 kg/m ³)	3.7E-05	---	X	
Growth 19-01 (Firm) (1480 kg/m ³)	3.8E-05	---	X	
Growth 19-02 (Firm) (1490 kg/m ³)	8.8E-05	6.7E-05	X	
Growth 19-03 (Firm) (1390 kg/m ³)	8.4E-05	---	X	
Growth 19-04 (Firm) (1410 kg/m ³)	5.5E-05	NA	X	

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NR = Not requested

NA = Not applicable



Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm^3/cm^3)
49-SWECO+1.0-D25B-138 (1250 kg/m^3)	0	53.7
	10	49.8
	30	43.8
	95	41.6
	337	37.3
	2651	26.1
	10606	22.0
	45483	17.9
	139101	13.0
	389462	6.7
	848426	4.6
9-SWECO+1.0-E22B-348 (1240 kg/m^3)	0	54.3
	10	54.0
	30	49.6
	95	46.0
	337	41.0
	1836	27.7
	10096	19.3
	81686	12.9
	412611	7.4
	848426	6.1
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m^3)	0	64.0
	27	62.9
	70	61.3
	153	59.7
	337	58.6
	848426	9.6

Volume adjustments are applicable at this matric potential (see data sheet for this sample).



**Summary of Moisture Characteristics
of the Initial Drainage Curve (Continued)**

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm^3/cm^3)
4381-Blend (Firm) (970 kg/m^3)	0	59.7
	27	57.0
	70	51.9
	153	49.5
	337	45.8
	848426	14.7
WD19-01 (1520 kg/m^3)	0	43.2 ‡
	18	43.1 ‡
	58	43.0 ‡
	128	42.5 ‡
	337	35.8 ‡
	4487	19.4 ‡
	22538	12.8 ‡
	89334	9.7 ‡
	548244	6.2 ‡
	848426	6.1 ‡
WD19-02 (1490 kg/m^3)	0	43.4
	27	43.4
	70	43.2
	153	40.8
	337	37.2
	1734	22.1
	8056	15.8
	36407	11.1
	174998	8.3
	848426	6.0

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm^3/cm^3)
WD19-03 (Firm) (1300 kg/m^3)	0	50.2 ‡
	18	50.1 ‡
	57	49.3 ‡
	130	43.9 ‡
	377	42.7 ‡
	2244	28.9 ‡
	10810	21.0 ‡
	73528	14.0 ‡
	303900	10.2 ‡
	848426	8.4 ‡
Growth 19-01 (Firm) (1480 kg/m^3)	0	42.0
	18	41.8
	58	40.9
	128	35.7
	337	30.7
	1632	23.9
	9790	15.9
	57211	9.9
	240163	7.4
	848426	5.4
Growth 19-02 (Firm) (1490 kg/m^3)	0	42.0
	10	42.0
	30	41.8
	95	36.9
	337	27.3
	2651	10.4
	8872	7.2
	52316	4.5
	247811	3.3
	848426	2.4

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



**Summary of Moisture Characteristics
of the Initial Drainage Curve (Continued)**

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm ³ /cm ³)
Growth 19-03 (Firm) (1390 kg/m ³)	0	45.1 ‡
	10	44.9 ‡
	30	44.5 ‡
	95	40.4 ‡
	337	32.7 ‡
	1836	21.3 ‡
	12849	14.3 ‡
	55069	9.9 ‡
	336432	6.9 ‡
	848426	5.5 ‡
Growth 19-04 (Firm) (1410 kg/m ³)	0	45.0
	18	44.4
	58	43.9
	128	43.2
	337	31.3
	3875	18.6
	11932	14.0
	42730	11.0
	193456	8.2
	848426	5.2

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm ⁻¹)	N (dimensionless)	θ_r (% vol)	θ_s (% vol)	Oversize Corrected	
					θ_r (% vol)	θ_s (% vol)
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	0.0224	1.1757	0.00	51.24	0.00	49.46
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	0.0097	1.2242	0.00	53.42	0.00	51.01
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	0.0017	1.2568	0.00	62.95	NA	NA
4381-Blend (Firm) (970 kg/m ³)	0.0195	1.1419	0.00	59.49	---	---
WD19-01 (1520 kg/m ³)	0.0033	1.3415	3.46	43.77	3.22	40.73
WD19-02 (1490 kg/m ³)	0.0030	1.4430	5.71	43.90	5.15	39.57
WD19-03 (Firm) (1300 kg/m ³)	0.0048	1.2244	0.63	50.17	---	---
Growth 19-01 (Firm) (1480 kg/m ³)	0.0094	1.2236	0.00	42.46	---	---
Growth 19-02 (Firm) (1490 kg/m ³)	0.0060	1.5489	2.42	42.20	2.05	35.83
Growth 19-03 (Firm) (1390 kg/m ³)	0.0084	1.2866	2.42	45.42	---	---
Growth 19-04 (Firm) (1410 kg/m ³)	0.0063	1.3305	3.76	45.67	NA	NA

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NR = Not requested

NA = Not applicable



Summary of Particle Size Characteristics

Sample Number	d ₁₀ (mm)	d ₅₀ (mm)	d ₆₀ (mm)	C _u	C _c	Method	ASTM Classification	USDA Classification	
49-SWECO+1.0-D25B-138	0.00022	0.044	0.065	295	1.5	WS/H	Sandy lean clay s(CL)	Loam [†]	(Est)
9-SWECO+1.0-E22B-348	6.6E-05	0.050	0.15	2273	2.0	WS/H	Sandy fat clay s(CH)	Clay Loam [†]	(Est)
4-LFILTCAKE-E05B-315	6.5E-09	0.41	0.82	1.3E+08	1.9E+04	WS/H	Silty sand (SM)	Sandy Clay Loam [†]	(Est)
4381-Blend	5.7E-52	0.11	0.26	4.6E+50	2.6E+27	WS/H	Silty sand (SM)	Sandy Clay	(Est)
WD19-01	0.0037	0.084	0.13	35	4.4	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
WD19-02	0.0022	0.089	0.17	77	4.9	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
WD19-03	0.00063	0.067	0.11	175	5.8	WS/H	Sandy elastic silt s(MH)	Loam [†]	(Est)
Growth 19-01	0.0015	0.052	0.063	42	8.3	WS/H	Silt with sand (ML)s	Loam	
Growth 19-02	0.0065	0.084	0.14	22	2.5	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
Growth 19-03	0.0012	0.039	0.050	42	1.1	WS/H	Silt with sand (ML)s	Loam	(Est)
Growth 19-04	0.0027	0.047	0.056	21	2.4	WS/H	Silt with sand (ML)s	Loam	

d₅₀ = Median particle diameter

Est = Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{(d_{30})^2}{(d_{10})(d_{60})}$$

DS = Dry sieve

H = Hydrometer

WS = Wet sieve

[†] Greater than 10% of sample is coarse material



Percent Gravel, Sand, Silt and Clay*

Sample Number	% Gravel (>4.75mm)	% Sand (<4.75mm, >0.075mm)	% Silt (<0.075mm, >0.002mm)	% Clay (<0.002mm)
49-SWECO+1.0-D25B-138	7.1	29.5	39.7	23.8
9-SWECO+1.0-E22B-348	14.6	30.5	29.3	25.6
4-LFILTCAKE-E05B-315	0.0	61.4	17.1	21.4
4381-Blend	1.6	51.2	12.3	34.9
WD19-01	15.9	37.0	38.5	8.6
WD19-02	19.7	34.3	36.4	9.6
WD19-03	13.9	34.1	36.3	15.7
Growth 19-01	2.1	27.7	59.4	10.8
Growth 19-02	24.0	28.5	41.9	5.6
Growth 19-03	2.7	19.0	64.2	14.1
Growth 19-04	0.0	23.1	68.1	8.8

*USCS classification does not classify clay fraction based on particle size. USDA definition of clay (<0.002mm) used in this table.



Summary of Atterberg Tests

Sample Number	Liquid Limit	Plastic Limit	Plasticity Index	Classification
49-SWECO+1.0-D25B-138	49	25	24	CL
9-SWECO+1.0-E22B-348	52	26	26	CH
4-LFILTCAKE-E05B-315	---	---	---	ML
4381-Blend	43	37	6	ML
WD19-01	---	---	---	ML
WD19-02	---	---	---	ML
WD19-03	53	30	23	MH
Growth 19-01	---	---	---	ML
Growth 19-02	---	---	---	ML
Growth 19-03	---	---	---	ML
Growth 19-04	---	---	---	ML

--- = Soil requires visual-manual classification due to non-plasticity

Initial Properties



**Summary of Initial Moisture Content, Dry Bulk Density
Wet Bulk Density and Calculated Porosity**

Sample Number	As Remolded Moisture Content				Dry Bulk Density		Wet Bulk Density		Calculated Porosity	
	Test Sample		Oversize Corrected		Test Sample	Oversize Corrected	Test Sample	Oversize Corrected	Test Sample	Oversize Corrected
	Gravimetric (%, g/g)	Volumetric (%, cm ³ /cm ³)	Gravimetric (%, g/g)	Volumetric (%, cm ³ /cm ³)						
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	20.7	25.9	19.2	25.0	1.25	1.30	1.51	1.49	52.7	50.9
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	18.7	23.1	16.9	22.1	1.24	1.30	1.47	1.45	53.2	50.8
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	67.8	63.1	NA	NA	0.93	NA	1.56	NA	64.9	NA
4381-Blend (Firm) (970 kg/m ³)	60.4	58.5	---	---	0.97	---	1.55	---	63.4	---
WD19-01 (1520 kg/m ³)	19.2	29.0	16.9	27.0	1.52	1.60	1.81	1.77	42.8	39.8
WD19-02 (1490 kg/m ³)	22.0	32.9	18.4	29.7	1.49	1.61	1.82	1.77	43.6	39.3
WD19-03 (Firm) (1300 kg/m ³)	28.0	36.5	---	---	1.30	---	1.67	---	50.8	---
Growth 19-01 (Firm) (1480 kg/m ³)	18.1	26.8	---	---	1.48	---	1.75	---	44.0	---
Growth 19-02 (Firm) (1490 kg/m ³)	15.5	23.1	11.8	19.6	1.49	1.66	1.72	1.66	43.8	37.2
Growth 19-03 (Firm) (1390 kg/m ³)	15.8	22.1	---	---	1.39	---	1.62	---	47.4	---
Growth 19-04 (Firm) (1410 kg/m ³)	15.4	21.6	NA	NA	1.41	NA	1.63	NA	46.8	NA

NA = Not applicable

'---' = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Daniel B. Stephens & Associates, Inc.

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)
Material Type: Gangue
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		478.30
<i>Tare weight, ring (g):</i>		139.51
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		280.67
<i>Sample volume (cm³):</i>		224.00
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		20.7
<i>Volumetric Moisture Content (% vol):</i>		25.9
<i>Dry bulk density (g/cm³):</i>		1.25
<i>Wet bulk density (g/cm³):</i>		1.51
<i>Calculated Porosity (% vol):</i>		52.7
<i>Percent Saturation:</i>		49.2
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)
Material Type: Gangue
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		691.60
<i>Tare weight, ring (g):</i>		276.00
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		350.27
<i>Sample volume (cm³):</i>		282.30
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		18.7
<i>Volumetric Moisture Content (% vol):</i>		23.1
<i>Dry bulk density (g/cm³):</i>		1.24
<i>Wet bulk density (g/cm³):</i>		1.47
<i>Calculated Porosity (% vol):</i>		53.2
<i>Percent Saturation:</i>		43.5
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)
Material Type: Tailings
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		490.40
<i>Tare weight, ring (g):</i>		140.05
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		208.81
<i>Sample volume (cm³):</i>		224.27
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		67.8
<i>Volumetric Moisture Content (% vol):</i>		63.1
<i>Dry bulk density (g/cm³):</i>		0.93
<i>Wet bulk density (g/cm³):</i>		1.56
<i>Calculated Porosity (% vol):</i>		64.9
<i>Percent Saturation:</i>		97.3
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4381-Blend (Firm) (970 kg/m³)
Material Type: Tailings
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		717.10
<i>Tare weight, ring (g):</i>		276.80
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		274.58
<i>Sample volume (cm³):</i>		283.34
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		60.4
<i>Volumetric Moisture Content (% vol):</i>		58.5
<i>Dry bulk density (g/cm³):</i>		0.97
<i>Wet bulk density (g/cm³):</i>		1.55
<i>Calculated Porosity (% vol):</i>		63.4
<i>Percent Saturation:</i>		92.2
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-01 (1520 kg/m³)
Material Type: Waste Rock
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	9-Sep-19
<i>Field weight* of sample (g):</i>		769.20
<i>Tare weight, ring (g):</i>		254.15
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		432.26
<i>Sample volume (cm³):</i>		285.19
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		19.2
<i>Volumetric Moisture Content (% vol):</i>		29.0
<i>Dry bulk density (g/cm³):</i>		1.52
<i>Wet bulk density (g/cm³):</i>		1.81
<i>Calculated Porosity (% vol):</i>		42.8
<i>Percent Saturation:</i>		67.8
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-02 (1490 kg/m³)
Material Type: Waste Rock
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	9-Sep-19
<i>Field weight* of sample (g):</i>		775.70
<i>Tare weight, ring (g):</i>		257.59
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		424.57
<i>Sample volume (cm³):</i>		284.27
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		22.0
<i>Volumetric Moisture Content (% vol):</i>		32.9
<i>Dry bulk density (g/cm³):</i>		1.49
<i>Wet bulk density (g/cm³):</i>		1.82
<i>Calculated Porosity (% vol):</i>		43.6
<i>Percent Saturation:</i>		75.4
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-03 (Firm) (1300 kg/m³)
Material Type: Waste Rock
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		2444.70
<i>Tare weight, ring (g):</i>		165.76
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		1780.90
<i>Sample volume (cm³):</i>		1365.76
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		28.0
<i>Volumetric Moisture Content (% vol):</i>		36.5
<i>Dry bulk density (g/cm³):</i>		1.30
<i>Wet bulk density (g/cm³):</i>		1.67
<i>Calculated Porosity (% vol):</i>		50.8
<i>Percent Saturation:</i>		71.8
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)
Material Type: Growth Media
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		535.60
<i>Tare weight, ring (g):</i>		141.30
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		333.97
<i>Sample volume (cm³):</i>		225.05
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		18.1
<i>Volumetric Moisture Content (% vol):</i>		26.8
<i>Dry bulk density (g/cm³):</i>		1.48
<i>Wet bulk density (g/cm³):</i>		1.75
<i>Calculated Porosity (% vol):</i>		44.0
<i>Percent Saturation:</i>		60.9
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)
Material Type: Growth Media
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		524.30
<i>Tare weight, ring (g):</i>		139.98
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		332.78
<i>Sample volume (cm³):</i>		223.49
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		15.5
<i>Volumetric Moisture Content (% vol):</i>		23.1
<i>Dry bulk density (g/cm³):</i>		1.49
<i>Wet bulk density (g/cm³):</i>		1.72
<i>Calculated Porosity (% vol):</i>		43.8
<i>Percent Saturation:</i>		52.6
<i>Laboratory analysis by:</i>		D. O'Dowd
<i>Data entered by:</i>		D. O'Dowd
<i>Checked by:</i>		J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)
Material Type: Growth Media
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		501.07
<i>Tare weight, ring (g):</i>		139.35
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		312.27
<i>Sample volume (cm³):</i>		223.89
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		15.8
<i>Volumetric Moisture Content (% vol):</i>		22.1
<i>Dry bulk density (g/cm³):</i>		1.39
<i>Wet bulk density (g/cm³):</i>		1.62
<i>Calculated Porosity (% vol):</i>		47.4
<i>Percent Saturation:</i>		46.6
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded



Daniel B. Stephens & Associates, Inc.

**Data for Initial Moisture Content,
Bulk Density, Porosity, and Percent Saturation**

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)
Material Type: Growth Media
Depth: NA

	<u>As Received</u>	<u>Remolded</u>
<i>Test Date:</i>	NA	10-Sep-19
<i>Field weight* of sample (g):</i>		502.90
<i>Tare weight, ring (g):</i>		139.98
<i>Tare weight, pan/plate (g):</i>		0.00
<i>Tare weight, other (g):</i>		0.00
<i>Dry weight of sample (g):</i>		314.60
<i>Sample volume (cm³):</i>		223.27
<i>Assumed particle density (g/cm³):</i>		2.65
<i>Gravimetric Moisture Content (% g/g):</i>		15.4
<i>Volumetric Moisture Content (% vol):</i>		21.6
<i>Dry bulk density (g/cm³):</i>		1.41
<i>Wet bulk density (g/cm³):</i>		1.63
<i>Calculated Porosity (% vol):</i>		46.8
<i>Percent Saturation:</i>		46.2
<i>Laboratory analysis by:</i>	D. O'Dowd	
<i>Data entered by:</i>	D. O'Dowd	
<i>Checked by:</i>	J. Hines	

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Saturated Hydraulic Conductivity



Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K _{sat} (cm/sec)	Oversize Corrected K _{sat} (cm/sec)	Method of Analysis	
			Constant Head	Falling Head
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	6.1E-04	5.6E-04	X	
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	4.1E-04	3.7E-04	X	
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	8.3E-07	NA		X
4381-Blend (Firm) (970 kg/m ³)	4.8E-06	---		X
WD19-01 (1520 kg/m ³)	1.8E-05	1.6E-05		X
WD19-02 (1490 kg/m ³)	8.4E-06	7.1E-06		X
WD19-03 (Firm) (1300 kg/m ³)	3.7E-05	---	X	
Growth 19-01 (Firm) (1480 kg/m ³)	3.8E-05	---	X	
Growth 19-02 (Firm) (1490 kg/m ³)	8.8E-05	6.7E-05	X	
Growth 19-03 (Firm) (1390 kg/m ³)	8.4E-05	---	X	
Growth 19-04 (Firm) (1410 kg/m ³)	5.5E-05	NA	X	

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NR = Not requested

NA = Not applicable



Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)
Material Type: Gangue
Depth: NA

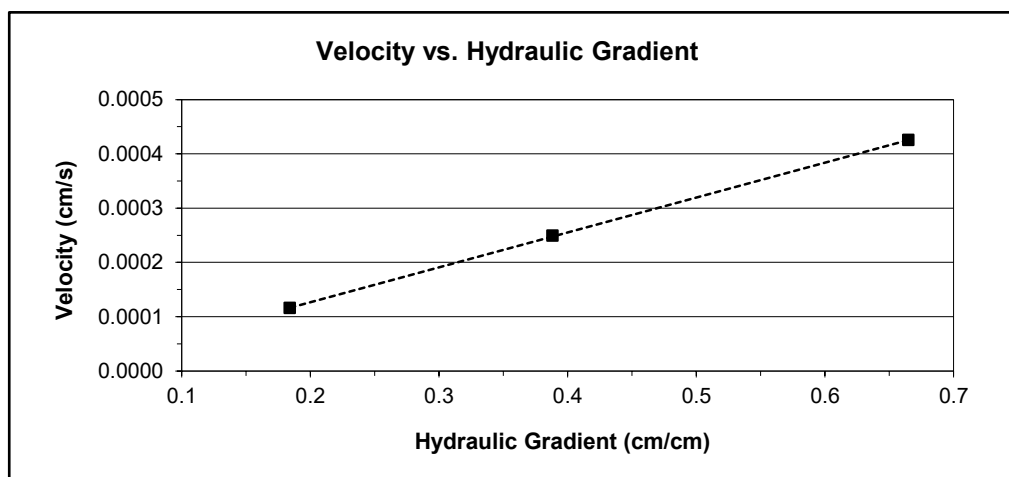
Type of water used: TAP
Collection vessel tare (g): 66.54
Sample length (cm): 7.60
Sample diameter (cm): 6.13
Sample x-sectional area (cm²): 29.49

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:54:00	22.0	5.05	69.55	3.0	240	6.4E-04	6.1E-04
12-Sep-19	13:58:00							
Test # 2:								
12-Sep-19	14:09:00	22.0	2.95	68.30	1.8	240	6.4E-04	6.1E-04
12-Sep-19	14:13:00							
Test # 3:								
12-Sep-19	14:23:00	22.0	1.4	67.36	0.8	240	6.3E-04	6.0E-04
12-Sep-19	14:27:00							

Average Ksat (cm/sec): 6.1E-04
Oversize Corrected Ksat (cm/sec): 5.6E-04

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd
Data entered by: D. O'Dowd
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)

Material Type: Gangue

Depth: NA

Split (3/4", 3/8", #4): #4

Calculated Porosity of Fines (% vol): 52.7

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	7.10	92.90	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.25	1.30
<i>Volume of Solids (cm³):</i>	2.68	35.06	37.74
<i>Volume of Voids (cm³):</i>	0.00	39.09	39.09
<i>Total Volume (cm³):</i>	2.68	74.15	76.82
<i>Volumetric Fraction (%):</i>	3.49	96.51	100.00
<i>Mass Fraction (%):</i>	7.10	92.90	100.00
<i>Ksat (cm/sec):</i>	NM	6.1E-04	5.6E-04

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)
Material Type: Gangue
Depth: NA

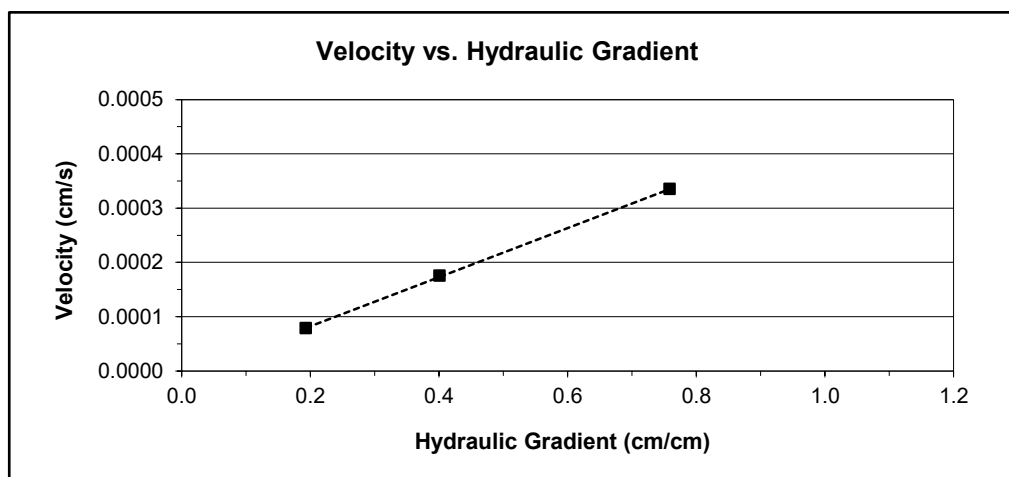
Type of water used: TAP
Collection vessel tare (g): 67.98
Sample length (cm): 6.98
Sample diameter (cm): 7.18
Sample x-sectional area (cm²): 40.43

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:53:30	22.0	5.3	71.23	3.3	240	4.4E-04	4.2E-04
12-Sep-19	13:57:30							
Test # 2:								
12-Sep-19	14:08:30	22.0	2.8	69.68	1.7	240	4.4E-04	4.2E-04
12-Sep-19	14:12:30							
Test # 3:								
12-Sep-19	14:22:30	22.0	1.35	68.74	0.8	240	4.1E-04	3.9E-04
12-Sep-19	14:26:30							

Average Ksat (cm/sec): 4.1E-04
Oversize Corrected Ksat (cm/sec): 3.7E-04

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)

Material Type: Gangue

Depth: NA

Split (3/4", 3/8", #4): 3/8"

Calculated Porosity of Fines (% vol): 53.2

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	9.17	90.83	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.24	1.30
<i>Volume of Solids (cm³):</i>	3.46	34.28	37.74
<i>Volume of Voids (cm³):</i>	0.00	38.93	38.93
<i>Total Volume (cm³):</i>	3.46	73.20	76.66
<i>Volumetric Fraction (%):</i>	4.51	95.49	100.00
<i>Mass Fraction (%):</i>	9.17	90.83	100.00
<i>Ksat (cm/sec):</i>	NM	4.1E-04	3.7E-04

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Saturated Hydraulic Conductivity Falling Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4-LFILTCake-E05B-315 (Firm) (930 kg/m³)
Material Type: Tailings
Depth: NA

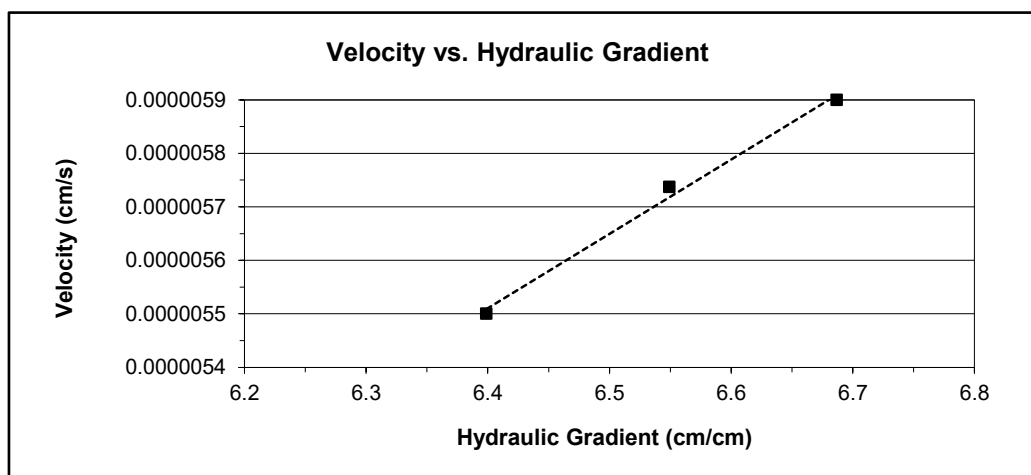
Type of water used: TAP
Backpressure (psi): 0.0
Offset (cm): 0.1
Sample length (cm): 7.64
Sample x-sectional area (cm²): 29.36
Reservoir x-sectional area (cm²): 0.70

Date	Time	Temp (°C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:							
12-Sep-19	12:53:47	22.5	51.1	51.0	2425	8.9E-07	8.4E-07
12-Sep-19	13:34:12	22.5	50.5	50.4			
Test # 2:							
12-Sep-19	14:09:12	22.5	50	49.9	2078	8.8E-07	8.3E-07
12-Sep-19	14:43:50	22.5	49.5	49.4			
Test # 3:							
12-Sep-19	15:25:59	22.5	48.9	48.8	2601	8.7E-07	8.2E-07
12-Sep-19	16:09:20	22.5	48.3	48.2			

Average Ksat (cm/sec): 8.3E-07
Oversize Corrected Ksat (cm/sec): NA

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass
NA = Not applicable



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Saturated Hydraulic Conductivity Falling Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4381-Blend (Firm) (970 kg/m³)
Material Type: Tailings
Depth: NA

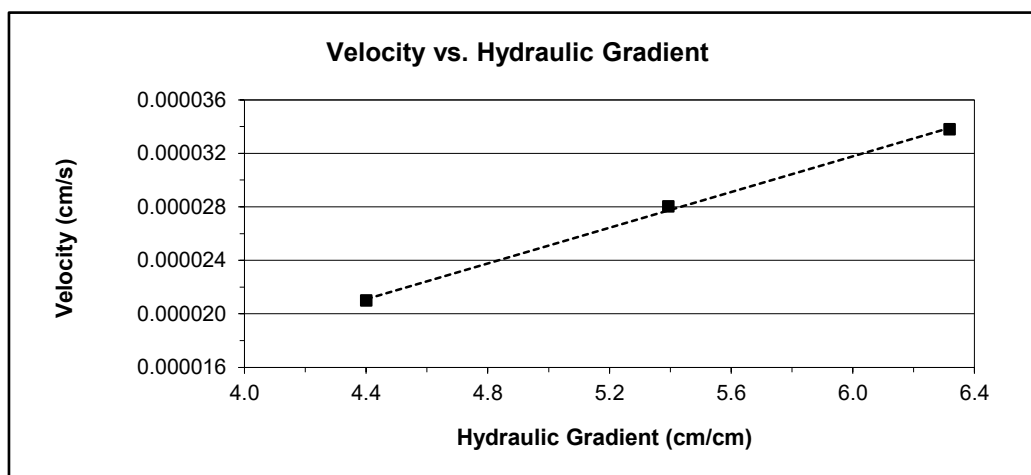
Type of water used: TAP
Backpressure (psi): 0.0
Offset (cm): 0.1
Sample length (cm): 7.00
Sample x-sectional area (cm²): 40.49
Reservoir x-sectional area (cm²): 0.70

Date	Time	Temp (°C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:							
12-Sep-19	13:11:45	22.5	45.7	45.6	1408	5.3E-06	5.0E-06
12-Sep-19	13:35:13	22.5	42.95	42.9			
Test # 2:							
12-Sep-19	14:06:01	22.5	39.6	39.5	2160	5.2E-06	4.9E-06
12-Sep-19	14:42:01	22.5	36.1	36.0			
Test # 3:							
12-Sep-19	15:24:35	22.5	32.55	32.5	2718	4.8E-06	4.5E-06
12-Sep-19	16:09:53	22.5	29.25	29.2			

Average Ksat (cm/sec): 4.8E-06
Oversize Corrected Ksat (cm/sec): ---

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: 4381-Blend (Firm) (970 kg/m³)

Material Type: Tailings

Depth: NA

Split (3/4", 3/8", #4): 3/8"

Calculated Porosity of Fines (% vol): 63.4

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	0.82	99.18	100.00
<i>Bulk Density (g/cm³):</i>	2.65	0.97	0.97
<i>Volume of Solids (cm³):</i>	0.31	37.43	37.74
<i>Volume of Voids (cm³):</i>	0.00	64.92	64.92
<i>Total Volume (cm³):</i>	0.31	102.35	102.66
<i>Volumetric Fraction (%):</i>	0.30	99.70	100.00
<i>Mass Fraction (%):</i>	0.82	99.18	100.00
<i>Ksat (cm/sec):</i>	NM	4.8E-06	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Saturated Hydraulic Conductivity Falling Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-01 (1520 kg/m³)
Material Type: Waste Rock
Depth: NA

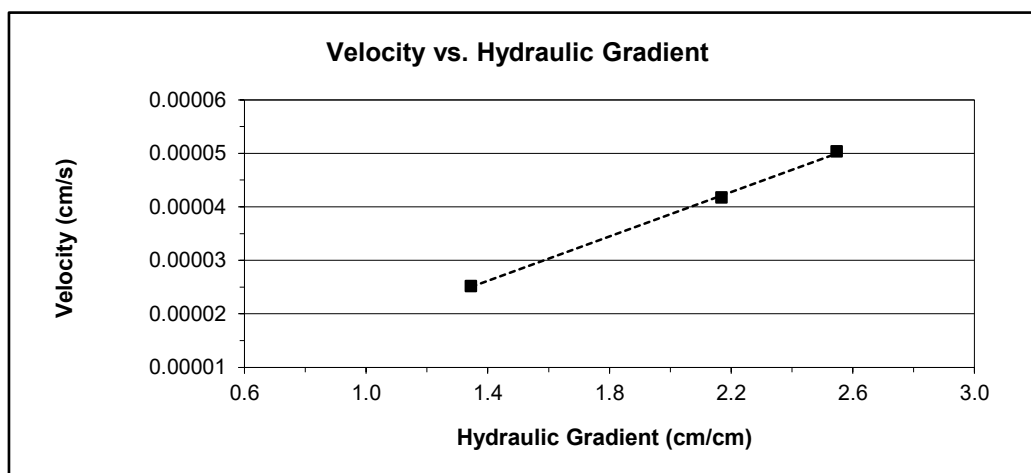
Type of water used: TAP
Backpressure (psi): 0.0
Offset (cm): 0.0
Sample length (cm): 6.99
Sample x-sectional area (cm²): 40.83
Reservoir x-sectional area (cm²): 0.70

Date	Time	Temp (°C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:							
12-Sep-19	12:47:00	22.5	18.5	18.5	477	2.0E-05	1.9E-05
12-Sep-19	12:54:57	22.5	17.1	17.1			
Test # 2:							
12-Sep-19	13:02:10	22.5	15.9	15.9	617	1.9E-05	1.8E-05
12-Sep-19	13:12:27	22.5	14.4	14.4			
Test # 3:							
12-Sep-19	13:48:00	22.5	10.2	10.2	1090	1.9E-05	1.8E-05
12-Sep-19	14:06:10	22.5	8.6	8.6			

Average Ksat (cm/sec): 1.8E-05
Oversize Corrected Ksat (cm/sec): 1.6E-05

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: WD19-01 (1520 kg/m³)

Material Type: Waste Rock

Depth: NA

Split (3/4", 3/8", #4): 3/8"

Calculated Porosity of Fines (% vol): 42.8

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	11.73	88.27	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.52	1.60
<i>Volume of Solids (cm³):</i>	4.43	33.31	37.74
<i>Volume of Voids (cm³):</i>	0.00	24.93	24.93
<i>Total Volume (cm³):</i>	4.43	58.24	62.66
<i>Volumetric Fraction (%):</i>	7.06	92.94	100.00
<i>Mass Fraction (%):</i>	11.73	88.27	100.00
<i>Ksat (cm/sec):</i>	NM	1.8E-05	1.6E-05

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Saturated Hydraulic Conductivity Falling Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-02 (1490 kg/m³)
Material Type: Waste Rock
Depth: NA

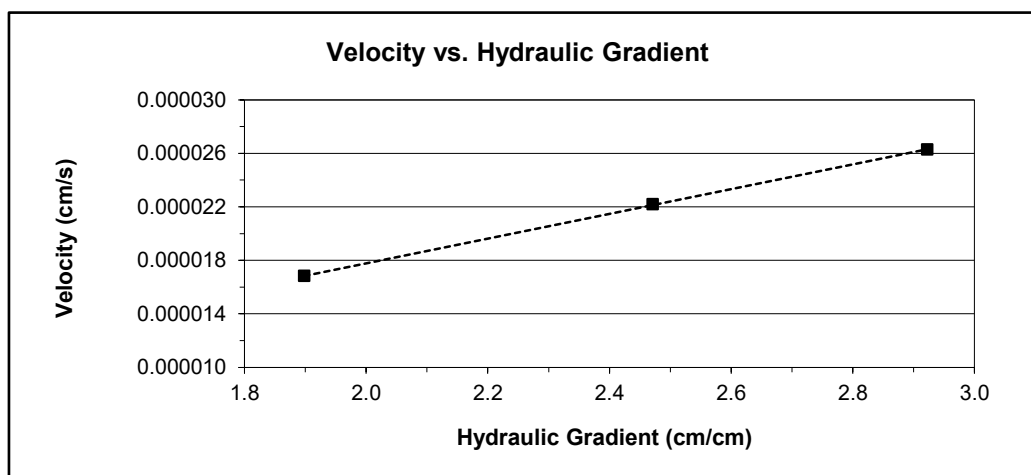
Type of water used: TAP
Backpressure (psi): 0.0
Offset (cm): 0.0
Sample length (cm): 6.98
Sample x-sectional area (cm²): 40.73
Reservoir x-sectional area (cm²): 0.70

Date	Time	Temp (°C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:							
12-Sep-19	12:39:29	22.5	21	21.0	785	9.0E-06	8.5E-06
12-Sep-19	12:52:34	22.5	19.8	19.8			
Test # 2:							
12-Sep-19	13:11:32	22.5	18.2	18.2	1473	9.0E-06	8.5E-06
12-Sep-19	13:36:05	22.5	16.3	16.3			
Test # 3:							
12-Sep-19	14:05:34	22.5	14.3	14.3	2146	8.9E-06	8.4E-06
12-Sep-19	14:41:20	22.5	12.2	12.2			

Average Ksat (cm/sec): 8.4E-06
Oversize Corrected Ksat (cm/sec): 7.1E-06

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: WD19-02 (1490 kg/m³)

Material Type: Waste Rock

Depth: NA

Split (3/4", 3/8", #4): 3/8"

Calculated Porosity of Fines (% vol): 43.6

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	16.26	83.74	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.49	1.61
<i>Volume of Solids (cm³):</i>	6.13	31.60	37.74
<i>Volume of Voids (cm³):</i>	0.00	24.47	24.47
<i>Total Volume (cm³):</i>	6.13	56.07	62.20
<i>Volumetric Fraction (%):</i>	9.86	90.14	100.00
<i>Mass Fraction (%):</i>	16.26	83.74	100.00
<i>Ksat (cm/sec):</i>	NM	8.4E-06	7.1E-06

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-03 (Firm) (1300 kg/m³)
Material Type: Waste Rock
Depth: NA

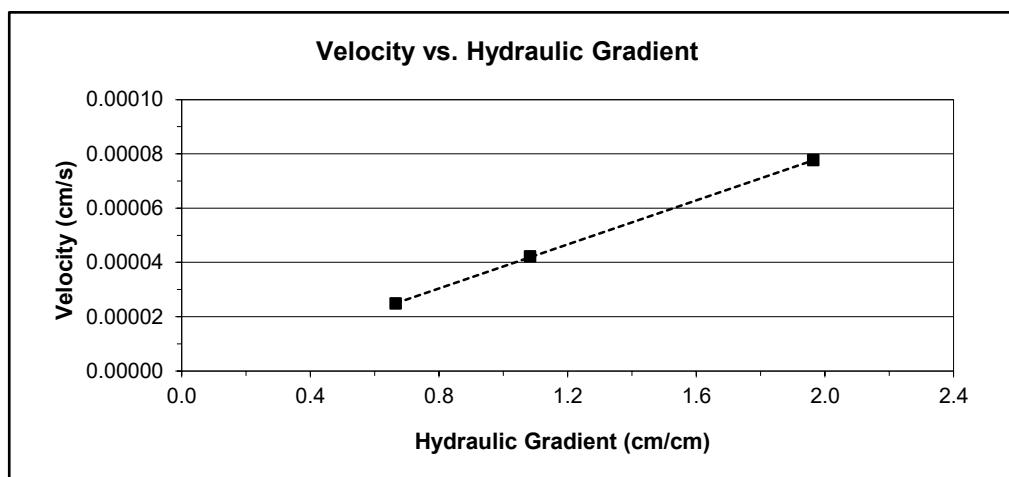
Type of water used: TAP
Collection vessel tare (g): 29.27
Sample length (cm): 7.66
Sample diameter (cm): 15.07
Sample x-sectional area (cm²): 178.32

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:52:00	22.0	15.05	32.59	3.3	240	3.9E-05	3.8E-05
12-Sep-19	13:56:00							
Test # 2:								
12-Sep-19	14:07:00	22.0	8.3	31.07	1.8	240	3.9E-05	3.7E-05
12-Sep-19	14:11:00							
Test # 3:								
12-Sep-19	14:21:00	22.0	5.1	30.33	1.1	240	3.7E-05	3.6E-05
12-Sep-19	14:25:00							

Average Ksat (cm/sec): 3.7E-05
Oversize Corrected Ksat (cm/sec): ---

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: WD19-03 (Firm) (1300 kg/m³)

Material Type: Waste Rock

Depth: NA

Split (3/4", 3/8", #4): 3/4"

Calculated Porosity of Fines (% vol): 50.8

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	3.66	96.34	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.30	1.33
<i>Volume of Solids (cm³):</i>	1.38	36.35	37.74
<i>Volume of Voids (cm³):</i>	0.00	37.53	37.53
<i>Total Volume (cm³):</i>	1.38	73.88	75.26
<i>Volumetric Fraction (%):</i>	1.84	98.16	100.00
<i>Mass Fraction (%):</i>	3.66	96.34	100.00
<i>Ksat (cm/sec):</i>	NM	3.7E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)
Material Type: Growth Media
Depth: NA

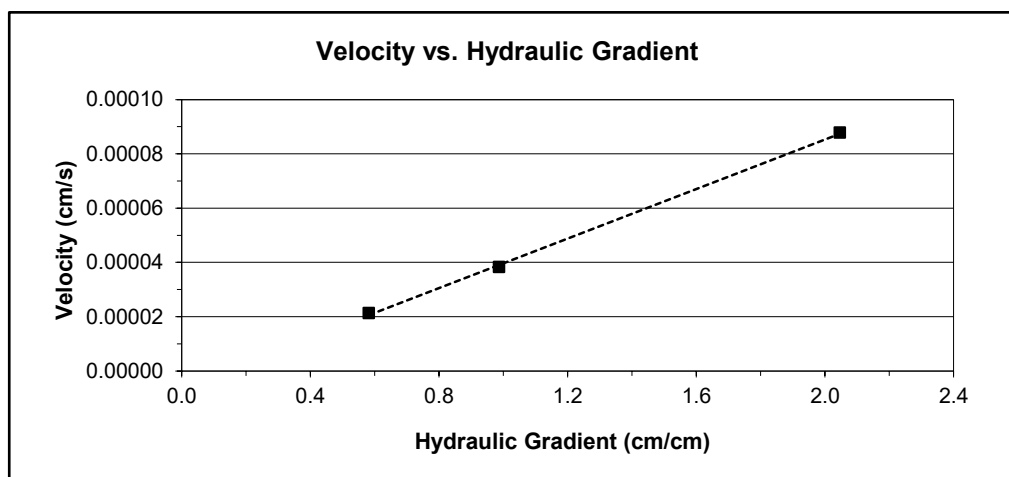
Type of water used: TAP
Collection vessel tare (g): 29.96
Sample length (cm): 7.64
Sample diameter (cm): 6.12
Sample x-sectional area (cm²): 29.45

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:53:00	22.0	15.65	30.58	0.6	240	4.3E-05	4.1E-05
12-Sep-19	13:57:00							
Test # 2:								
12-Sep-19	14:08:00	22.0	7.55	30.23	0.3	240	3.9E-05	3.7E-05
12-Sep-19	14:12:00							
Test # 3:								
12-Sep-19	14:22:00	22.0	4.45	30.11	0.1	240	3.6E-05	3.5E-05
12-Sep-19	14:26:00							

Average Ksat (cm/sec): 3.8E-05
Oversize Corrected Ksat (cm/sec): ---

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-01 (Firm) (1480 kg/m³)

Material Type: Growth Media

Depth: NA

Split (3/4", 3/8", #4): #4

Calculated Porosity of Fines (% vol): 44.0

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	2.12	97.88	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.48	1.50
<i>Volume of Solids (cm³):</i>	0.80	36.94	37.74
<i>Volume of Voids (cm³):</i>	0.00	29.02	29.02
<i>Total Volume (cm³):</i>	0.80	65.96	66.76
<i>Volumetric Fraction (%):</i>	1.20	98.80	100.00
<i>Mass Fraction (%):</i>	2.12	97.88	100.00
<i>Ksat (cm/sec):</i>	NM	3.8E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)
Material Type: Growth Media
Depth: NA

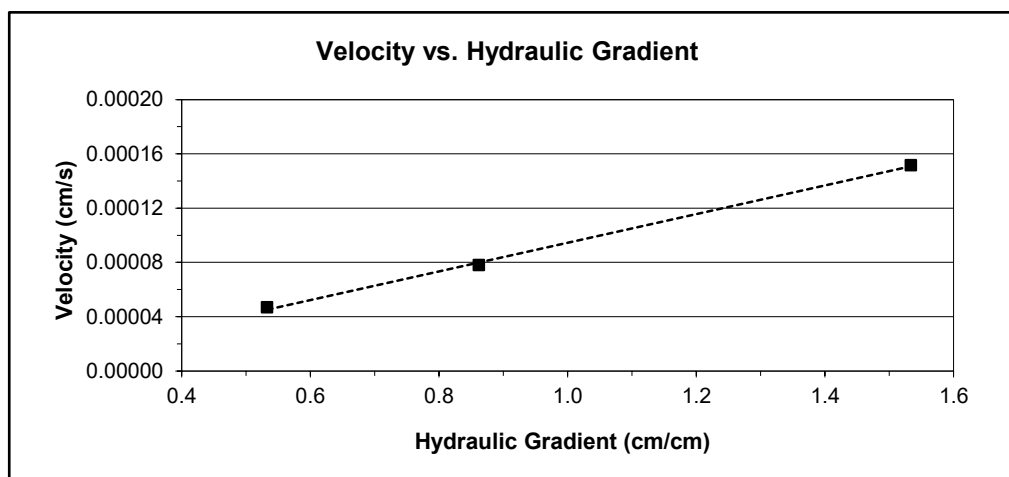
Type of water used: TAP
Collection vessel tare (g): 29.48
Sample length (cm): 7.60
Sample diameter (cm): 6.12
Sample x-sectional area (cm²): 29.43

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:51:00	22.0	11.65	30.55	1.1	240	9.9E-05	9.4E-05
12-Sep-19	13:55:00							
Test # 2:								
12-Sep-19	14:06:00	22.0	6.55	30.03	0.6	240	9.0E-05	8.6E-05
12-Sep-19	14:10:00							
Test # 3:								
12-Sep-19	14:20:00	22.0	4.05	29.81	0.3	240	8.8E-05	8.4E-05
12-Sep-19	14:24:00							

Average Ksat (cm/sec): 8.8E-05
Oversize Corrected Ksat (cm/sec): 6.7E-05

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)

Material Type: Growth Media

Depth: NA

Split (3/4", 3/8", #4): #4

Calculated Porosity of Fines (% vol): 43.8

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	24.04	75.96	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.49	1.66
<i>Volume of Solids (cm³):</i>	9.07	28.66	37.74
<i>Volume of Voids (cm³):</i>	0.00	22.35	22.35
<i>Total Volume (cm³):</i>	9.07	51.01	60.09
<i>Volumetric Fraction (%):</i>	15.10	84.90	100.00
<i>Mass Fraction (%):</i>	24.04	75.96	100.00
<i>Ksat (cm/sec):</i>	NM	8.8E-05	6.7E-05

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)
Material Type: Growth Media
Depth: NA

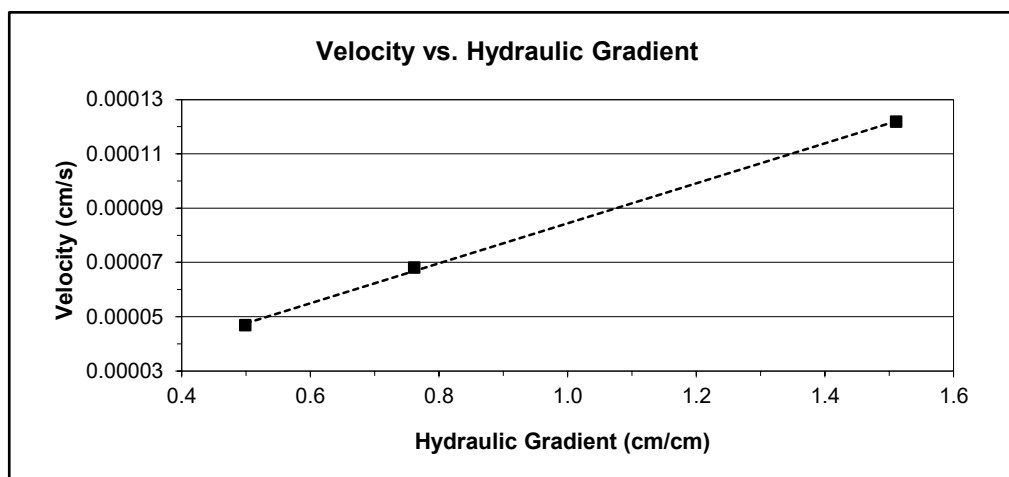
Type of water used: TAP
Collection vessel tare (g): 29.38
Sample length (cm): 7.61
Sample diameter (cm): 6.12
Sample x-sectional area (cm²): 29.42

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:51:30	22.0	11.5	30.24	0.9	240	8.1E-05	7.7E-05
12-Sep-19	13:55:30							
Test # 2:								
12-Sep-19	14:06:30	22.0	5.8	29.86	0.5	240	8.9E-05	8.5E-05
12-Sep-19	14:10:30							
Test # 3:								
12-Sep-19	14:20:30	22.0	3.8	29.71	0.3	240	9.4E-05	8.9E-05
12-Sep-19	14:24:30							

Average Ksat (cm/sec): 8.4E-05
Oversize Corrected Ksat (cm/sec): ---

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass



Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-03 (Firm) (1390 kg/m³)

Material Type: Growth Media

Depth: NA

Split (3/4", 3/8", #4): #4

Calculated Porosity of Fines (% vol): 47.4

	<u>Coarse Fraction*</u>	<u>Fines Fraction</u>	<u>Composite</u>
<i>Subsample Mass (g):</i>	2.75	97.25	100.00
<i>Bulk Density (g/cm³):</i>	2.65	1.39	1.41
<i>Volume of Solids (cm³):</i>	1.04	36.70	37.74
<i>Volume of Voids (cm³):</i>	0.00	33.03	33.03
<i>Total Volume (cm³):</i>	1.04	69.73	70.76
<i>Volumetric Fraction (%):</i>	1.47	98.53	100.00
<i>Mass Fraction (%):</i>	2.75	97.25	100.00
<i>Ksat (cm/sec):</i>	NM	8.4E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NM = Not measured

Laboratory analysis by: D. O'Dowd

Data entered by: D. O'Dowd

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity Constant Head Method

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)
Material Type: Growth Media
Depth: NA

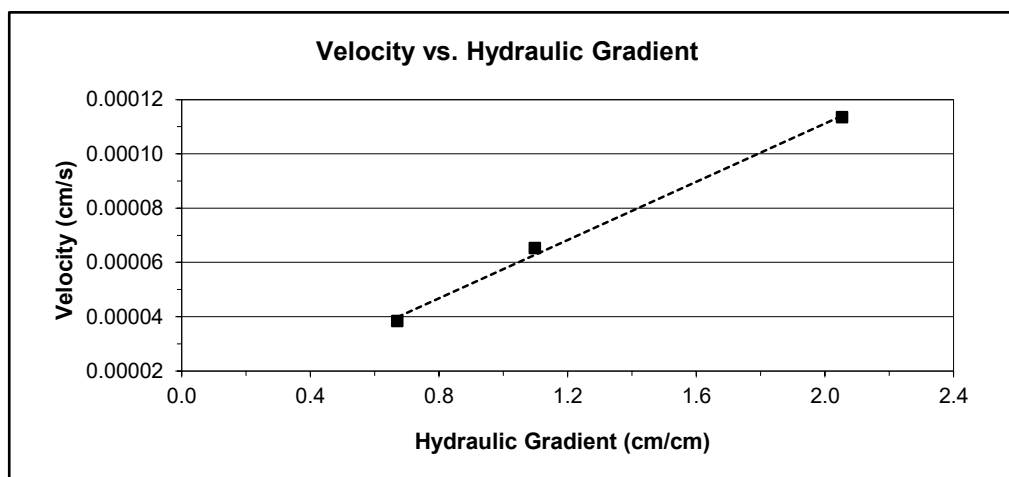
Type of water used: TAP
Collection vessel tare (g): 29.38
Sample length (cm): 7.60
Sample diameter (cm): 6.12
Sample x-sectional area (cm²): 29.40

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm ³)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
12-Sep-19	13:52:30	22.0	15.6	30.18	0.8	240	5.5E-05	5.3E-05
12-Sep-19	13:56:30							
Test # 2:								
12-Sep-19	14:07:30	22.0	8.35	29.84	0.5	240	5.9E-05	5.7E-05
12-Sep-19	14:11:30							
Test # 3:								
12-Sep-19	14:21:30	22.0	5.1	29.65	0.3	240	5.7E-05	5.4E-05
12-Sep-19	14:25:30							

Average Ksat (cm/sec): 5.5E-05
Oversize Corrected Ksat (cm/sec): NA

Comments:

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass
NA = Not applicable



Laboratory analysis by: D. O'Dowd
Data entered by: D. O'Dowd
Checked by: J. Hines

Moisture Retention Characteristics



**Summary of Moisture Characteristics
of the Initial Drainage Curve**

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm ³ /cm ³)
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	0	53.7
	10	49.8
	30	43.8
	95	41.6
	337	37.3
	2651	26.1
	10606	22.0
	45483	17.9
	139101	13.0
	389462	6.7
	848426	4.6
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	0	54.3
	10	54.0
	30	49.6
	95	46.0
	337	41.0
	1836	27.7
	10096	19.3
	81686	12.9
	412611	7.4
	848426	6.1
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	0	64.0
	27	62.9
	70	61.3
	153	59.7
	337	58.6
	848426	9.6

Volume adjustments are applicable at this matric potential (see data sheet for this sample).



**Summary of Moisture Characteristics
of the Initial Drainage Curve (Continued)**

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm ³ /cm ³)
4381-Blend (Firm) (970 kg/m ³)	0	59.7
	27	57.0
	70	51.9
	153	49.5
	337	45.8
	848426	14.7
WD19-01 (1520 kg/m ³)	0	43.2 ‡
	18	43.1 ‡
	58	43.0 ‡
	128	42.5 ‡
	337	35.8 ‡
	4487	19.4 ‡
	22538	12.8 ‡
	89334	9.7 ‡
	548244	6.2 ‡
	848426	6.1 ‡
WD19-02 (1490 kg/m ³)	0	43.4
	27	43.4
	70	43.2
	153	40.8
	337	37.2
	1734	22.1
	8056	15.8
	36407	11.1
	174998	8.3
	848426	6.0

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm ³ /cm ³)
WD19-03 (Firm) (1300 kg/m ³)	0	50.2 ‡
	18	50.1 ‡
	57	49.3 ‡
	130	43.9 ‡
	377	42.7 ‡
	2244	28.9 ‡
	10810	21.0 ‡
	73528	14.0 ‡
	303900	10.2 ‡
	848426	8.4 ‡
Growth 19-01 (Firm) (1480 kg/m ³)	0	42.0
	18	41.8
	58	40.9
	128	35.7
	337	30.7
	1632	23.9
	9790	15.9
	57211	9.9
	240163	7.4
	848426	5.4
Growth 19-02 (Firm) (1490 kg/m ³)	0	42.0
	10	42.0
	30	41.8
	95	36.9
	337	27.3
	2651	10.4
	8872	7.2
	52316	4.5
	247811	3.3
	848426	2.4

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



**Summary of Moisture Characteristics
of the Initial Drainage Curve (Continued)**

Sample Number	Pressure Head (-cm water)	Test Sample Moisture Content (%, cm ³ /cm ³)
Growth 19-03 (Firm) (1390 kg/m ³)	0	45.1 ‡
	10	44.9 ‡
	30	44.5 ‡
	95	40.4 ‡
	337	32.7 ‡
	1836	21.3 ‡
	12849	14.3 ‡
	55069	9.9 ‡
	336432	6.9 ‡
	848426	5.5 ‡
Growth 19-04 (Firm) (1410 kg/m ³)	0	45.0
	18	44.4
	58	43.9
	128	43.2
	337	31.3
	3875	18.6
	11932	14.0
	42730	11.0
	193456	8.2
	848426	5.2

‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).



Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm ⁻¹)	N (dimensionless)	θ_r (% vol)	θ_s (% vol)	Oversize Corrected	
					θ_r (% vol)	θ_s (% vol)
49-SWECO+1.0-D25B-138 (1250 kg/m ³)	0.0224	1.1757	0.00	51.24	0.00	49.46
9-SWECO+1.0-E22B-348 (1240 kg/m ³)	0.0097	1.2242	0.00	53.42	0.00	51.01
4-LFILTCAKE-E05B-315 (Firm) (930 kg/m ³)	0.0017	1.2568	0.00	62.95	NA	NA
4381-Blend (Firm) (970 kg/m ³)	0.0195	1.1419	0.00	59.49	---	---
WD19-01 (1520 kg/m ³)	0.0033	1.3415	3.46	43.77	3.22	40.73
WD19-02 (1490 kg/m ³)	0.0030	1.4430	5.71	43.90	5.15	39.57
WD19-03 (Firm) (1300 kg/m ³)	0.0048	1.2244	0.63	50.17	---	---
Growth 19-01 (Firm) (1480 kg/m ³)	0.0094	1.2236	0.00	42.46	---	---
Growth 19-02 (Firm) (1490 kg/m ³)	0.0060	1.5489	2.42	42.20	2.05	35.83
Growth 19-03 (Firm) (1390 kg/m ³)	0.0084	1.2866	2.42	45.42	---	---
Growth 19-04 (Firm) (1410 kg/m ³)	0.0063	1.3305	3.76	45.67	NA	NA

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NR = Not requested

NA = Not applicable



Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)
 Material Type: Gangue
 Depth: NA

Dry wt. of sample (g): 280.67
 Tare wt., ring (g): 139.51
 Tare wt., screen & clamp (g): 26.72
 Initial sample volume (cm³): 224.00
 Initial dry bulk density (g/cm³): 1.25
 Assumed particle density (g/cm³): 2.65
 Initial calculated total porosity (%): 52.72

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:20	567.27	0	53.74
	20-Sep-19	9:00	558.55	10.0	49.84
	27-Sep-19	9:30	545.10	30.0	43.84
	10-Oct-19	13:10	539.99	95.0	41.56
<i>Pressure plate:</i>	18-Oct-19	15:00	530.37	337	37.26

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	10.0	---	---	---	---
	30.0	---	---	---	---
	95.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)

Initial sample bulk density (g/cm³): 1.25

Fraction of test sample used (<2.00mm fraction) (%): 82.01

Dry weight* of dew point potentiometer sample (g): 163.80

Tare weight, jar (g): 114.72

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	24-Sep-19	8:00	176.28	2651	26.13
	20-Sep-19	7:38	174.33	10606	22.05
	19-Sep-19	7:42	172.37	45483	17.94
	18-Sep-19	8:27	169.99	139101	12.96
	16-Sep-19	13:08	167.01	389462	6.72

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	2651	---	---	---	---
	10606	---	---	---	---
	45483	---	---	---	---
	139101	---	---	---	---
	389462	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '-' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)

Initial sample bulk density (g/cm³): 1.25

Fraction of test sample used (<2.00mm fraction) (%): 82.01

Dry weight* of relative humidity box sample (g): 68.47

Tare weight (g): 41.39

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	23-Sep-19	7:30	69.68	848426	4.59

Volume Adjusted Data ¹				
	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)
Relative humidity box:	848426	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd

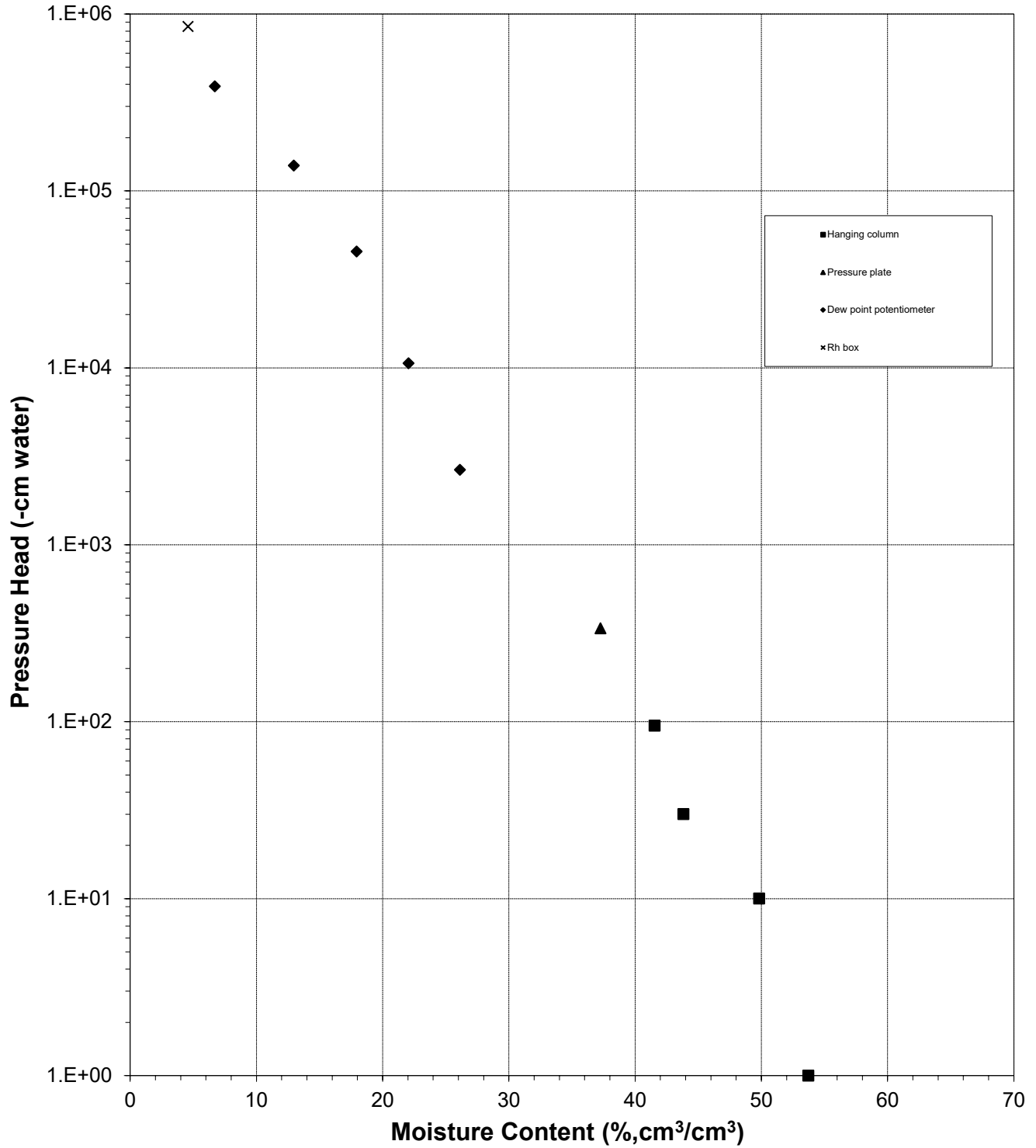
Data entered by: A. Albay-Yenney

Checked by: J. Hines



Water Retention Data Points

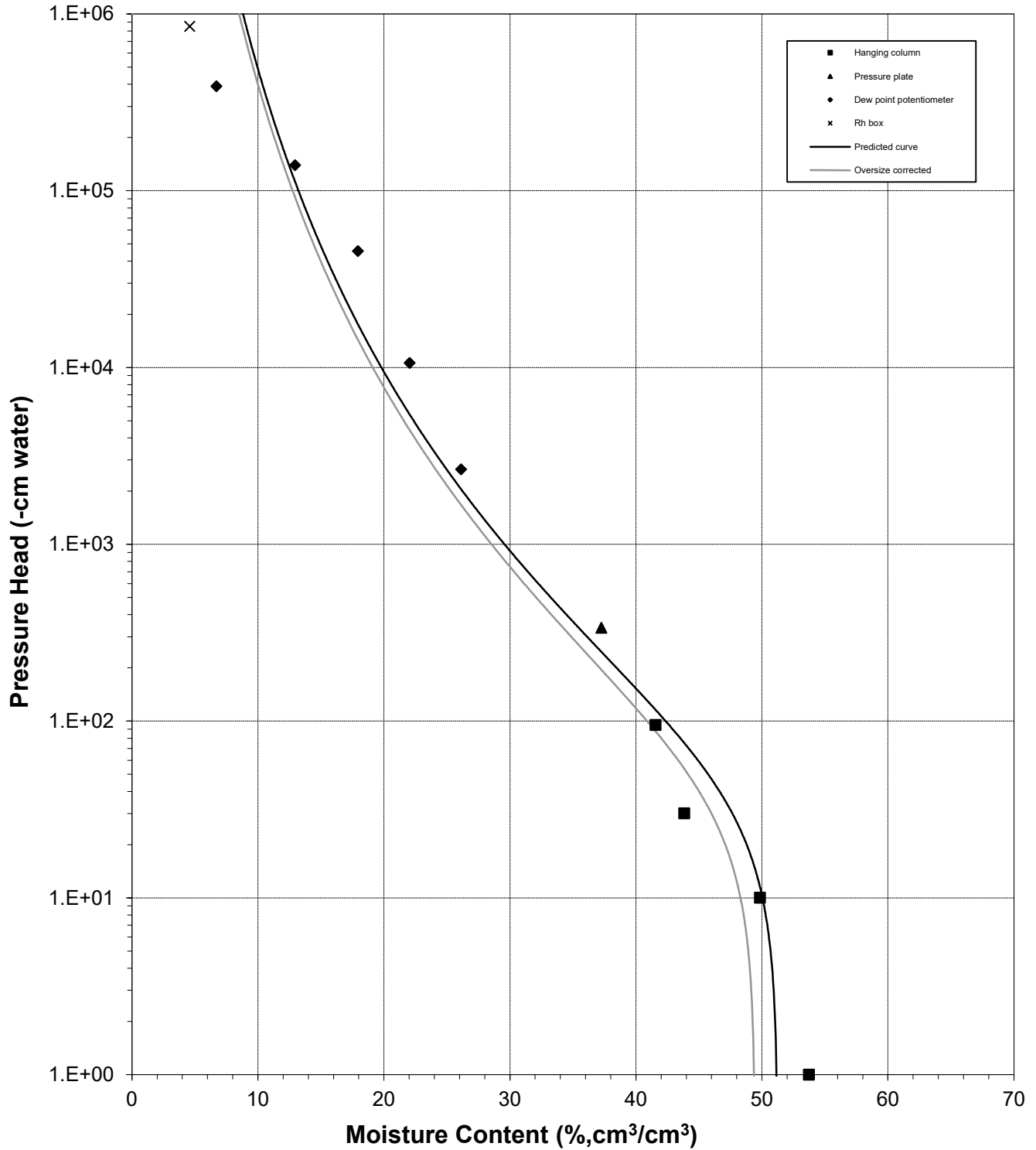
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)





Predicted Calibration Curve and Data Points

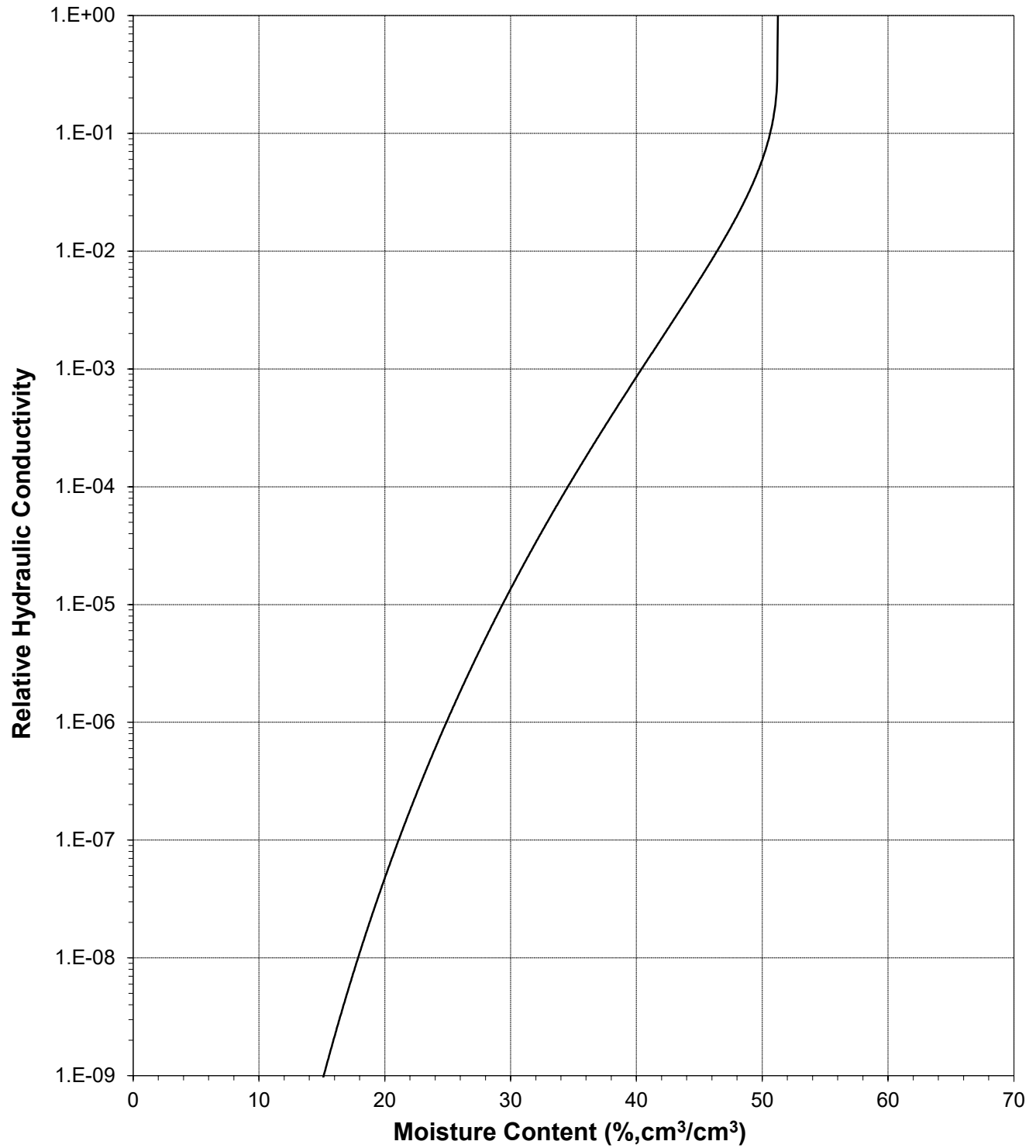
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

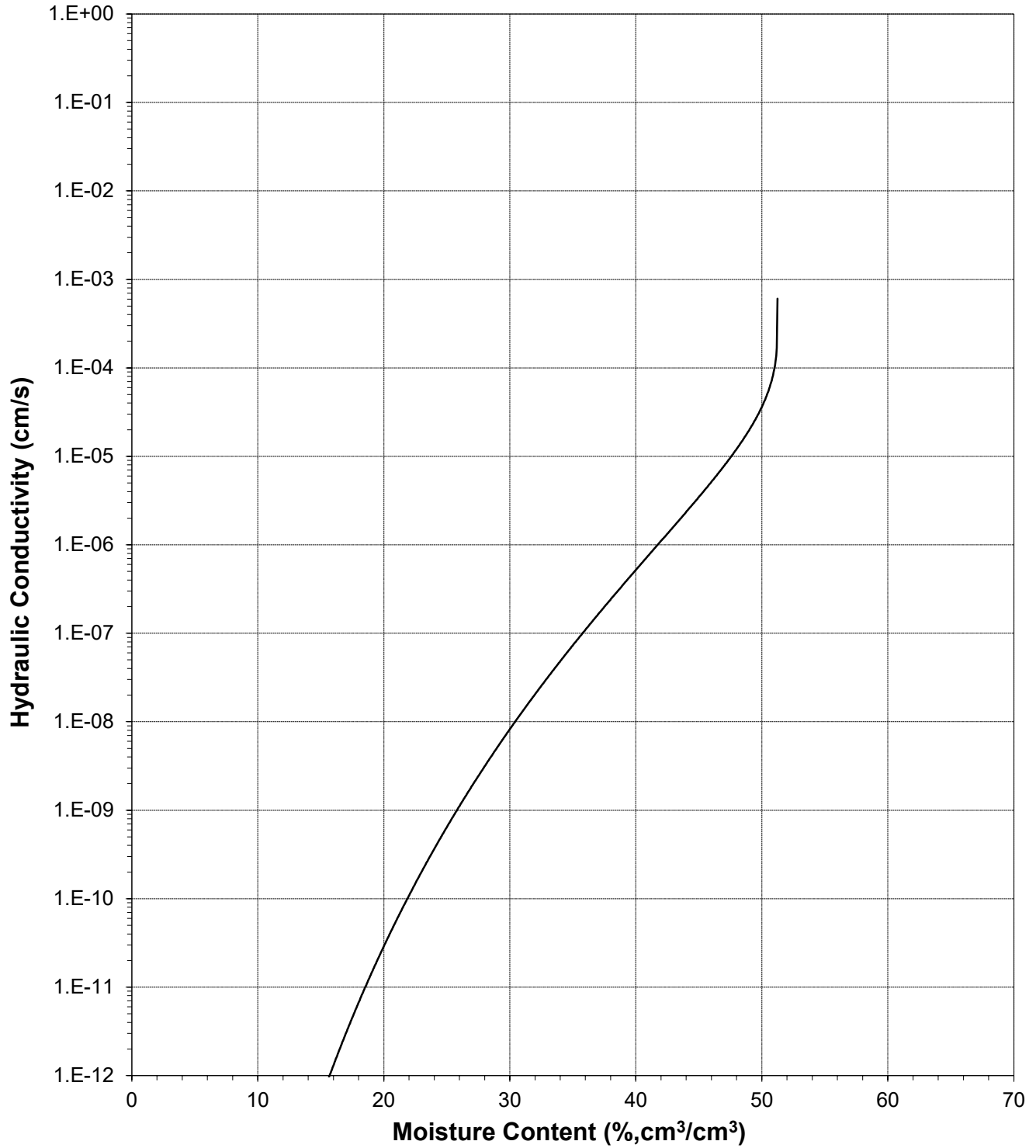
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)

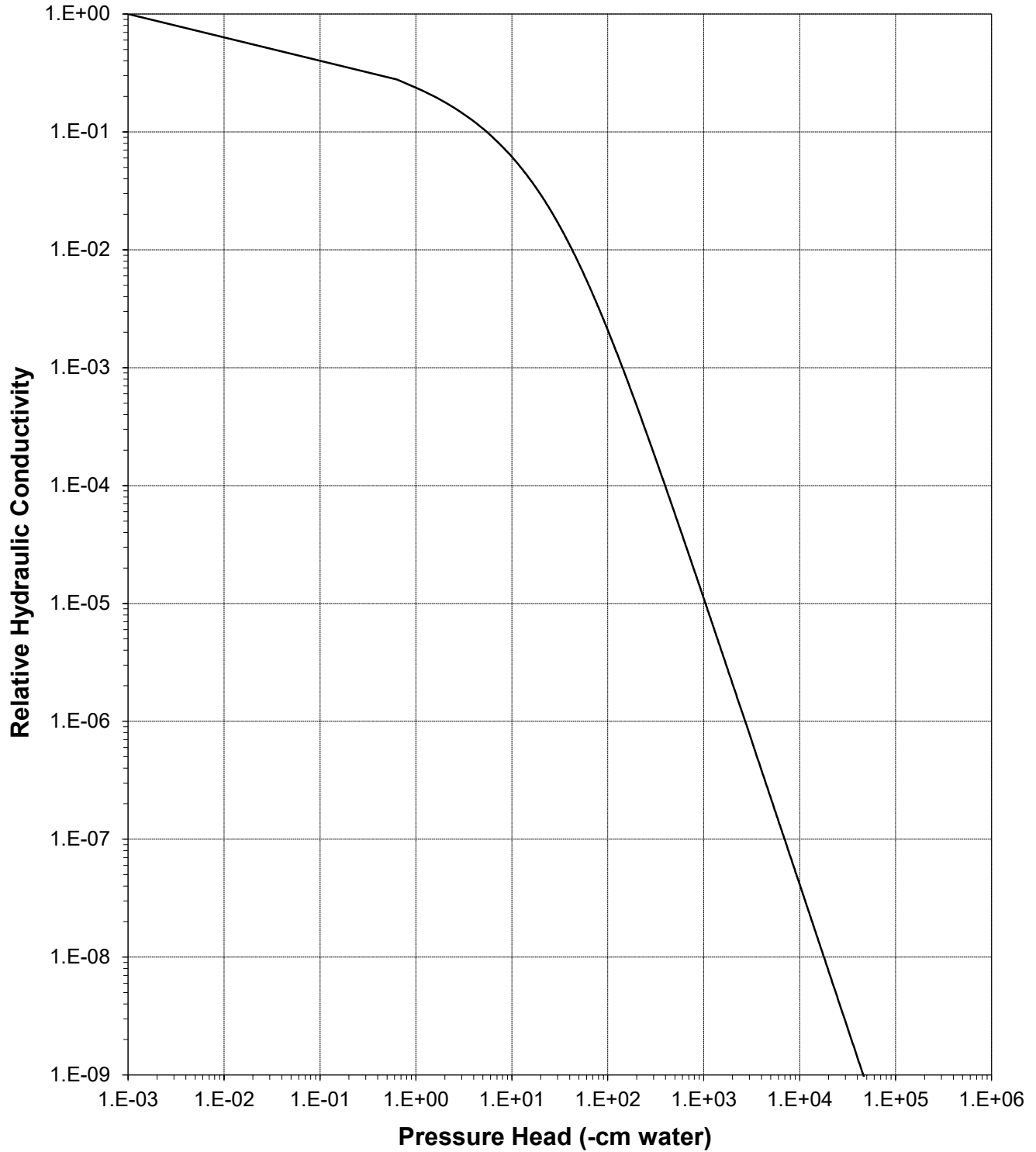




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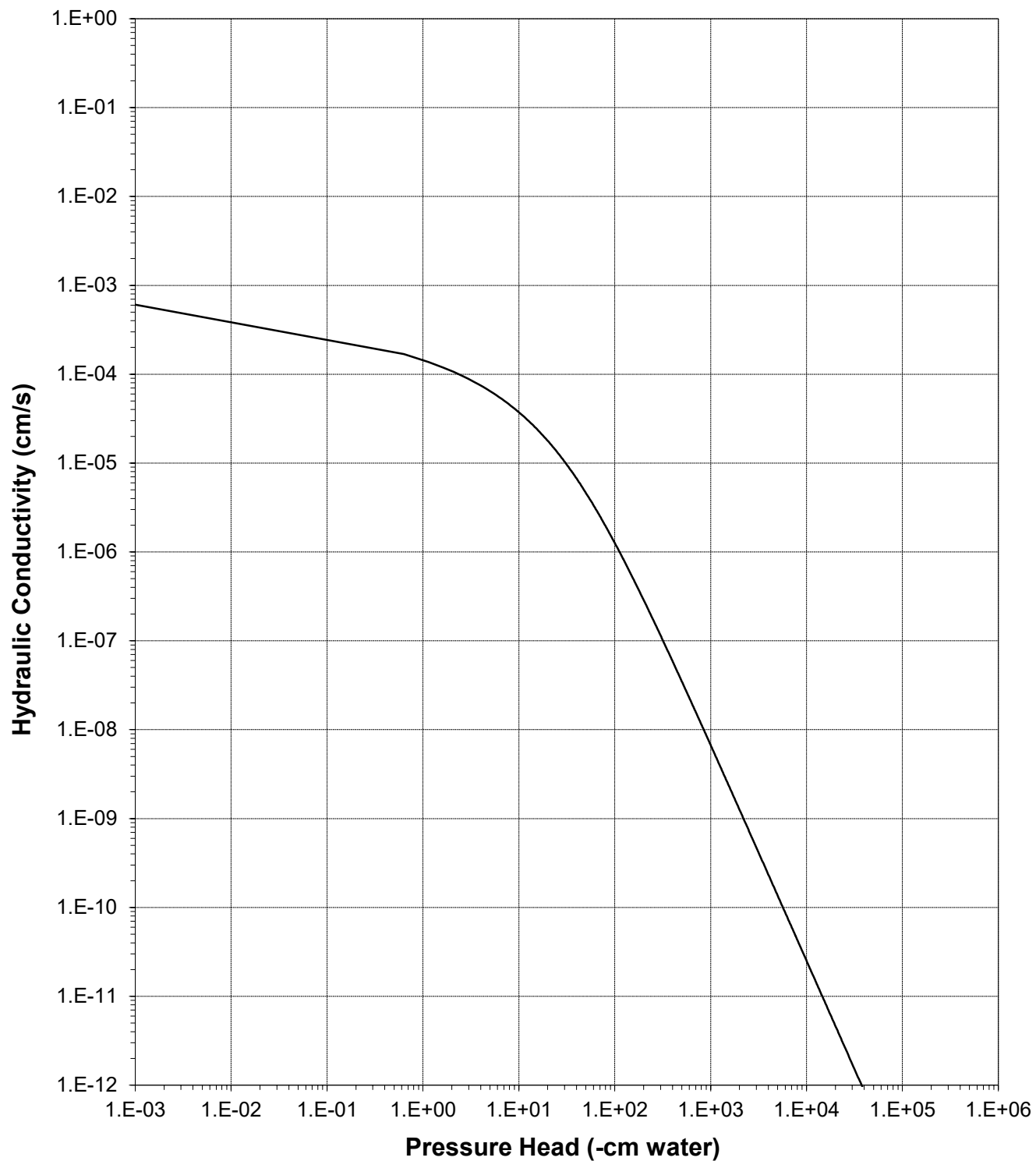
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)





Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138 (1250 kg/m³)
Material Type: Gangue
Depth: NA

Split (3/4", 3/8", #4): #4

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	7.10	92.90	100.00
Mass Fraction (%):	7.10	92.90	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.25	1.30
Calculated Porosity (% vol):	0.00	52.72	50.88
Volume of Solids (cm ³):	2.68	35.06	37.74
Volume of Voids (cm ³):	0.00	39.09	39.09
Total Volume (cm ³):	2.68	74.15	76.82
Volumetric Fraction (%):	3.49	96.51	100.00
Initial Moisture Content (% vol):	0.00	25.95	25.04
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.25	1.30
Calculated Porosity (% vol):	0.00	52.72	50.88
Volume of Solids (cm ³):	2.68	35.06	37.74
Volume of Voids (cm ³):	0.00	39.09	39.09
Total Volume (cm ³):	2.68	74.15	76.82
Volumetric Fraction (%):	3.49	96.51	100.00
Saturated Moisture Content (% vol):	0.00	51.24	49.46
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.25	1.30
Calculated Porosity (% vol):	0.00	52.72	50.88
Volume of Solids (cm ³):	2.68	35.06	37.74
Volume of Voids (cm ³):	0.00	39.09	39.09
Total Volume (cm ³):	2.68	74.15	76.82
Volumetric Fraction (%):	3.49	96.51	100.00
Residual Moisture Content (% vol):	0.00	0.00	0.00
Ksat (cm/sec):	NM	6.1E-04	5.6E-04

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)
Material Type: Gangue
Depth: NA

Dry wt. of sample (g): 350.27
Tare wt., ring (g): 276.00
Tare wt., screen & clamp (g): 29.10
Initial sample volume (cm³): 282.30
Initial dry bulk density (g/cm³): 1.24
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 53.18

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:20	808.59	0	54.28
	20-Sep-19	9:00	807.91	10.0	54.03
	27-Sep-19	9:30	795.51	30.0	49.64
	10-Oct-19	13:10	785.12	95.0	45.96
<i>Pressure plate:</i>	18-Oct-19	15:00	771.05	337	40.98

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	10.0	---	---	---	---
	30.0	---	---	---	---
	95.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)

Initial sample bulk density (g/cm³): 1.24

Fraction of test sample used (<2.00mm fraction) (%): 71.43

Dry weight* of dew point potentiometer sample (g): 173.64

Tare weight, jar (g): 117.43

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	25-Sep-19	9:50	191.23	1836	27.73
	20-Sep-19	8:00	185.89	10096	19.31
	17-Sep-19	8:33	181.85	81686	12.94
	13-Sep-19	13:05	178.33	412611	7.39

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	1836	---	---	---	---
	10096	---	---	---	---
	81686	---	---	---	---
	412611	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)

Initial sample bulk density (g/cm³): 1.24

Fraction of test sample used (<2.00mm fraction) (%): 71.43

Dry weight* of relative humidity box sample (g): 70.27

Tare weight (g): 39.99

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	19-Sep-19	7:30	72.33	848426	6.05

Volume Adjusted Data ¹				
	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)
Relative humidity box:	848426	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd

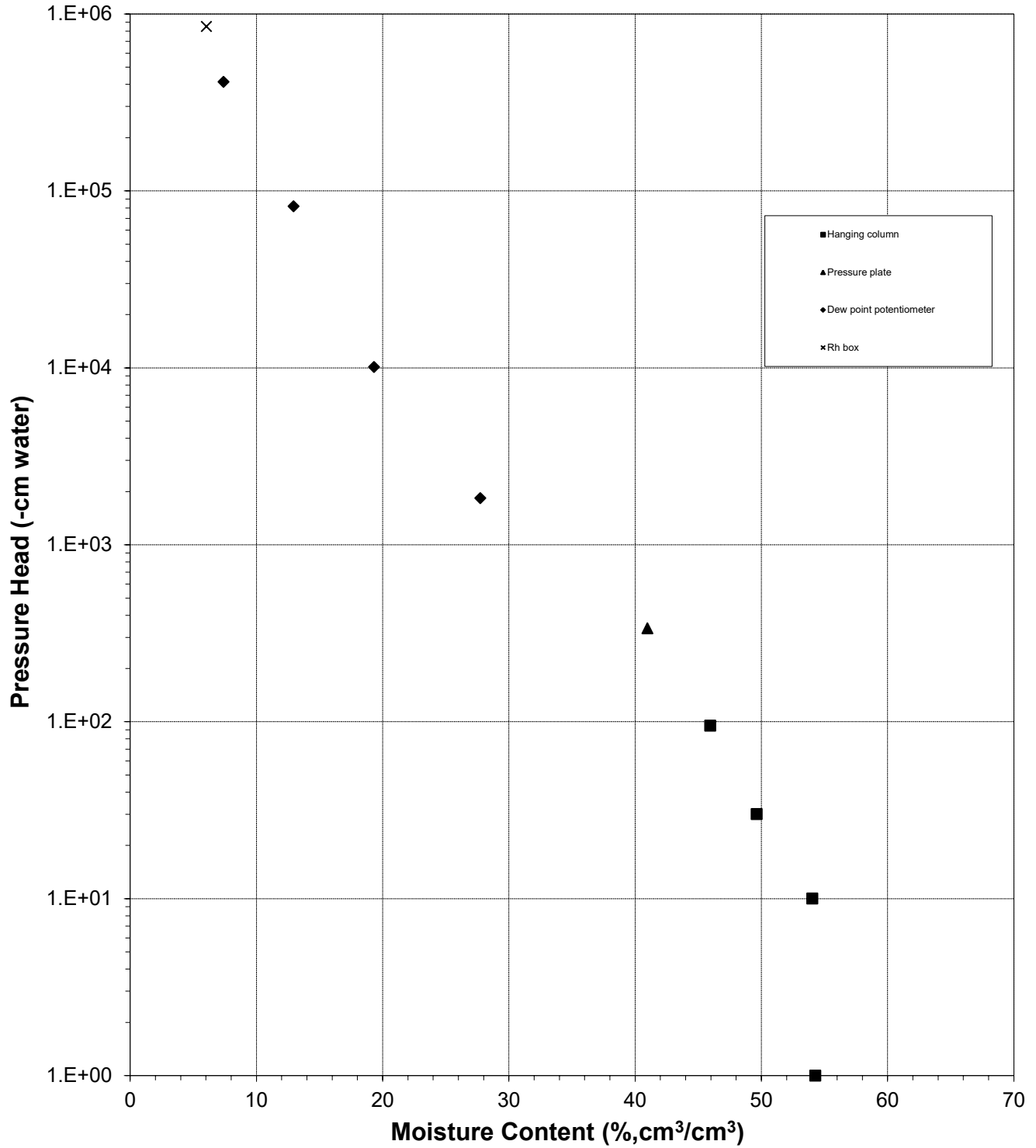
Data entered by: A. Albay-Yenney

Checked by: J. Hines



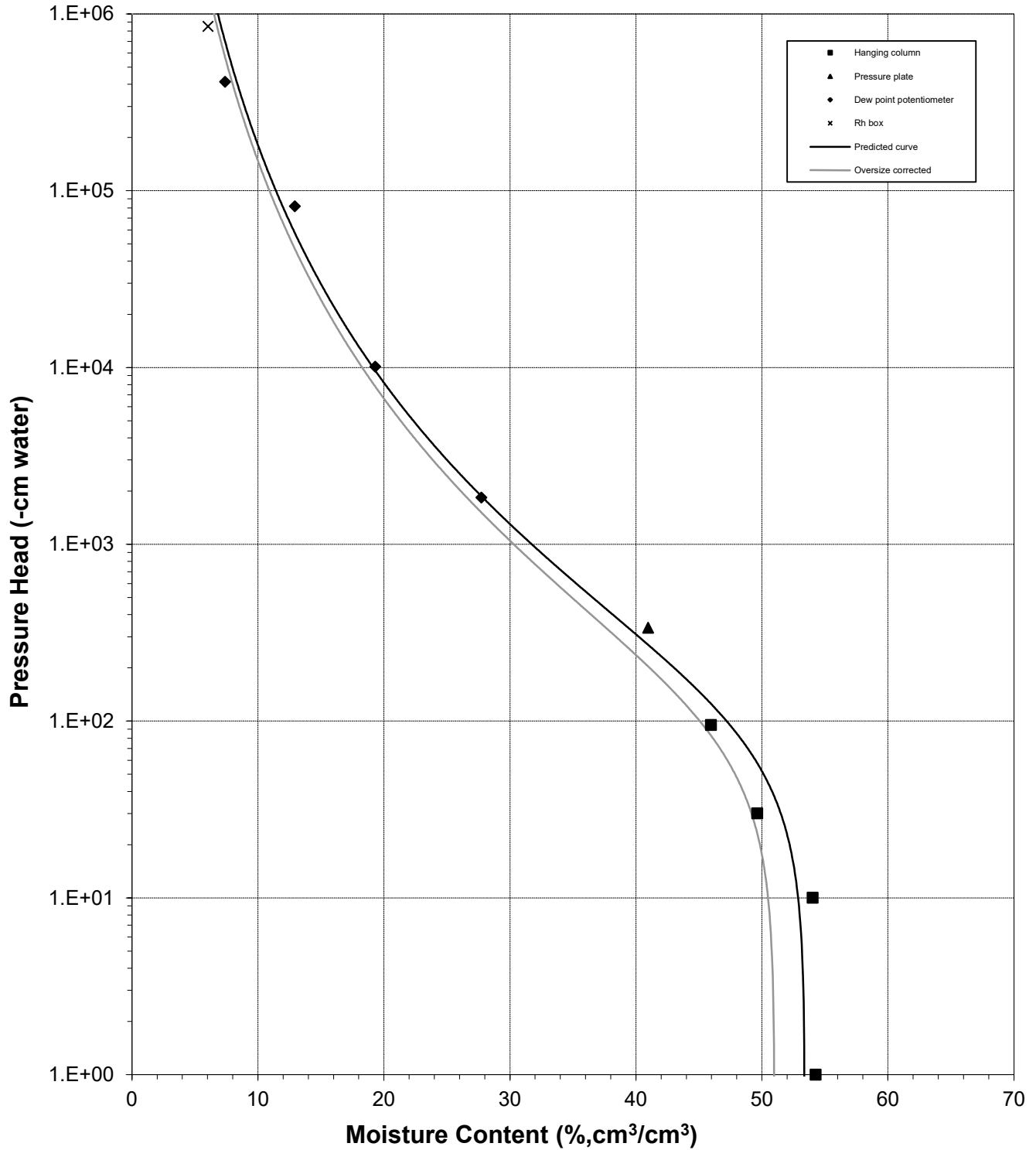
Water Retention Data Points

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)





Predicted Calibration Curve and Data Points
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)

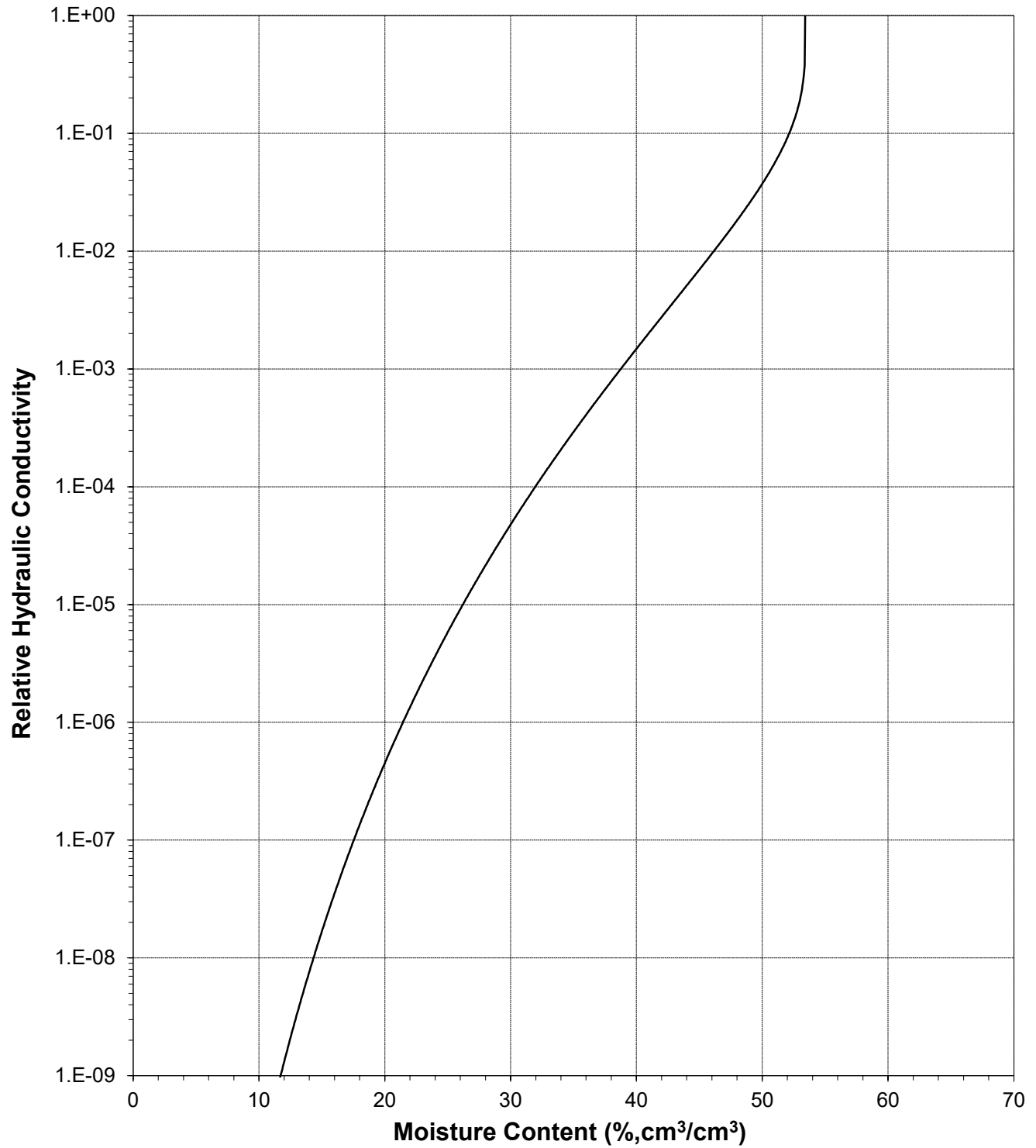




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)

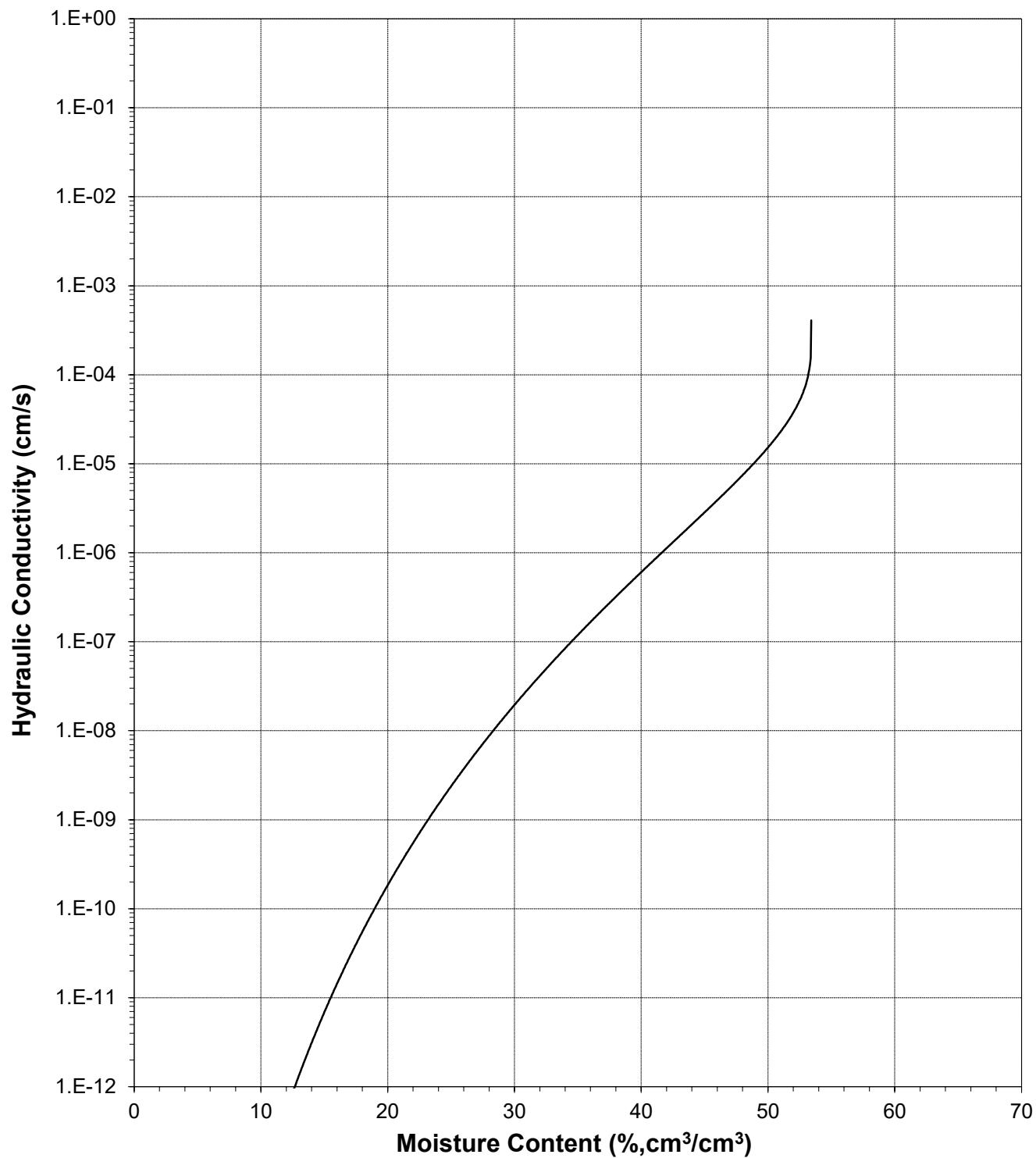




Daniel B. Stephens & Associates, Inc.

Plot of Hydraulic Conductivity vs Moisture Content

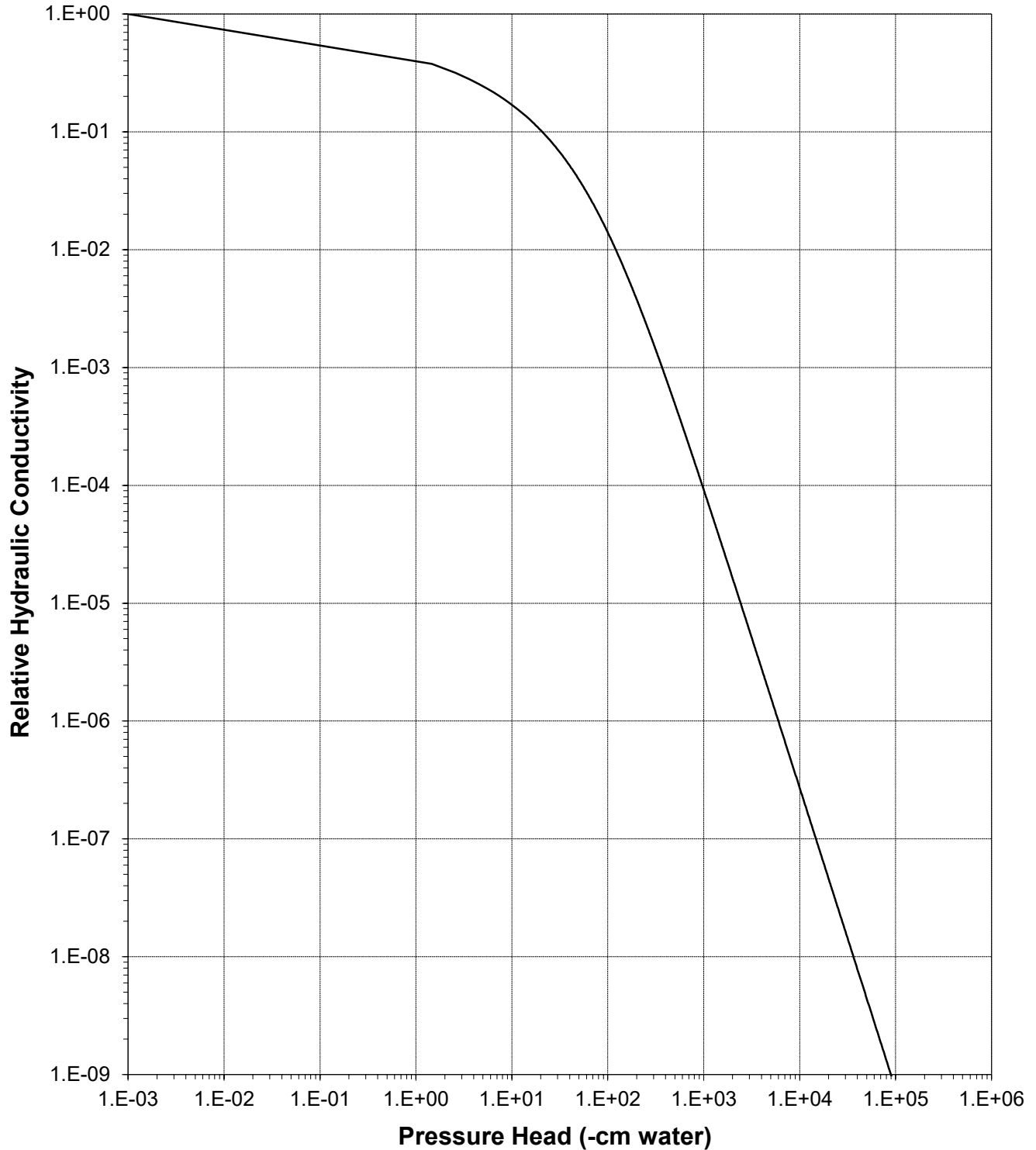
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)





Plot of Relative Hydraulic Conductivity vs Pressure Head

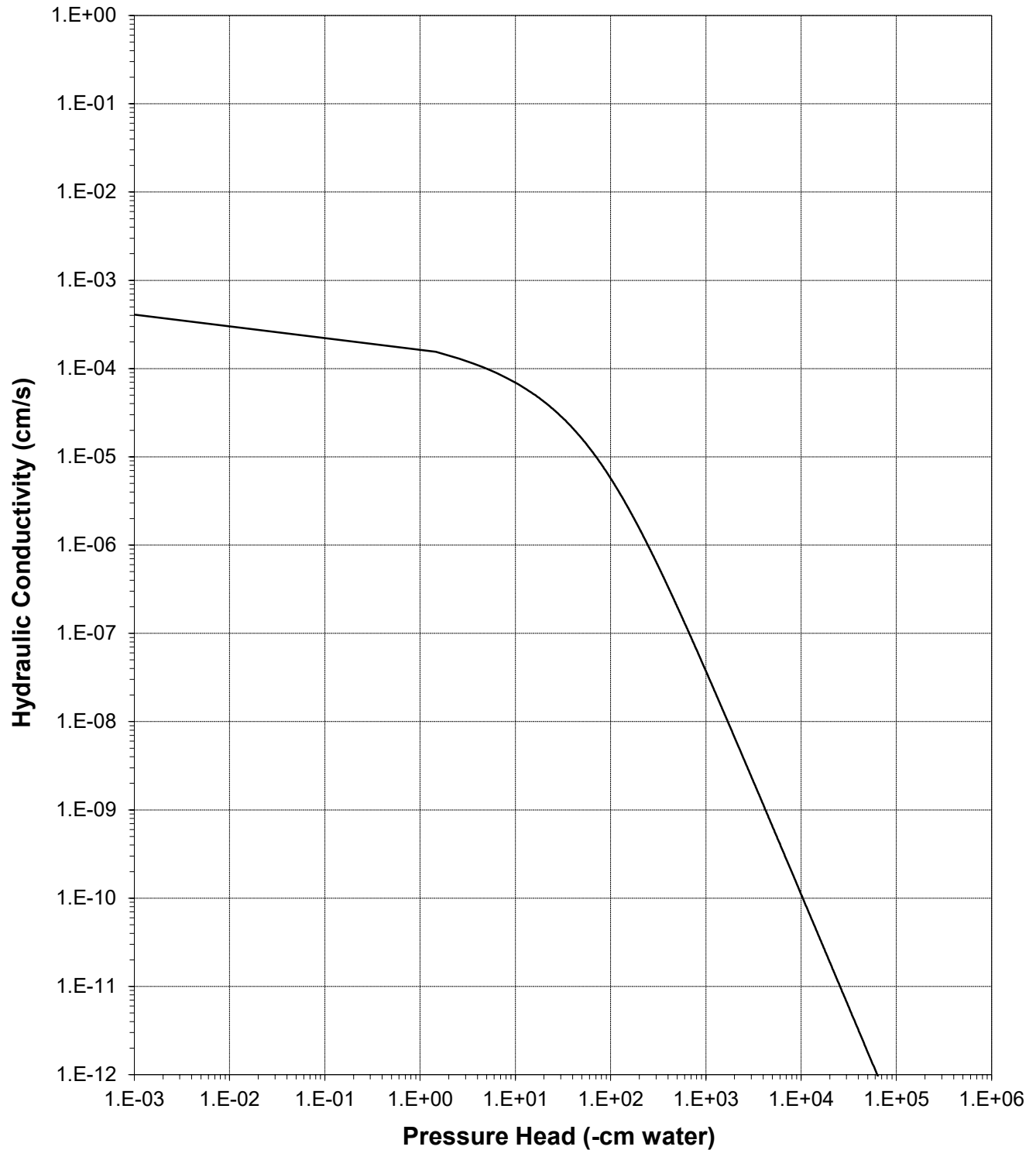
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348 (1240 kg/m³)
Material Type: Gangue
Depth: NA

Split (3/4", 3/8", #4): 3/8"

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	9.17	90.83	100.00
Mass Fraction (%):	9.17	90.83	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.24	1.30
Calculated Porosity (% vol):	0.00	53.18	50.78
Volume of Solids (cm ³):	3.46	34.28	37.74
Volume of Voids (cm ³):	0.00	38.93	38.93
Total Volume (cm ³):	3.46	73.20	76.66
Volumetric Fraction (%):	4.51	95.49	100.00
Initial Moisture Content (% vol):	0.00	23.14	22.10
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.24	1.30
Calculated Porosity (% vol):	0.00	53.18	50.78
Volume of Solids (cm ³):	3.46	34.28	37.74
Volume of Voids (cm ³):	0.00	38.93	38.93
Total Volume (cm ³):	3.46	73.20	76.66
Volumetric Fraction (%):	4.51	95.49	100.00
Saturated Moisture Content (% vol):	0.00	53.42	51.01
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.24	1.30
Calculated Porosity (% vol):	0.00	53.18	50.78
Volume of Solids (cm ³):	3.46	34.28	37.74
Volume of Voids (cm ³):	0.00	38.93	38.93
Total Volume (cm ³):	3.46	73.20	76.66
Volumetric Fraction (%):	4.51	95.49	100.00
Residual Moisture Content (% vol):	0.00	0.00	0.00
Ksat (cm/sec):	NM	4.1E-04	3.7E-04

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)
 Material Type: Tailings
 Depth: NA

Dry wt. of sample (g): 208.81
 Tare wt., ring (g): 140.05
 Tare wt., screen & clamp (g): 26.47
 Initial sample volume (cm³): 224.27
 Initial dry bulk density (g/cm³): 0.93
 Assumed particle density (g/cm³): 2.65
 Initial calculated total porosity (%): 64.87

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:30	518.76	0	63.95
	20-Sep-19	9:00	516.36	27.0	62.88
	27-Sep-19	9:30	512.73	70.0	61.26
	10-Oct-19	13:10	509.14	153.0	59.66
<i>Pressure plate:</i>	18-Oct-19	15:00	506.76	337	58.60

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	27.0	---	---	---	---
	70.0	---	---	---	---
	153.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)

Initial sample bulk density (g/cm³): 0.93

Fraction of test sample used (<2.00mm fraction) (%): 85.62

Dry weight* of relative humidity box sample (g): 66.75

Tare weight (g): 47.60

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	23-Sep-19	7:30	69.06	848426	9.61

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

^{‡‡} Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd

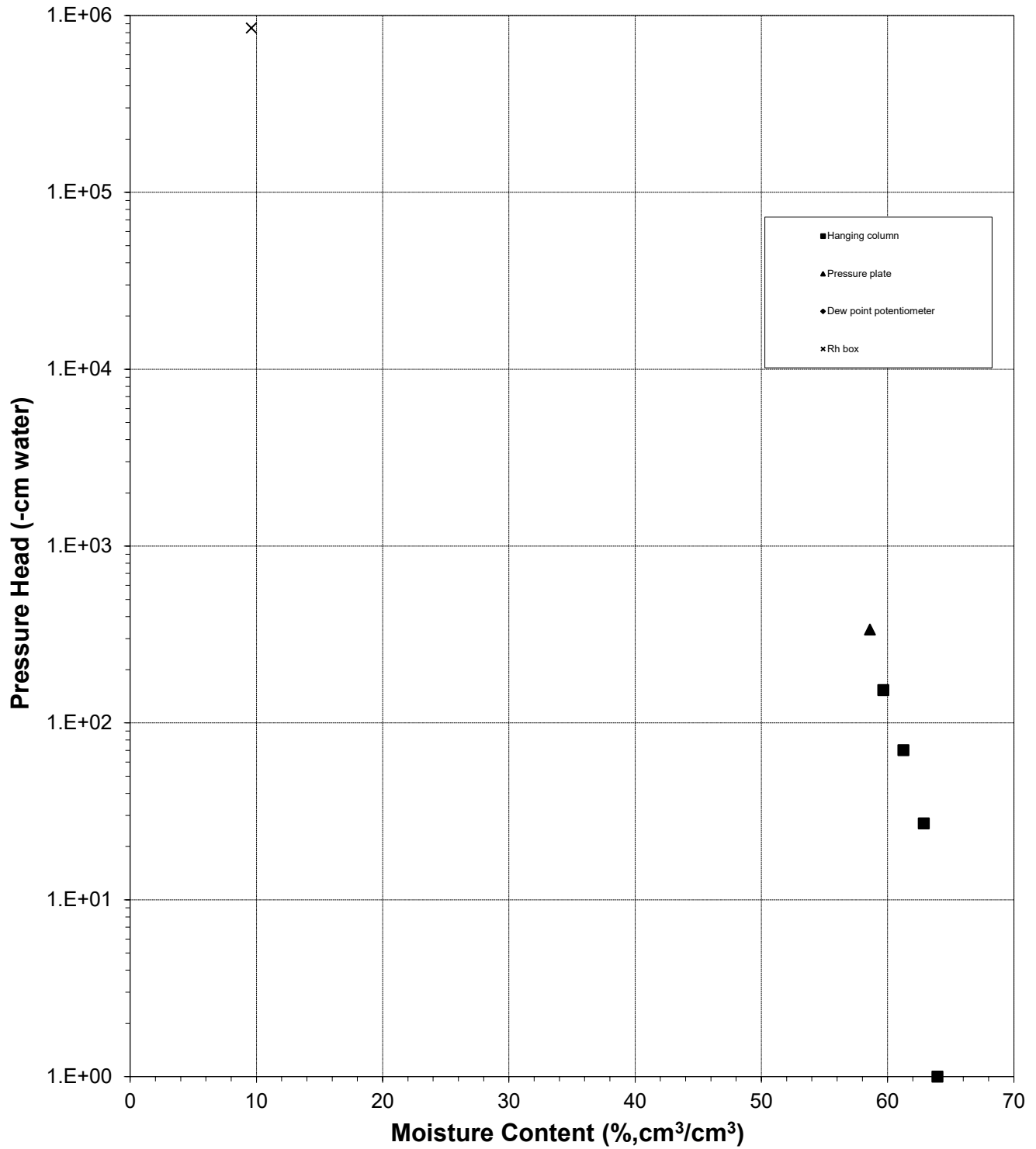
Data entered by: A. Albay-Yenney

Checked by: J. Hines



Water Retention Data Points

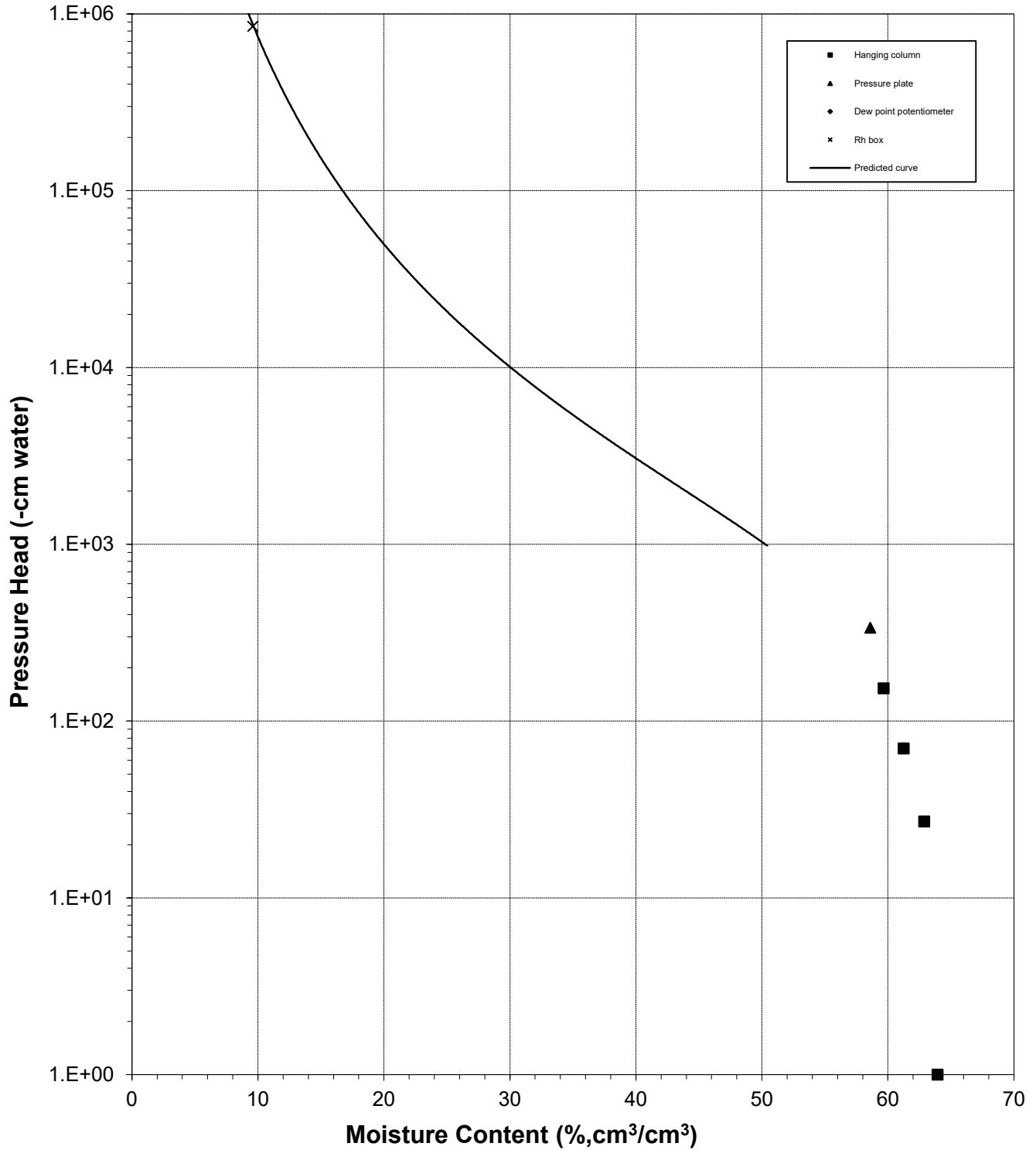
Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)





Predicted Calibration Curve and Data Points

Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)

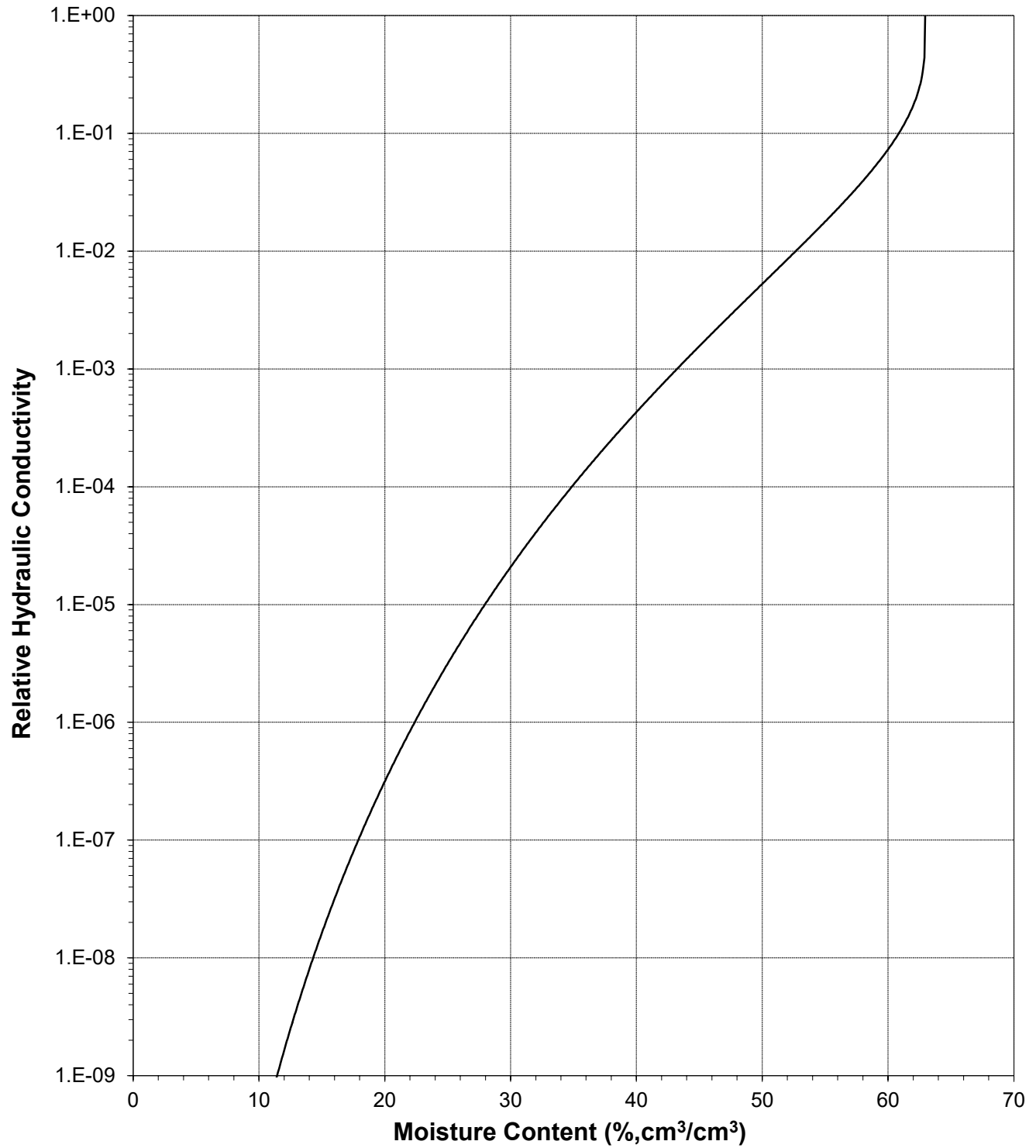




Daniel B. Stephens & Associates, Inc.

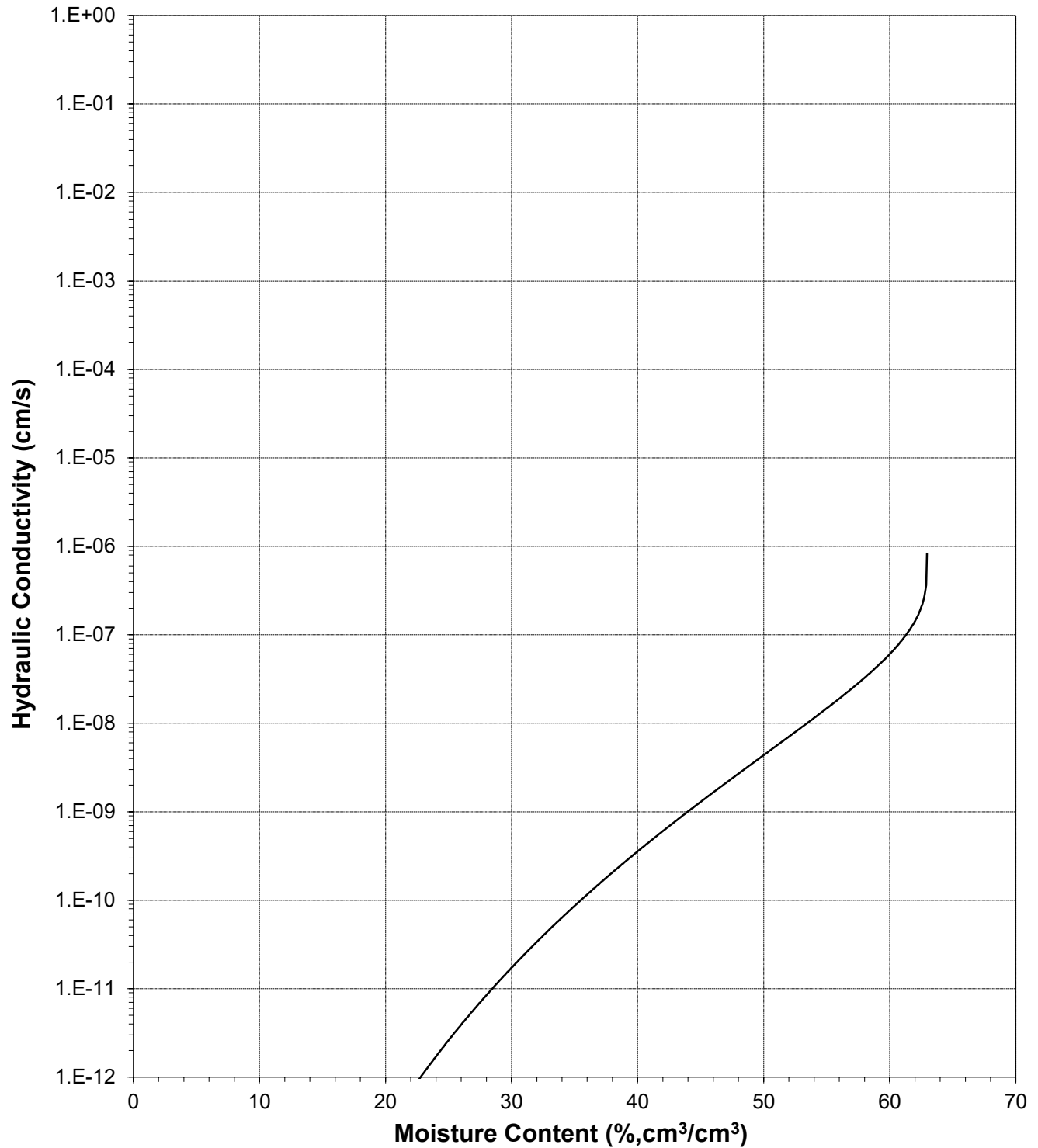
Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content
Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)

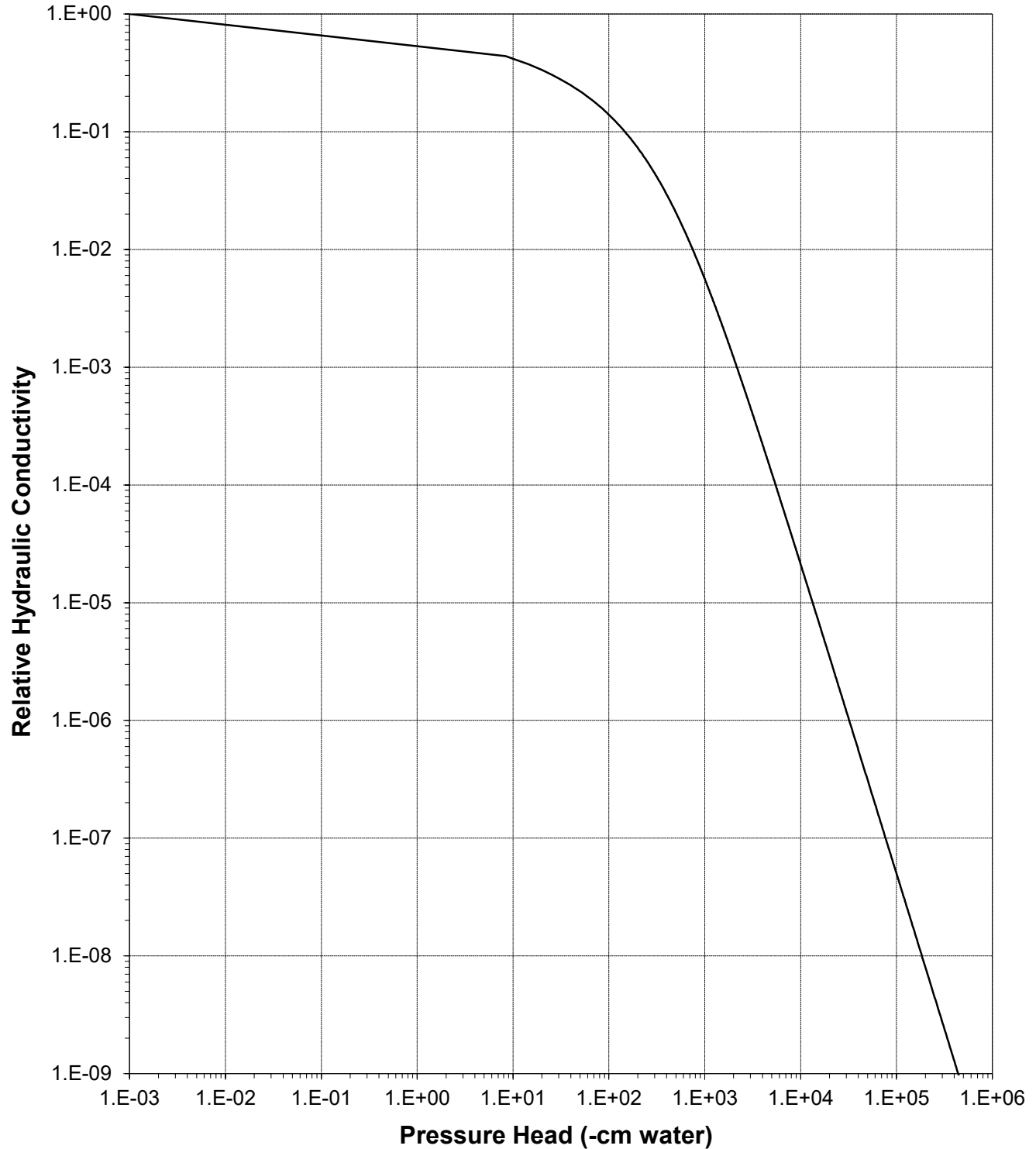




Daniel B. Stephens & Associates, Inc.

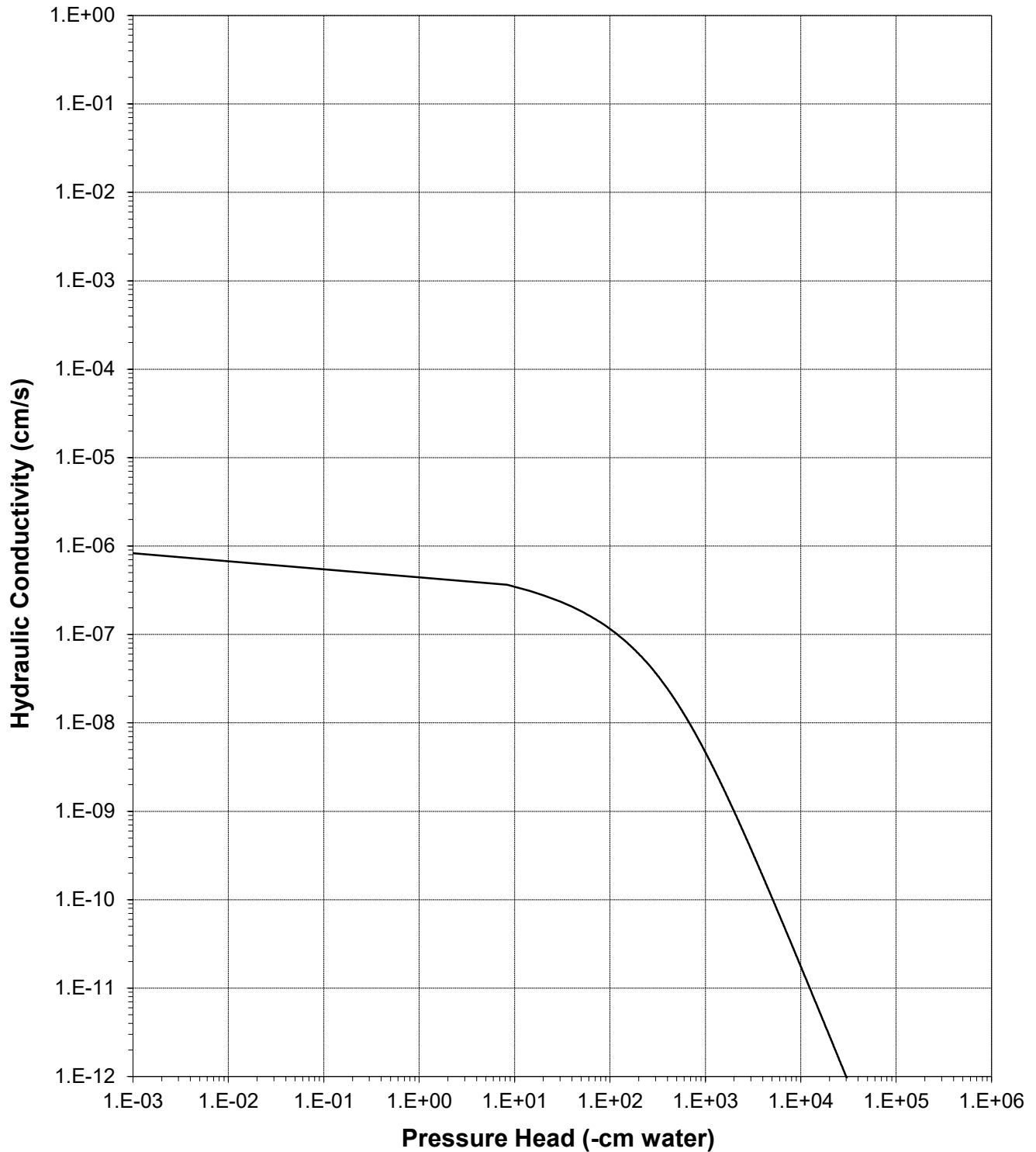
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head
Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: 4-LFILTCAKE-E05B-315 (Firm) (930 kg/m³)
 Material Type: Tailings
 Depth: NA

Split (3/4", 3/8", #4): #4

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	0.00	100.00	100.00
Mass Fraction (%):	0.00	100.00	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	0.93	0.93
Calculated Porosity (% vol):	0.00	64.87	64.87
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	69.67	69.67
Total Volume (cm ³):	0.00	107.41	107.41
Volumetric Fraction (%):	0.00	100.00	100.00
Initial Moisture Content (% vol):	0.00	63.11	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	0.93	0.93
Calculated Porosity (% vol):	0.00	64.87	64.87
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	69.67	69.67
Total Volume (cm ³):	0.00	107.41	107.41
Volumetric Fraction (%):	0.00	100.00	100.00
Saturated Moisture Content (% vol):	0.00	62.95	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	0.93	0.93
Calculated Porosity (% vol):	0.00	64.87	64.87
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	69.67	69.67
Total Volume (cm ³):	0.00	107.41	107.41
Volumetric Fraction (%):	0.00	100.00	100.00
Residual Moisture Content (% vol):	0.00	0.00	---
Ksat (cm/sec):	NM	8.3E-07	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: 4381-Blend (Firm) (970 kg/m³)
 Material Type: Tailings
 Depth: NA

Dry wt. of sample (g): 274.58
 Tare wt., ring (g): 276.80
 Tare wt., screen & clamp (g): 27.48
 Initial sample volume (cm³): 283.34
 Initial dry bulk density (g/cm³): 0.97
 Assumed particle density (g/cm³): 2.65
 Initial calculated total porosity (%): 63.43

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:30	747.89	0	59.66
	20-Sep-19	9:00	740.50	27.0	57.05
	27-Sep-19	9:30	725.98	70.0	51.92
	10-Oct-19	13:15	719.10	153.0	49.49
<i>Pressure plate:</i>	18-Oct-19	15:00	708.73	337	45.83

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	27.0	---	---	---	---
	70.0	---	---	---	---
	153.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data
Dew Point Potentiometer / Relative Humidity Box
 (Soil-Water Characteristic Curve)

Sample Number: 4381-Blend (Firm) (970 kg/m³)

Initial sample bulk density (g/cm³): 0.97

Fraction of test sample used (<2.00mm fraction) (%): 96.47

Dry weight of relative humidity box sample (g):* 63.22

Tare weight (g): 38.02

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
<i>Relative humidity box:</i>	23-Sep-19	7:30	67.19	848426	14.73

Volume Adjusted Data ¹				
	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)
<i>Relative humidity box:</i>	848426	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

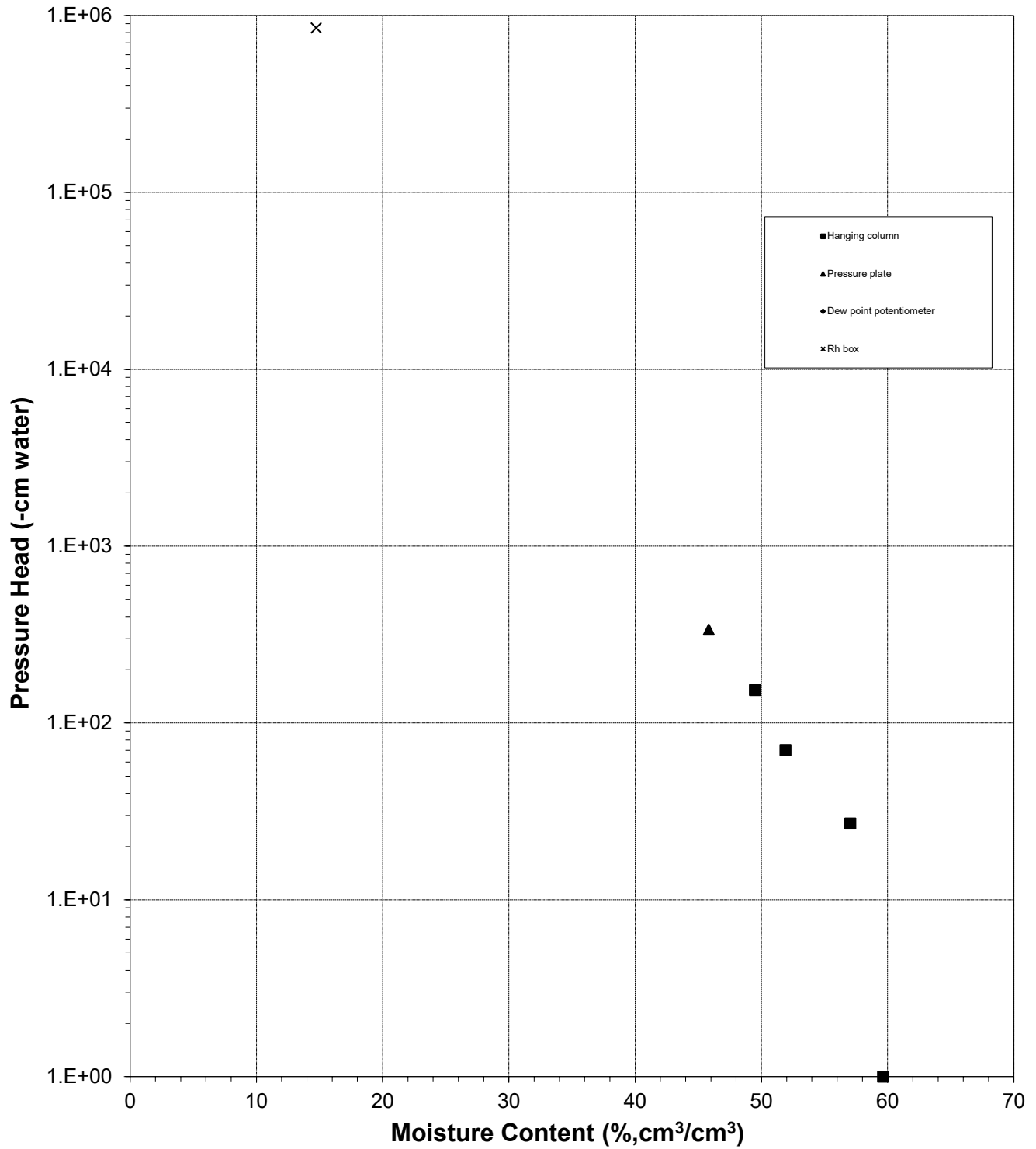
[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Water Retention Data Points

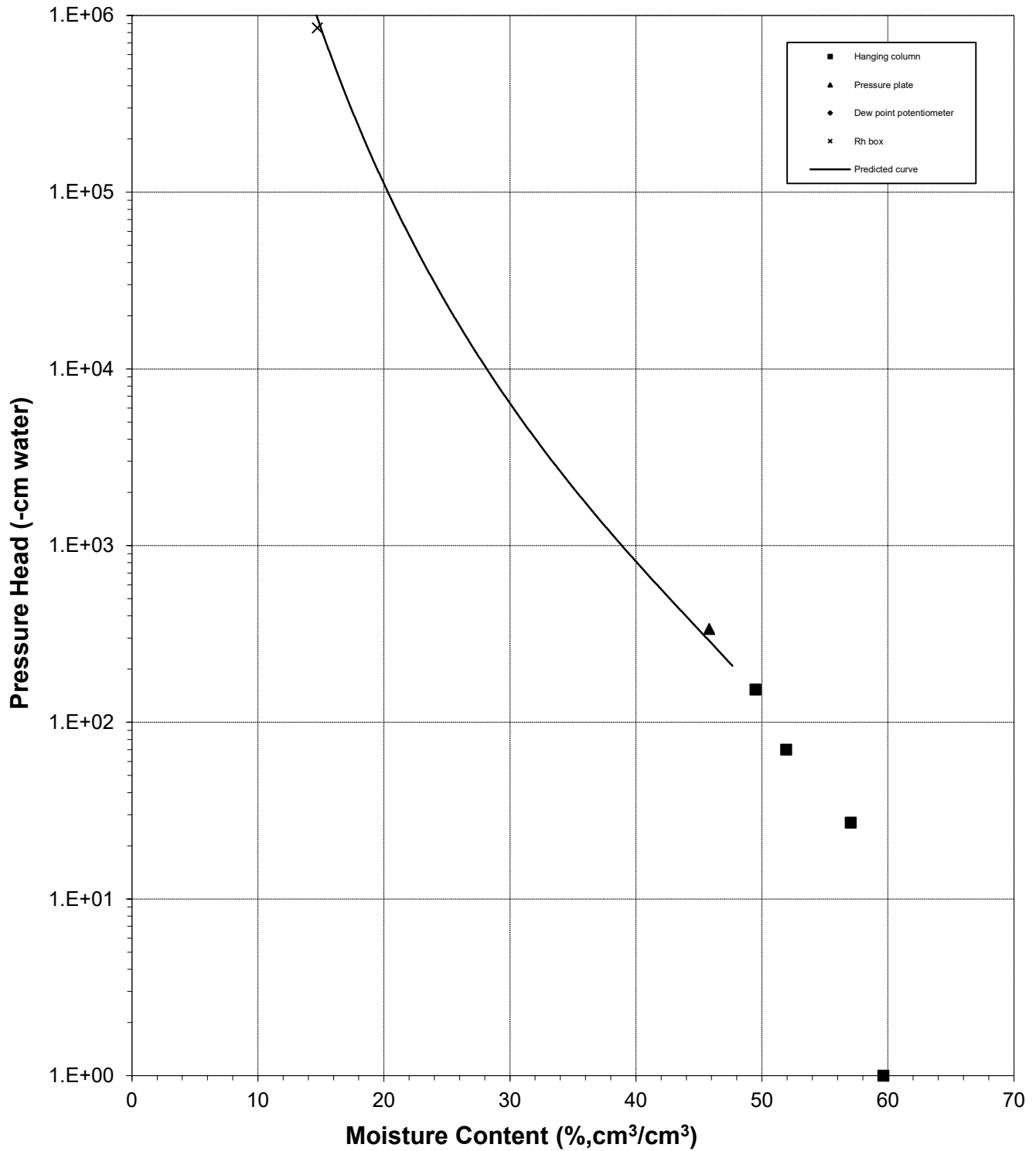
Sample Number: 4381-Blend (Firm) (970 kg/m³)





Predicted Calibration Curve and Data Points

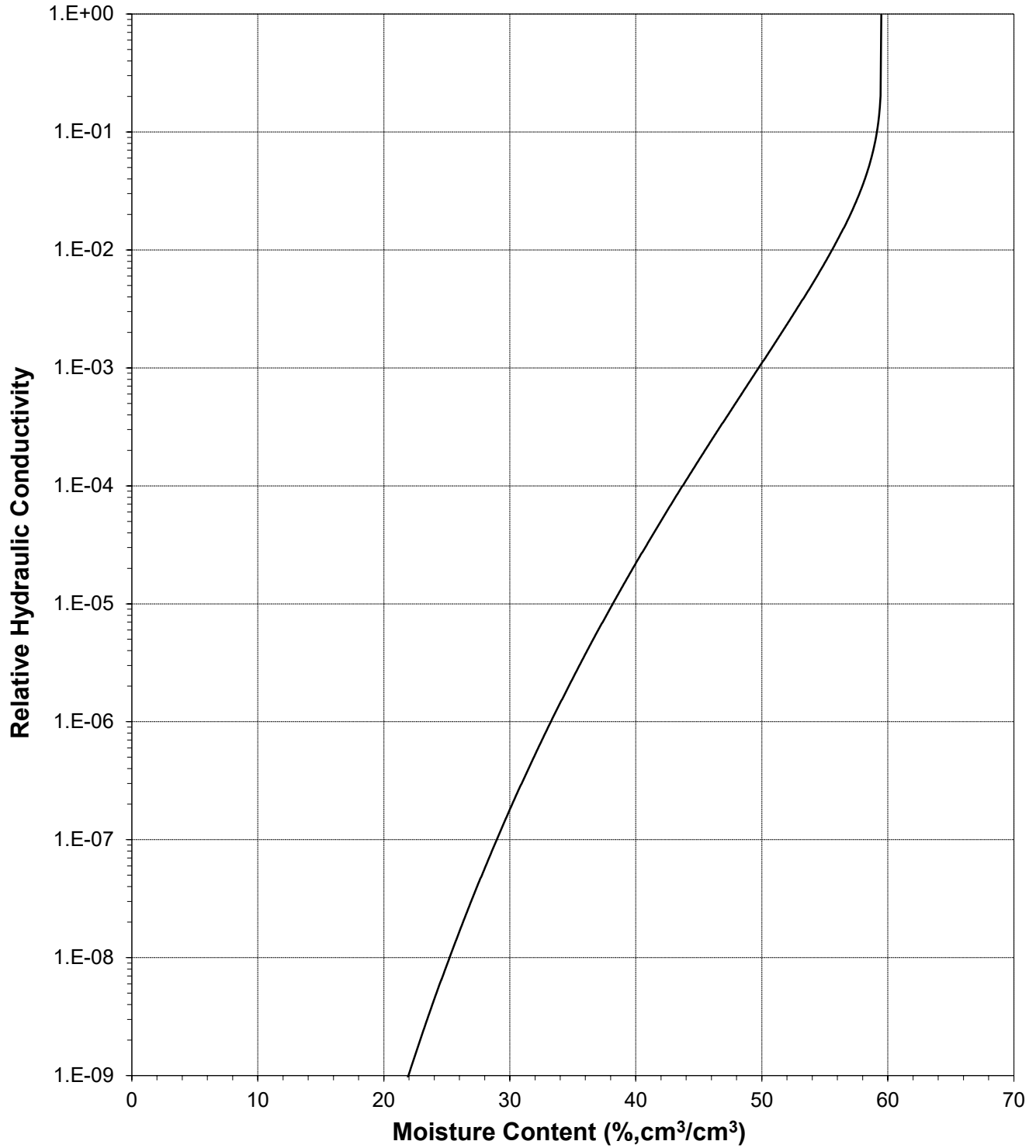
Sample Number: 4381-Blend (Firm) (970 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

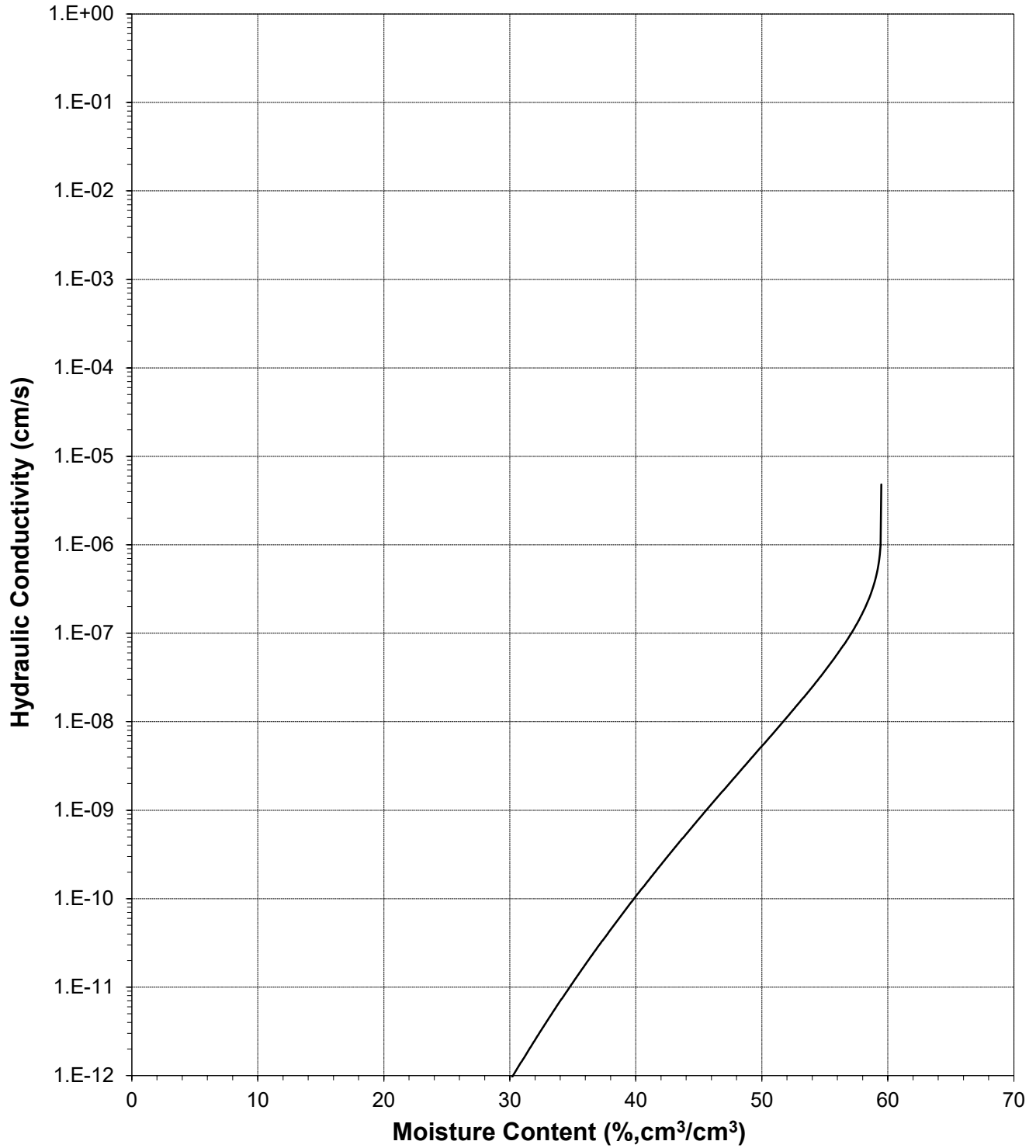
Sample Number: 4381-Blend (Firm) (970 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 4381-Blend (Firm) (970 kg/m³)

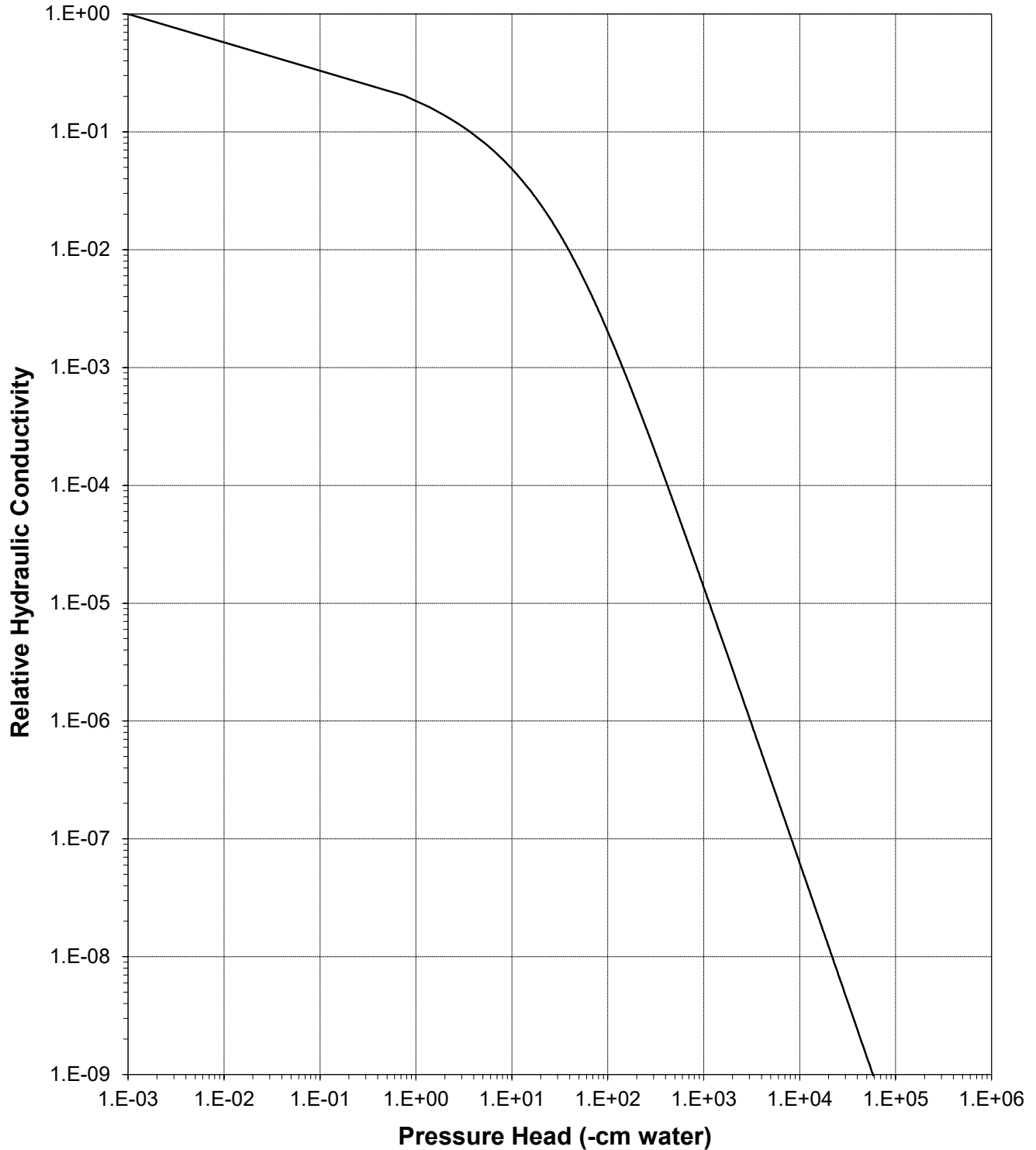




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Pressure Head

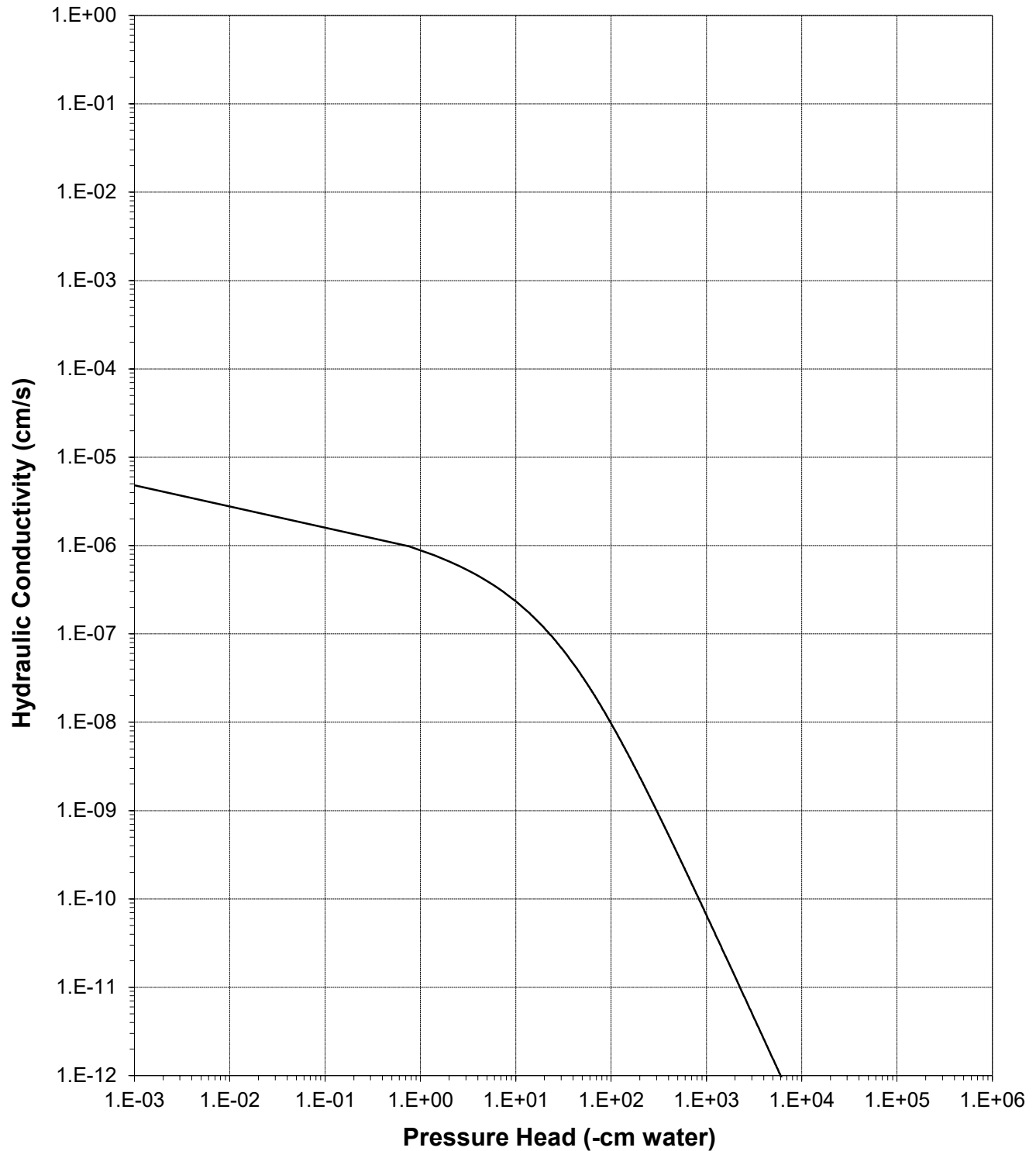
Sample Number: 4381-Blend (Firm) (970 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 4381-Blend (Firm) (970 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: 4381-Blend (Firm) (970 kg/m³)
 Material Type: Tailings
 Depth: NA

Split (3/4", 3/8", #4): 3/8"

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	0.82	99.18	100.00
Mass Fraction (%):	0.82	99.18	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	0.97	0.97
Calculated Porosity (% vol):	0.00	63.43	63.24
Volume of Solids (cm ³):	0.31	37.43	37.74
Volume of Voids (cm ³):	0.00	64.92	64.92
Total Volume (cm ³):	0.31	102.35	102.66
Volumetric Fraction (%):	0.30	99.70	100.00
Initial Moisture Content (% vol):	0.00	58.49	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	0.97	0.97
Calculated Porosity (% vol):	0.00	63.43	63.24
Volume of Solids (cm ³):	0.31	37.43	37.74
Volume of Voids (cm ³):	0.00	64.92	64.92
Total Volume (cm ³):	0.31	102.35	102.66
Volumetric Fraction (%):	0.30	99.70	100.00
Saturated Moisture Content (% vol):	0.00	59.49	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	0.97	0.97
Calculated Porosity (% vol):	0.00	63.43	63.24
Volume of Solids (cm ³):	0.31	37.43	37.74
Volume of Voids (cm ³):	0.00	64.92	64.92
Total Volume (cm ³):	0.31	102.35	102.66
Volumetric Fraction (%):	0.30	99.70	100.00
Residual Moisture Content (% vol):	0.00	0.00	---
Ksat (cm/sec):	NM	4.8E-06	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-01 (1520 kg/m³)
Material Type: Waste Rock
Depth: NA

Dry wt. of sample (g): 432.26
Tare wt., ring (g): 254.15
Tare wt., screen & clamp (g): 27.66
Initial sample volume (cm³): 285.19
Initial dry bulk density (g/cm³): 1.52
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 42.80

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)	
<i>Hanging column:</i>	13-Sep-19	10:55	839.63	0	43.18	##
	20-Sep-19	9:00	839.48	18.0	43.13	##
	27-Sep-19	9:30	839.24	58.0	43.05	##
	10-Oct-19	13:00	837.73	128.0	42.53	##
<i>Pressure plate:</i>	18-Oct-19	15:00	818.06	337	35.76	##

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	290.78	+1.96%	1.49	43.90
	18.0	290.78	+1.96%	1.49	43.90
	58.0	290.78	+1.96%	1.49	43.90
	128.0	290.78	+1.96%	1.49	43.90
<i>Pressure plate:</i>	337	290.78	+1.96%	1.49	43.90

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '-'-'-' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-01 (1520 kg/m³)

Initial sample bulk density (g/cm³): 1.52

Fraction of test sample used (<2.00mm fraction) (%): 71.39

Dry weight* of dew point potentiometer sample (g): 167.74

Tare weight, jar (g): 114.72

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
Dew point potentiometer:	24-Sep-19	7:50	177.42	4487	19.38	##
	19-Sep-19	7:35	174.13	22538	12.79	##
	17-Sep-19	8:11	172.59	89334	9.71	##
	13-Sep-19	12:45	170.83	548244	6.19	##

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	4487	290.78	+1.96%	1.49	43.90
	22538	290.78	+1.96%	1.49	43.90
	89334	290.78	+1.96%	1.49	43.90
	548244	290.78	+1.96%	1.49	43.90

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-01 (1520 kg/m³)

Initial sample bulk density (g/cm³): 1.52

Fraction of test sample used (<2.00mm fraction) (%): 71.39

Dry weight* of relative humidity box sample (g): 79.28

Tare weight (g): 40.69

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
Relative humidity box:	19-Sep-19	7:30	81.50	848426	6.10	††

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	290.78	+1.96%	1.49	43.90

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '----' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

†† Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

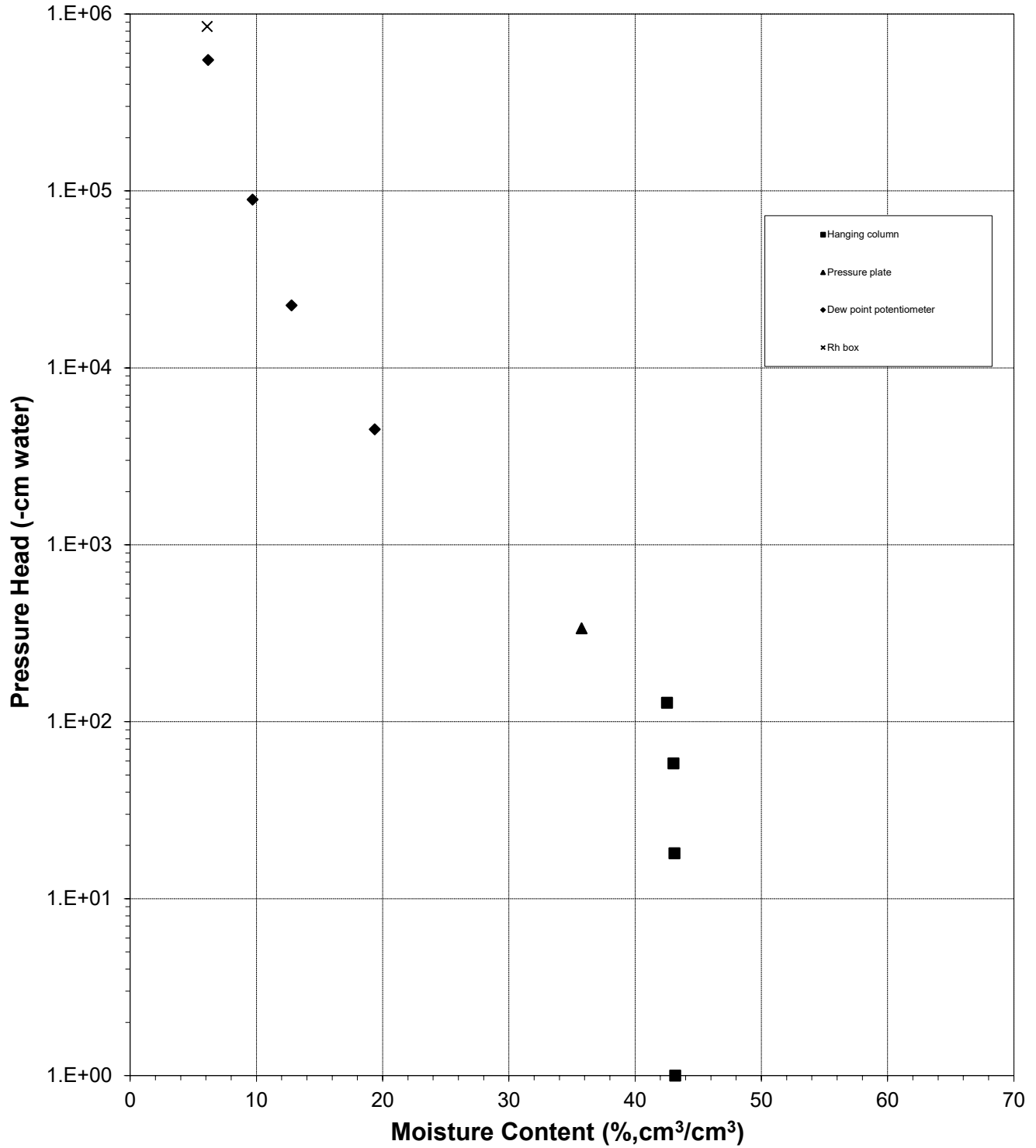
Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



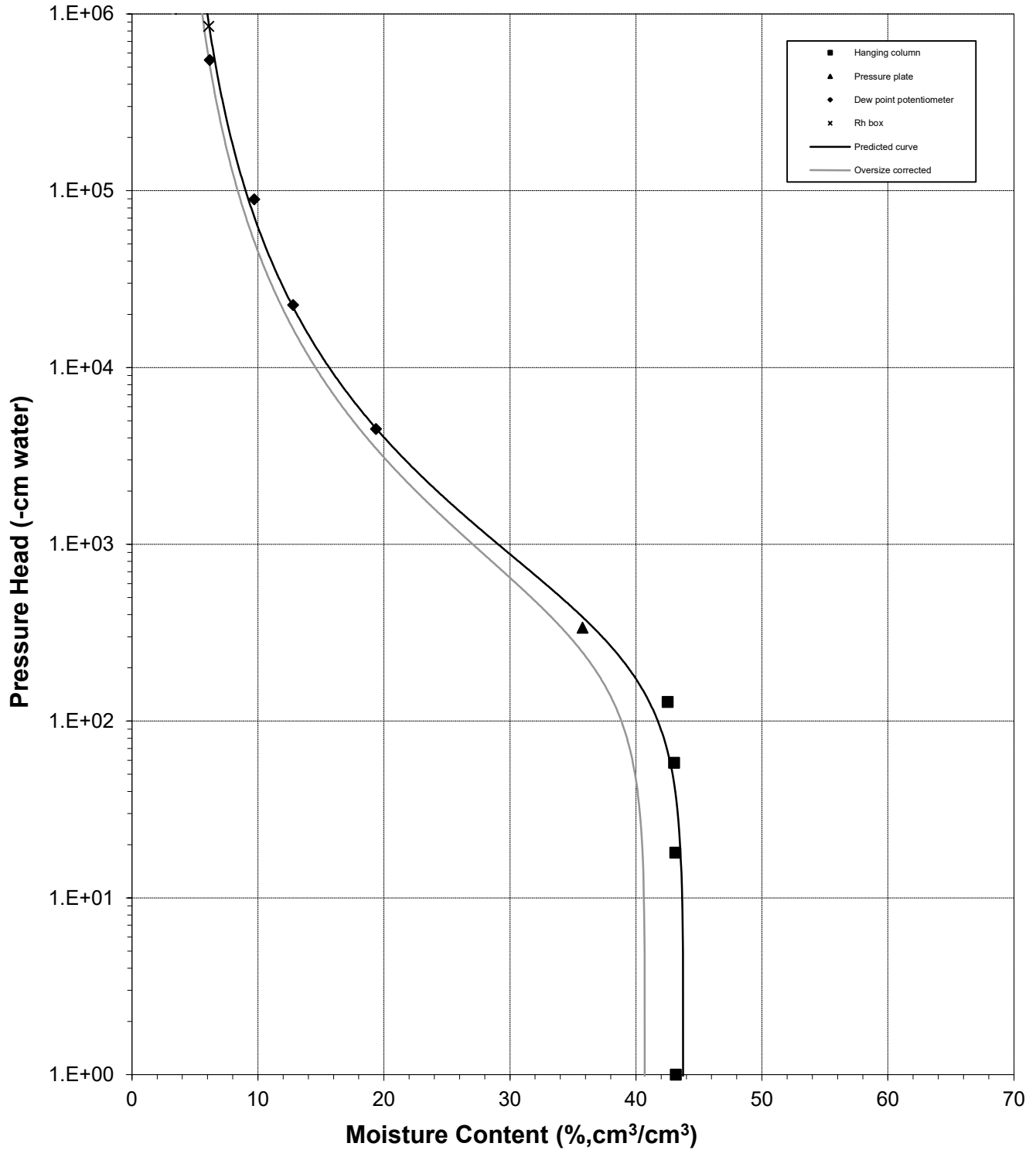
Water Retention Data Points
Sample Number: WD19-01 (1520 kg/m³)





Predicted Calibration Curve and Data Points

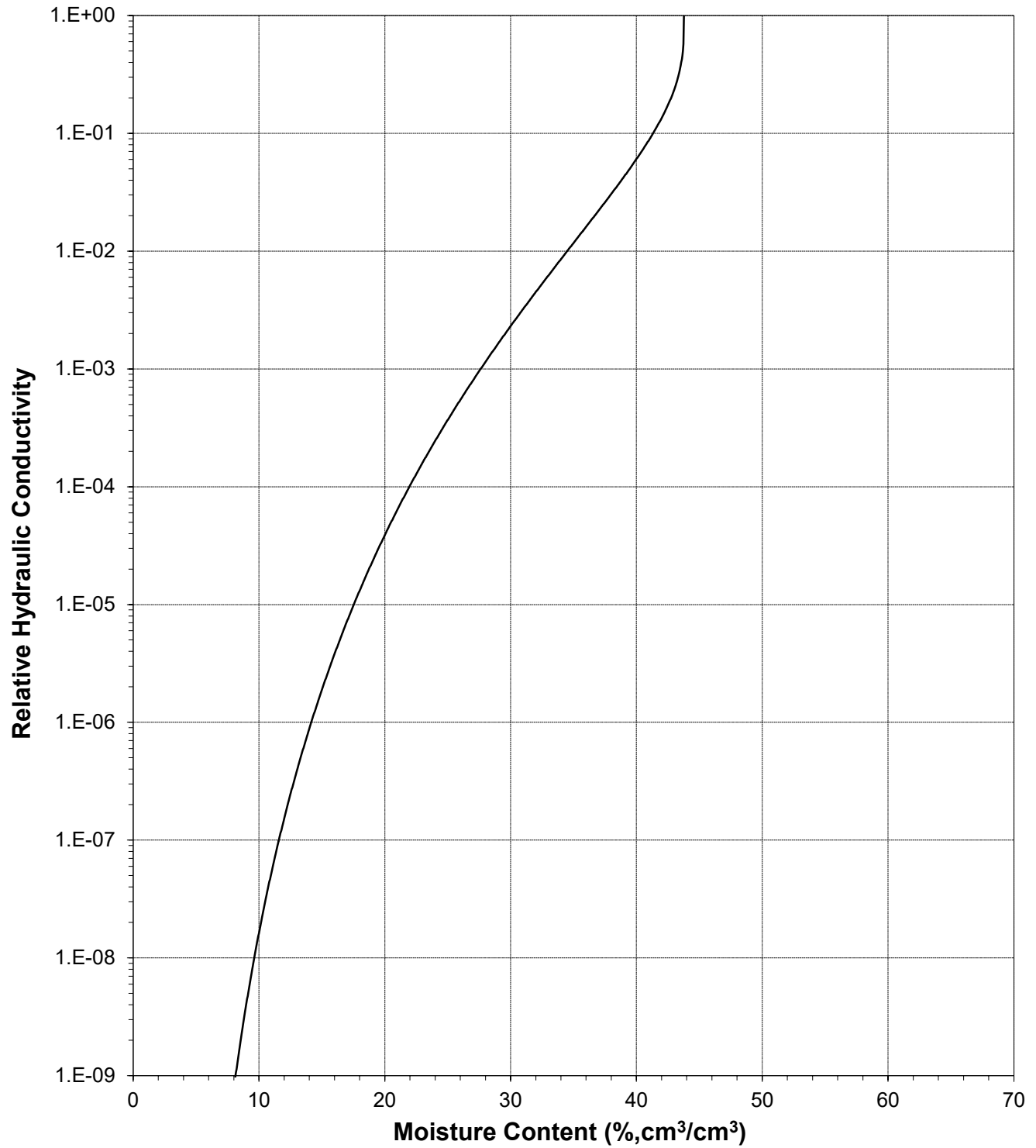
Sample Number: WD19-01 (1520 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

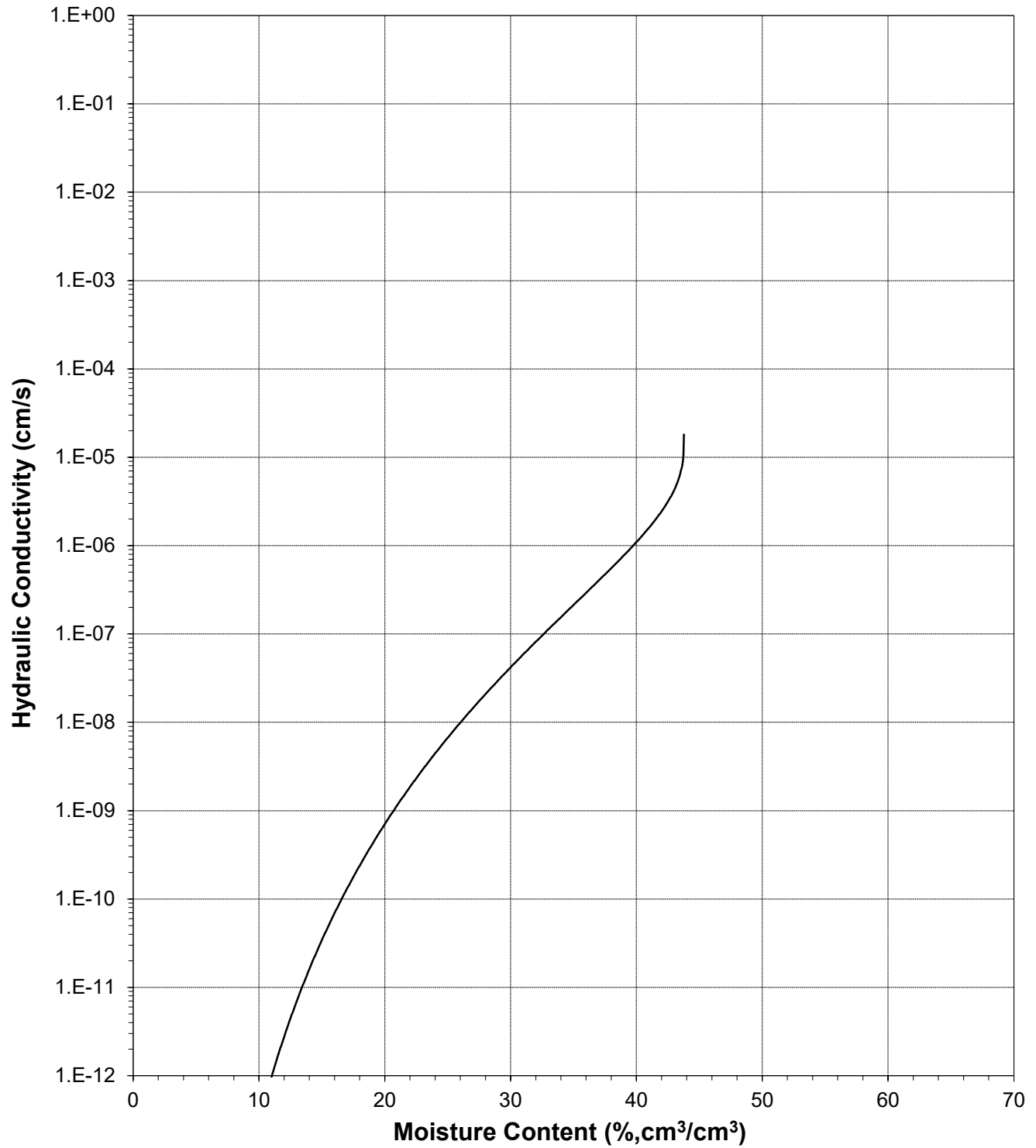
Sample Number: WD19-01 (1520 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: WD19-01 (1520 kg/m³)

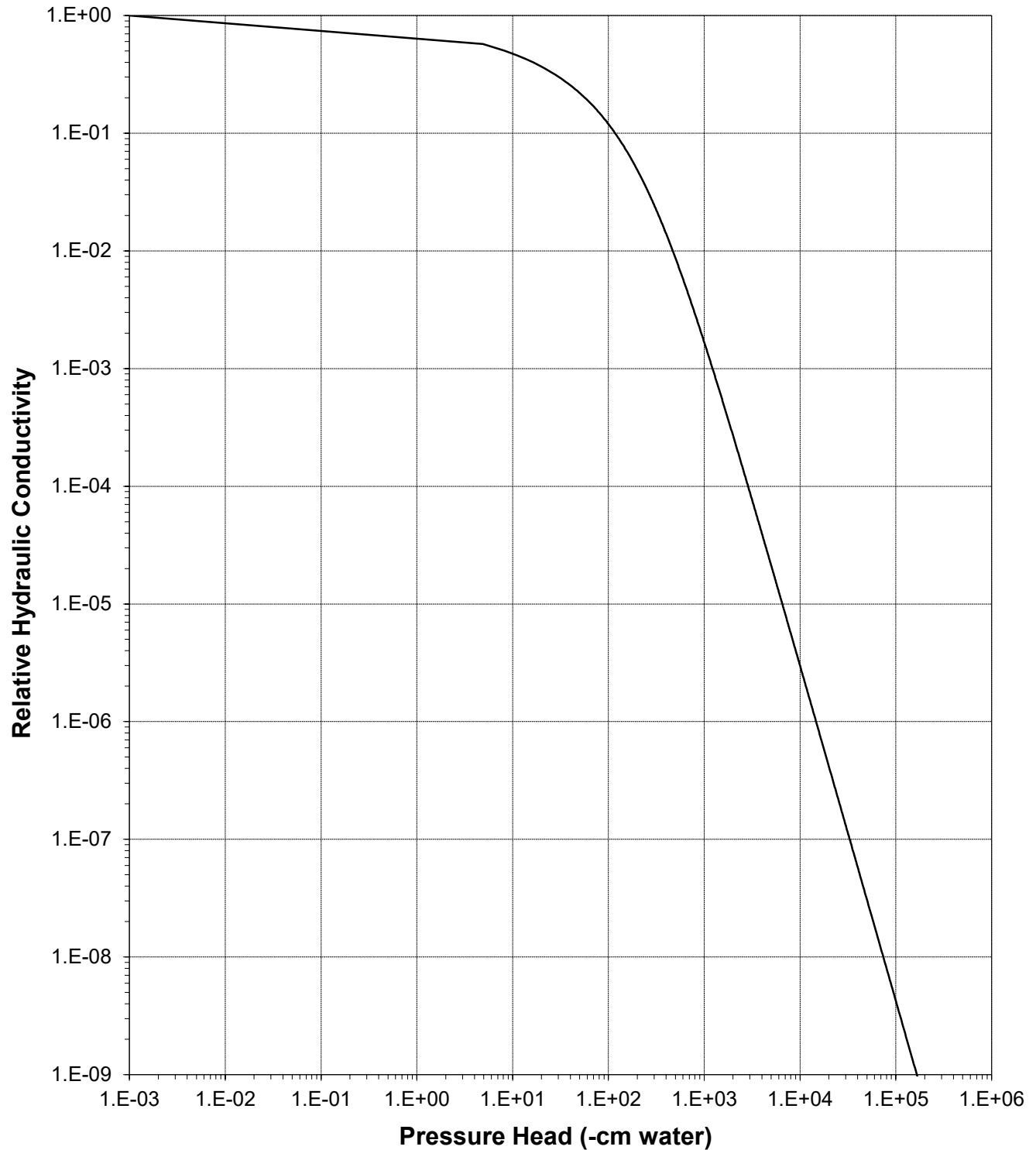




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Plot of Relative Hydraulic Conductivity vs Pressure Head

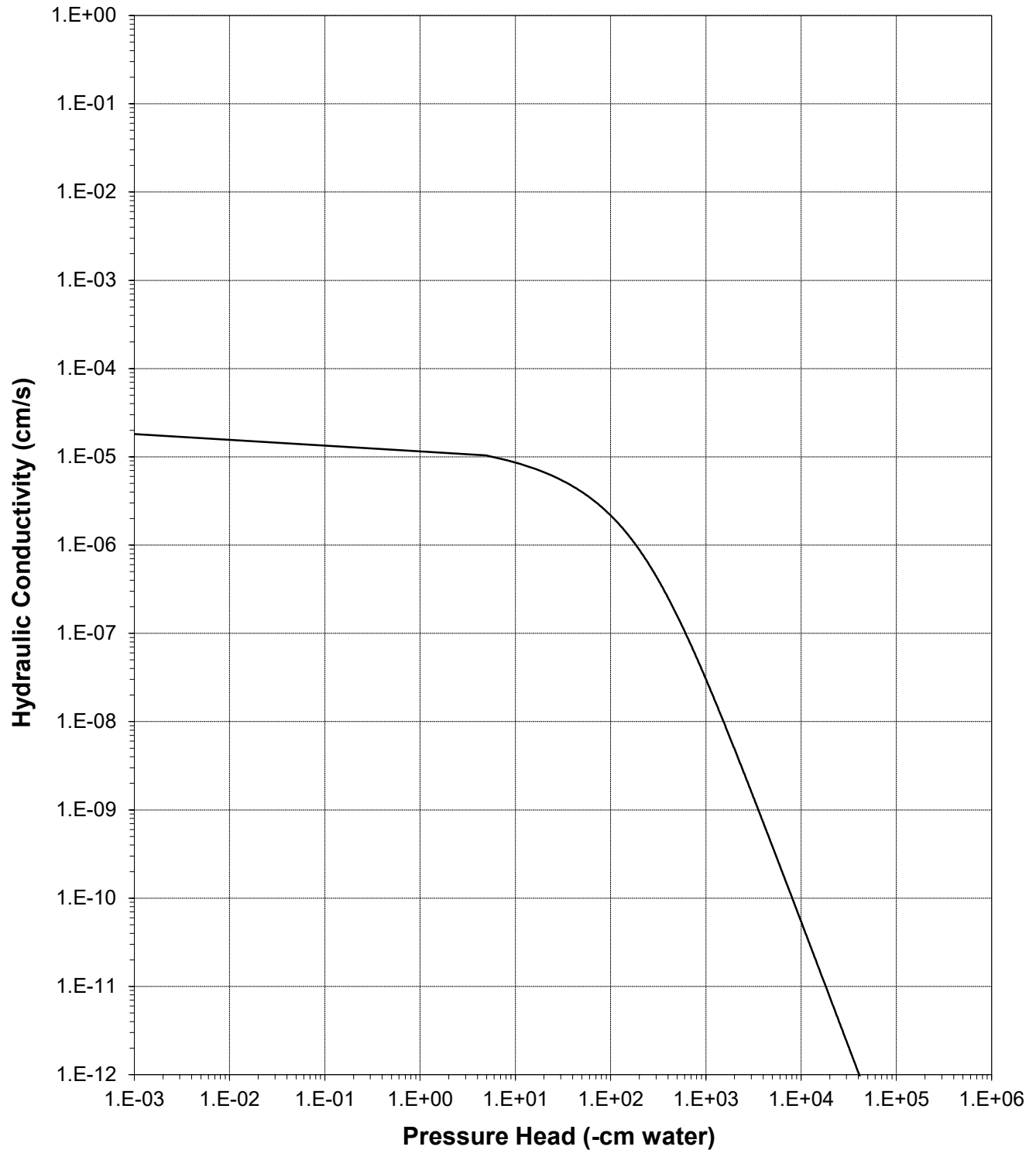
Sample Number: WD19-01 (1520 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: WD19-01 (1520 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-01 (1520 kg/m³)
 Material Type: Waste Rock
 Depth: NA

Split (3/4", 3/8", #4): 3/8"

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	11.73	88.27	100.00
Mass Fraction (%):	11.73	88.27	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.52	1.60
Calculated Porosity (% vol):	0.00	42.80	39.78
Volume of Solids (cm ³):	4.43	33.31	37.74
Volume of Voids (cm ³):	0.00	24.93	24.93
Total Volume (cm ³):	4.43	58.24	62.66
Volumetric Fraction (%):	7.06	92.94	100.00
Initial Moisture Content (% vol):	0.00	29.03	26.98
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.49	1.57
Calculated Porosity (% vol):	0.00	43.90	40.86
Volume of Solids (cm ³):	4.43	33.31	37.74
Volume of Voids (cm ³):	0.00	26.07	26.07
Total Volume (cm ³):	4.43	59.38	63.81
Volumetric Fraction (%):	6.94	93.06	100.00
Saturated Moisture Content (% vol):	0.00	43.77	40.73
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.49	1.57
Calculated Porosity (% vol):	0.00	43.90	40.86
Volume of Solids (cm ³):	4.43	33.31	37.74
Volume of Voids (cm ³):	0.00	26.07	26.07
Total Volume (cm ³):	4.43	59.38	63.81
Volumetric Fraction (%):	6.94	93.06	100.00
Residual Moisture Content (% vol):	0.00	3.46	3.22
Ksat (cm/sec):	NM	1.8E-05	1.6E-05

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

Laboratory analysis by: D. O'Dowd
 Data entered by: A. Albay-Yenney
 Checked by: J. Hines



Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-02 (1490 kg/m³)
 Material Type: Waste Rock
 Depth: NA

Dry wt. of sample (g): 424.57
 Tare wt., ring (g): 257.59
 Tare wt., screen & clamp (g): 26.41
 Initial sample volume (cm³): 284.27
 Initial dry bulk density (g/cm³): 1.49
 Assumed particle density (g/cm³): 2.65
 Initial calculated total porosity (%): 43.64

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:25	831.95	0	43.40
	20-Sep-19	9:00	831.90	27.0	43.38
	27-Sep-19	9:30	831.39	70.0	43.21
	10-Oct-19	13:15	824.46	153.0	40.77
<i>Pressure plate:</i>	18-Oct-19	15:00	814.34	337	37.21

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	27.0	---	---	---	---
	70.0	---	---	---	---
	153.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-02 (1490 kg/m³)

Initial sample bulk density (g/cm³): 1.49

Fraction of test sample used (<2.00mm fraction) (%): 64.52

Dry weight* of dew point potentiometer sample (g): 161.81

Tare weight, jar (g): 110.56

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	25-Sep-19	9:37	173.56	1734	22.09
	23-Sep-19	9:10	170.22	8056	15.81
	18-Sep-19	8:36	167.74	36407	11.15
	16-Sep-19	13:15	166.23	174998	8.31

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	1734	---	---	---	---
	8056	---	---	---	---
	36407	---	---	---	---
	174998	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-02 (1490 kg/m³)

Initial sample bulk density (g/cm³): 1.49

Fraction of test sample used (<2.00mm fraction) (%): 64.52

Dry weight* of relative humidity box sample (g): 66.28

Tare weight (g): 39.41

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	19-Sep-19	7:30	67.96	848426	6.04

Volume Adjusted Data ¹				
	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)
Relative humidity box:	848426	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd

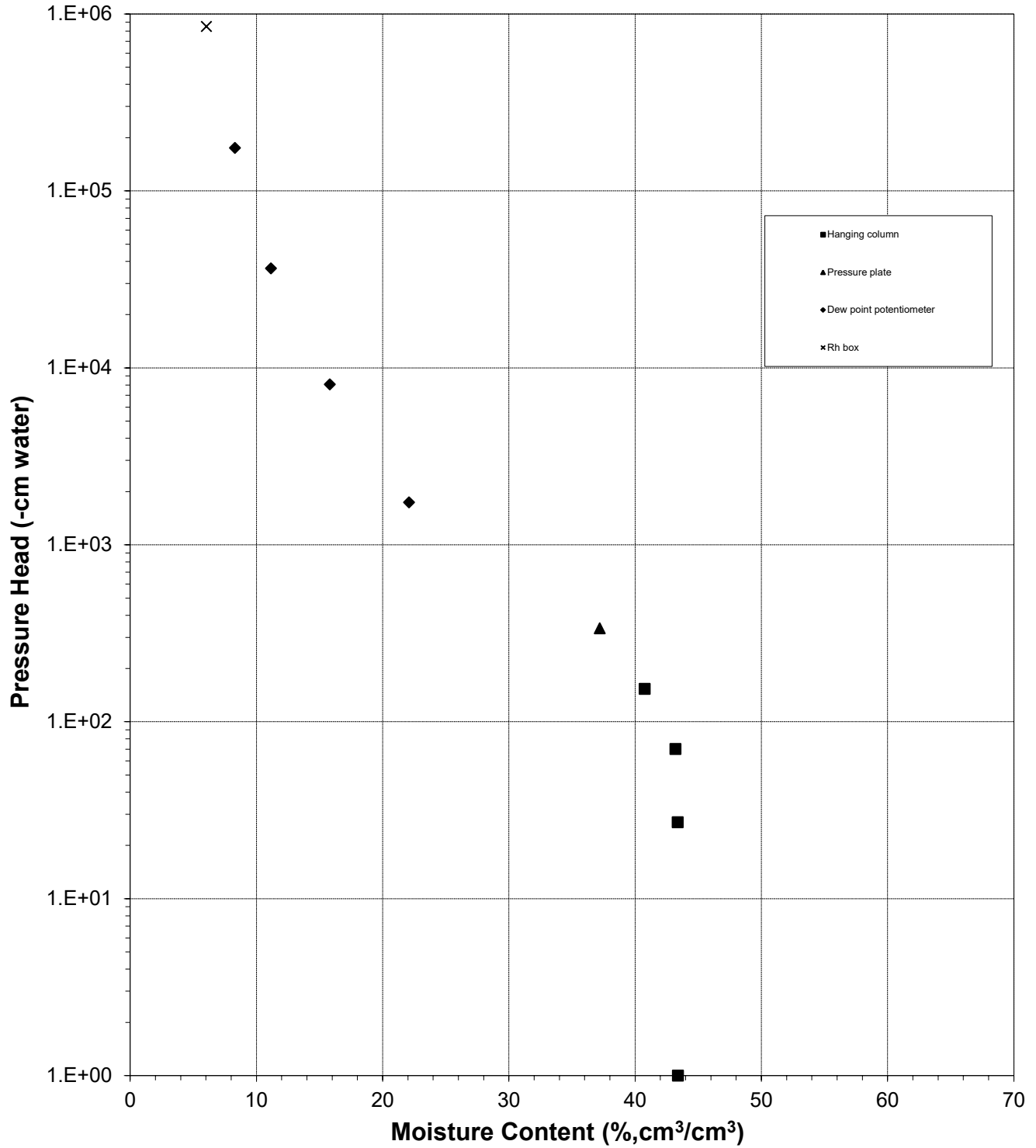
Data entered by: A. Albay-Yenney

Checked by: J. Hines



Water Retention Data Points

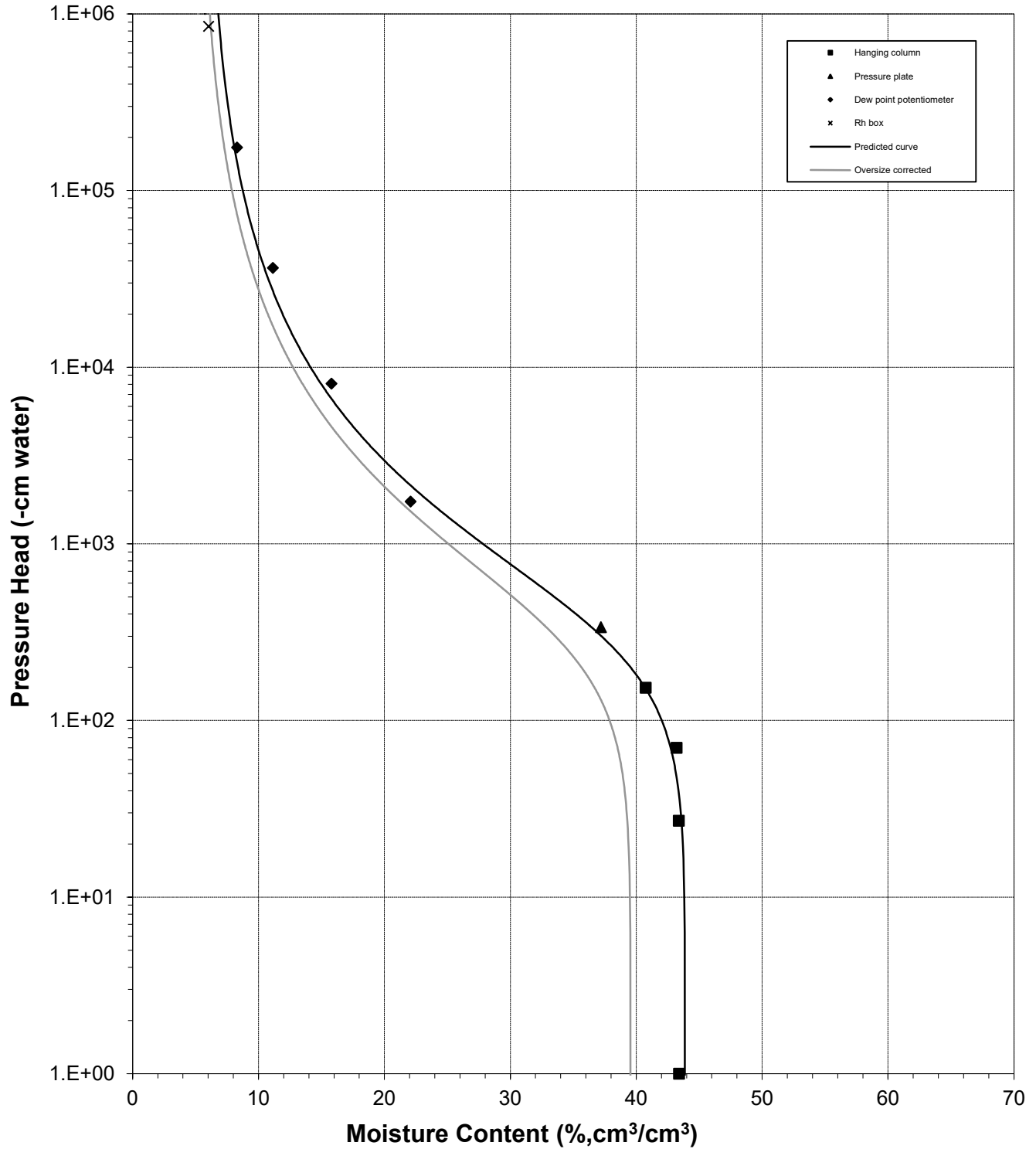
Sample Number: WD19-02 (1490 kg/m³)





Predicted Calibration Curve and Data Points

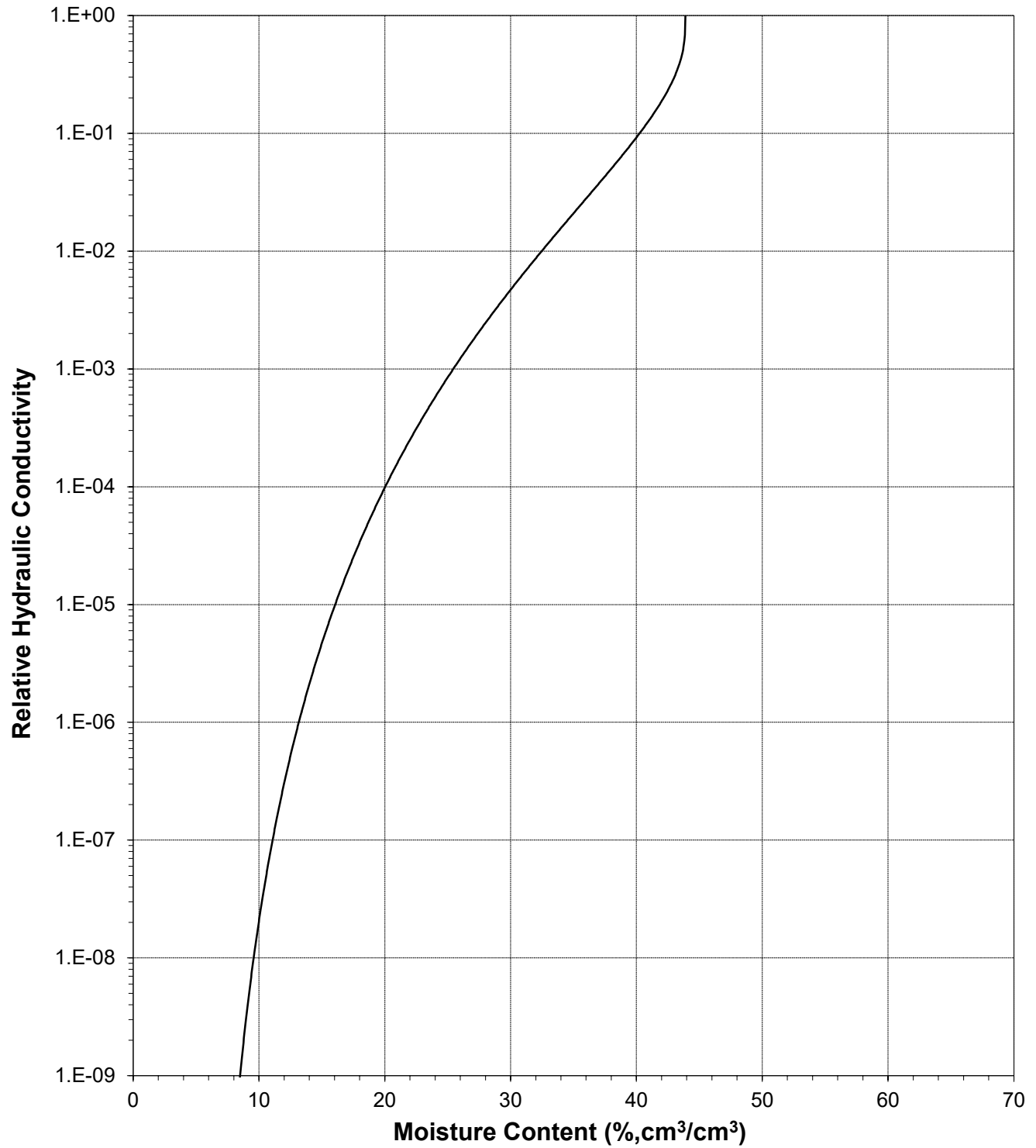
Sample Number: WD19-02 (1490 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

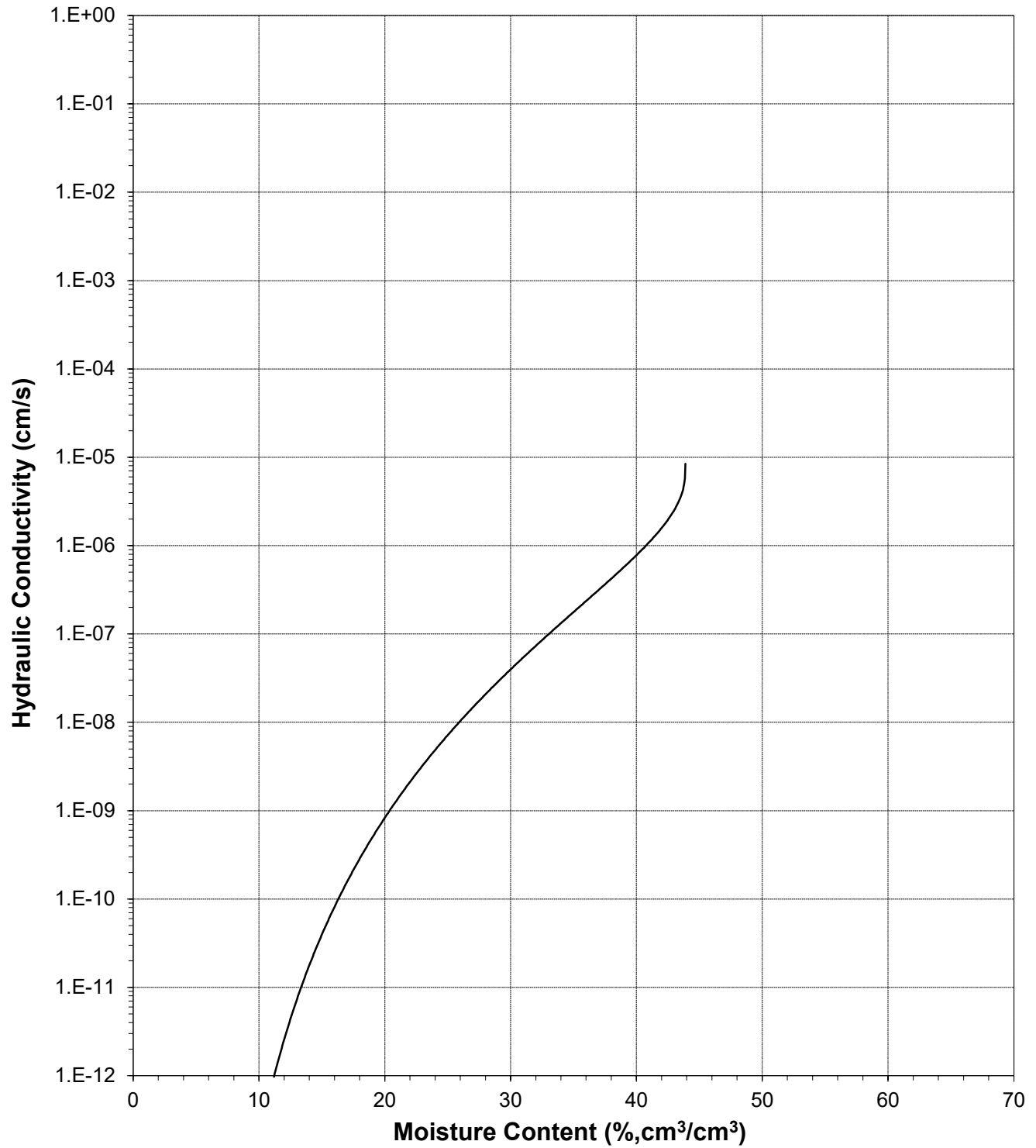
Sample Number: WD19-02 (1490 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: WD19-02 (1490 kg/m³)

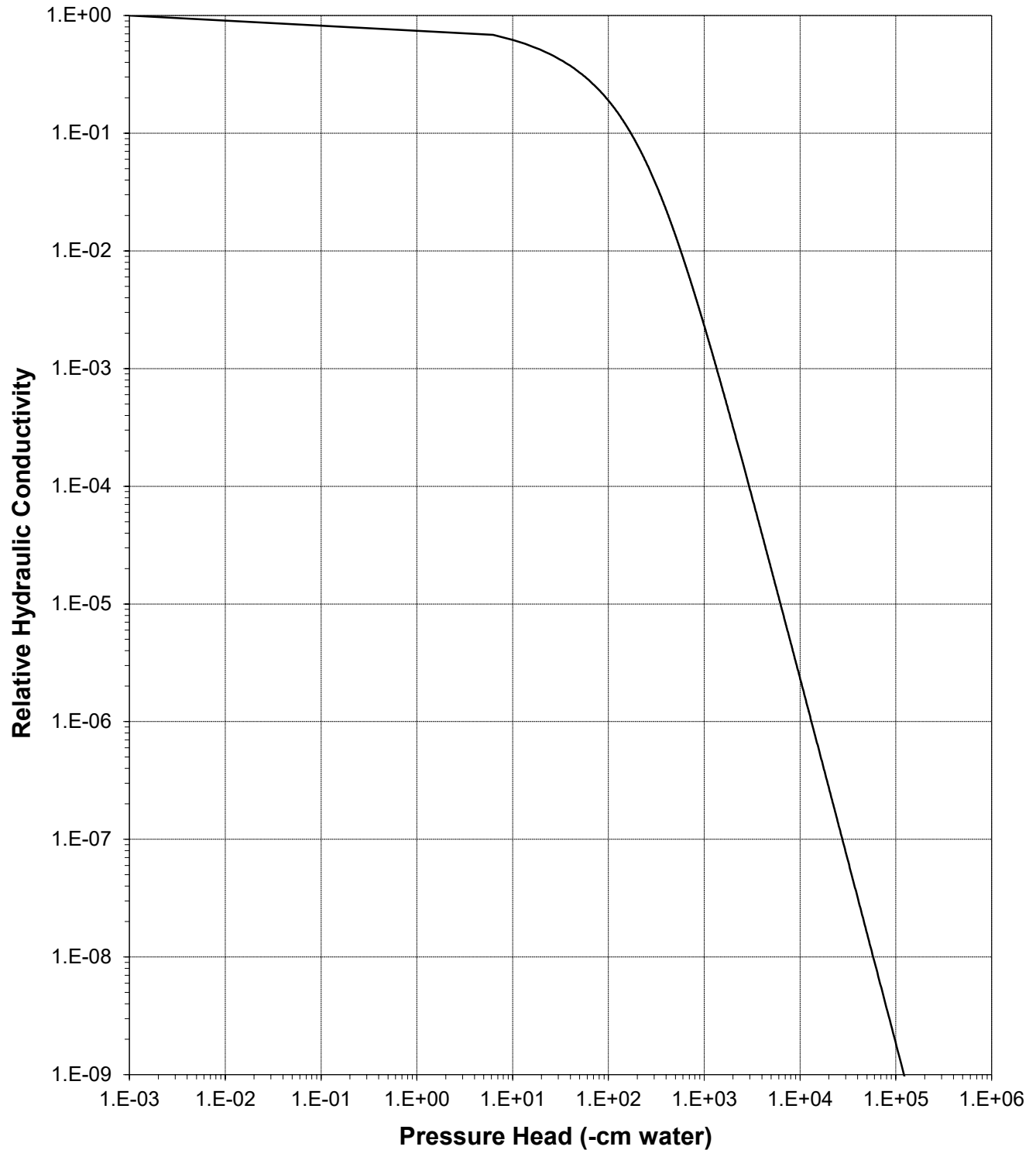




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Pressure Head

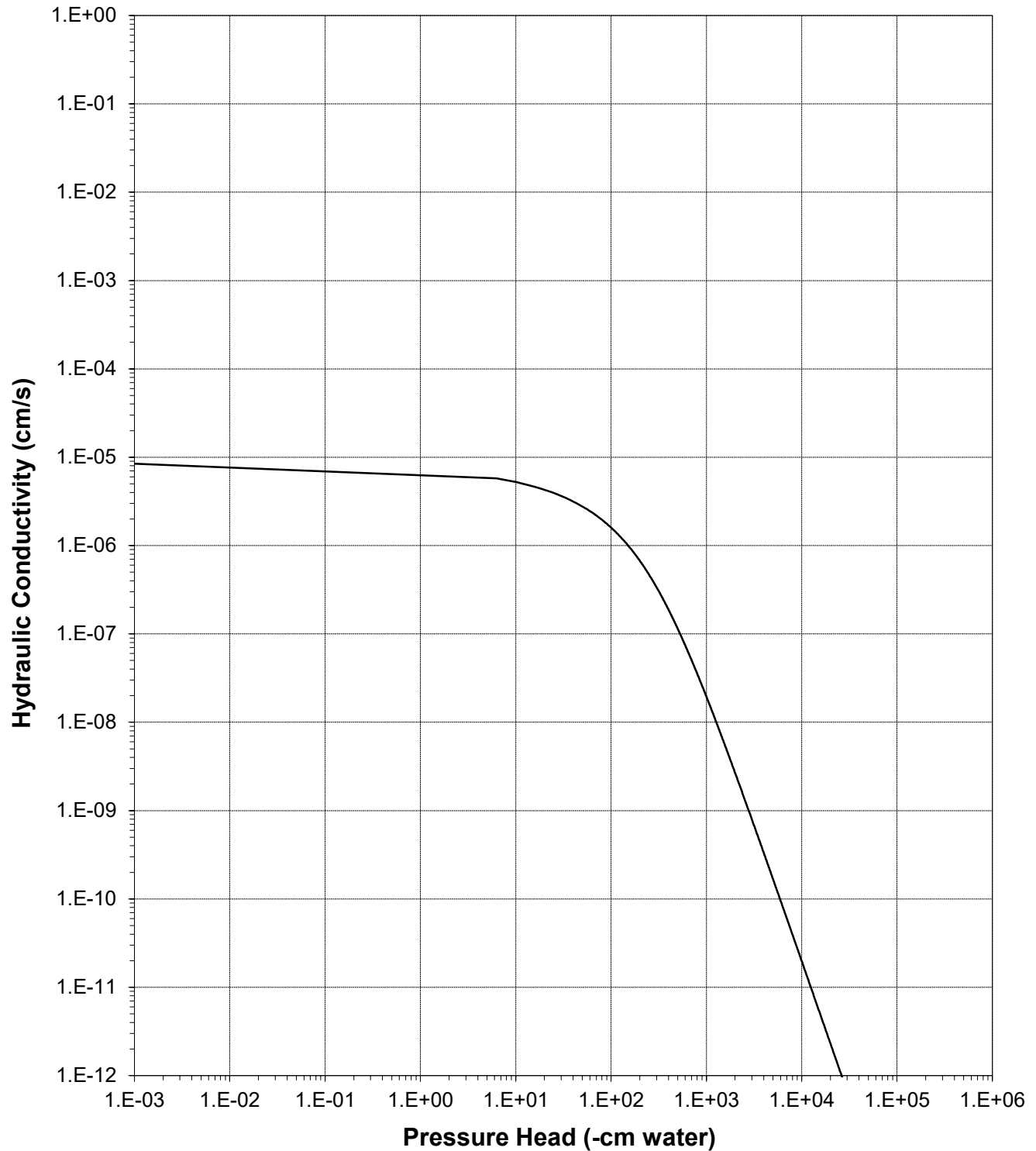
Sample Number: WD19-02 (1490 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: WD19-02 (1490 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-02 (1490 kg/m³)
 Material Type: Waste Rock
 Depth: NA

Split (3/4", 3/8", #4): 3/8"

	<u>Coarse Fraction*</u>	<u>Fines Fraction**</u>	<u>Composite</u>
Subsample Mass (g):	16.26	83.74	100.00
Mass Fraction (%):	16.26	83.74	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.49	1.61
Calculated Porosity (% vol):	0.00	43.64	39.34
Volume of Solids (cm ³):	6.13	31.60	37.74
Volume of Voids (cm ³):	0.00	24.47	24.47
Total Volume (cm ³):	6.13	56.07	62.20
Volumetric Fraction (%):	9.86	90.14	100.00
Initial Moisture Content (% vol):	0.00	32.91	29.66
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.49	1.61
Calculated Porosity (% vol):	0.00	43.64	39.34
Volume of Solids (cm ³):	6.13	31.60	37.74
Volume of Voids (cm ³):	0.00	24.47	24.47
Total Volume (cm ³):	6.13	56.07	62.20
Volumetric Fraction (%):	9.86	90.14	100.00
Saturated Moisture Content (% vol):	0.00	43.90	39.57
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.49	1.61
Calculated Porosity (% vol):	0.00	43.64	39.34
Volume of Solids (cm ³):	6.13	31.60	37.74
Volume of Voids (cm ³):	0.00	24.47	24.47
Total Volume (cm ³):	6.13	56.07	62.20
Volumetric Fraction (%):	9.86	90.14	100.00
Residual Moisture Content (% vol):	0.00	5.71	5.15
<i>Ksat (cm/sec):</i>			
	NM	8.4E-06	7.1E-06

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

Laboratory analysis by: D. O'Dowd
 Data entered by: A. Albay-Yenney
 Checked by: J. Hines



Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-03 (Firm) (1300 kg/m³)
 Material Type: Waste Rock
 Depth: NA

Dry wt. of sample (g): 1780.90
 Tare wt., ring (g): 165.76
 Tare wt., screen & clamp (g): 47.38
 Initial sample volume (cm³): 1365.76
 Initial dry bulk density (g/cm³): 1.30
 Assumed particle density (g/cm³): 2.65
 Initial calculated total porosity (%): 50.79

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)	
<i>Hanging column:</i>	13-Sep-19	10:40	2708.06	0	50.23	##
	20-Sep-19	9:00	2705.62	18.0	50.06	##
	27-Sep-19	9:30	2694.80	57.0	49.30	##
	10-Oct-19	13:00	2617.51	130.0	43.86	##
<i>Pressure plate:</i>	18-Oct-19	15:00	2600.69	377	42.68	##

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	1421.39	+4.07%	1.25	52.72
	18.0	1421.39	+4.07%	1.25	52.72
	57.0	1421.39	+4.07%	1.25	52.72
	130.0	1421.39	+4.07%	1.25	52.72
<i>Pressure plate:</i>	377	1421.39	+4.07%	1.25	52.72

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '-'-'-' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-03 (Firm) (1300 kg/m³)

Initial sample bulk density (g/cm³): 1.30

Fraction of test sample used (<2.00mm fraction) (%): 78.19

Dry weight* of dew point potentiometer sample (g): 158.92

Tare weight, jar (g): 114.73

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
Dew point potentiometer:	25-Sep-19	10:10	171.97	2244	28.93	##
	23-Sep-19	9:20	168.40	10810	21.02	##
	18-Sep-19	9:00	165.25	73528	14.03	##
	16-Sep-19	13:40	163.50	303900	10.15	##

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	2244	1421.39	+4.07%	1.25	52.72
	10810	1421.39	+4.07%	1.25	52.72
	73528	1421.39	+4.07%	1.25	52.72
	303900	1421.39	+4.07%	1.25	52.72

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: WD19-03 (Firm) (1300 kg/m³)

Initial sample bulk density (g/cm³): 1.30

Fraction of test sample used (<2.00mm fraction) (%): 78.19

Dry weight* of relative humidity box sample (g): 70.25

Tare weight (g): 38.82

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
Relative humidity box:	19-Sep-19	7:30	72.95	848426	8.43	††

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	1421.39	+4.07%	1.25	52.72

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '----' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

†† Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Laboratory analysis by: D. O'Dowd

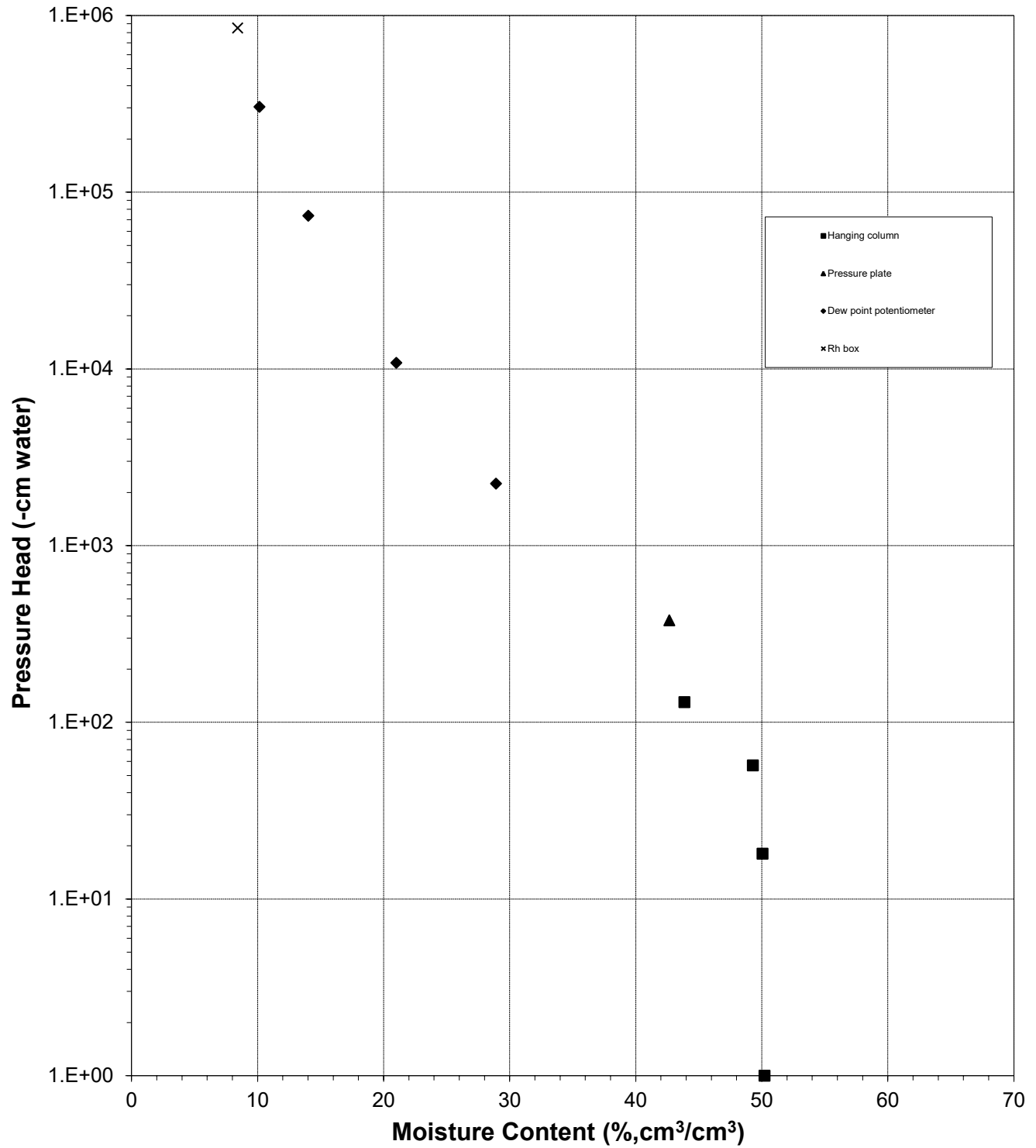
Data entered by: A. Albay-Yenney

Checked by: J. Hines



Water Retention Data Points

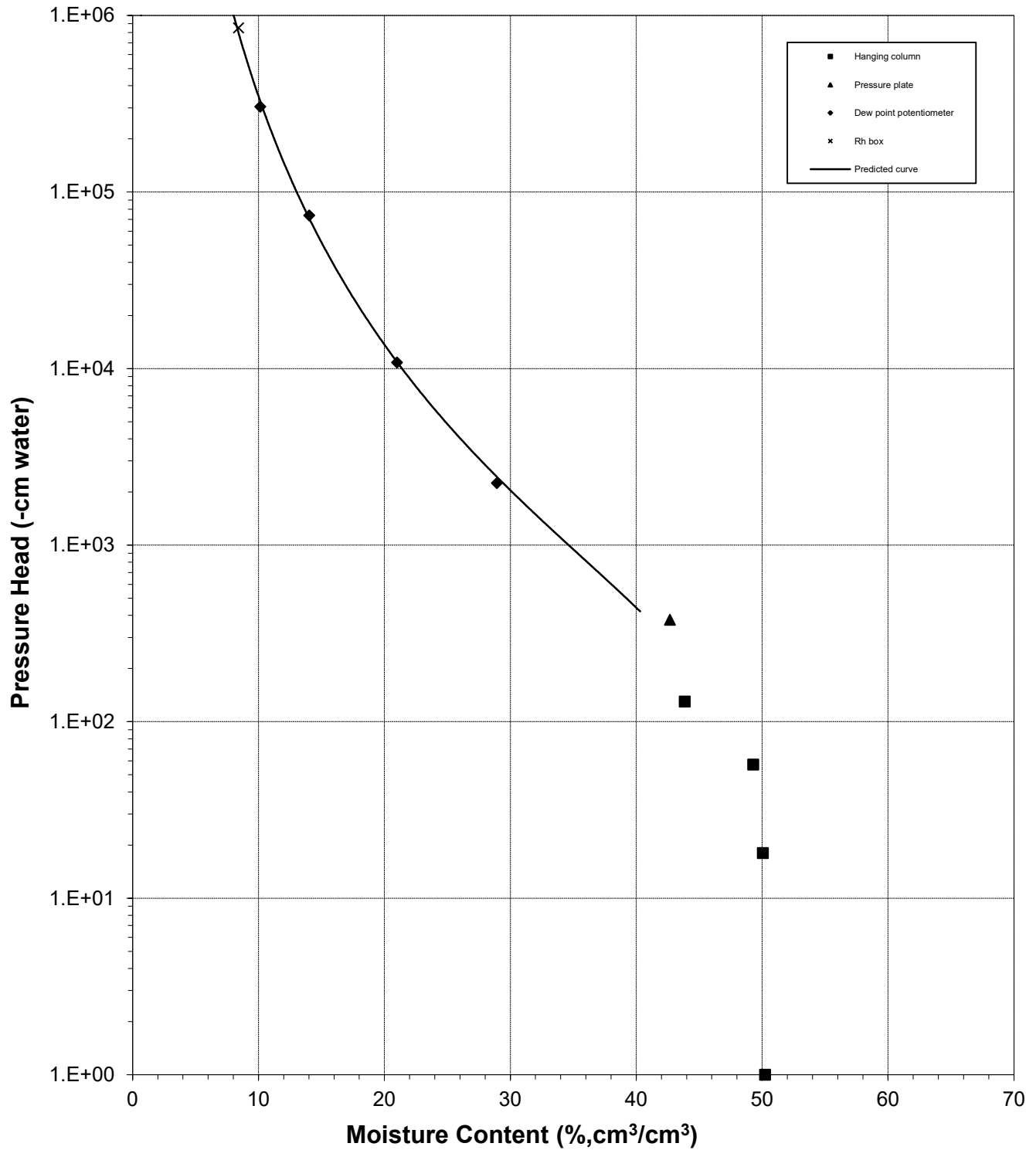
Sample Number: WD19-03 (Firm) (1300 kg/m³)





Predicted Calibration Curve and Data Points

Sample Number: WD19-03 (Firm) (1300 kg/m³)

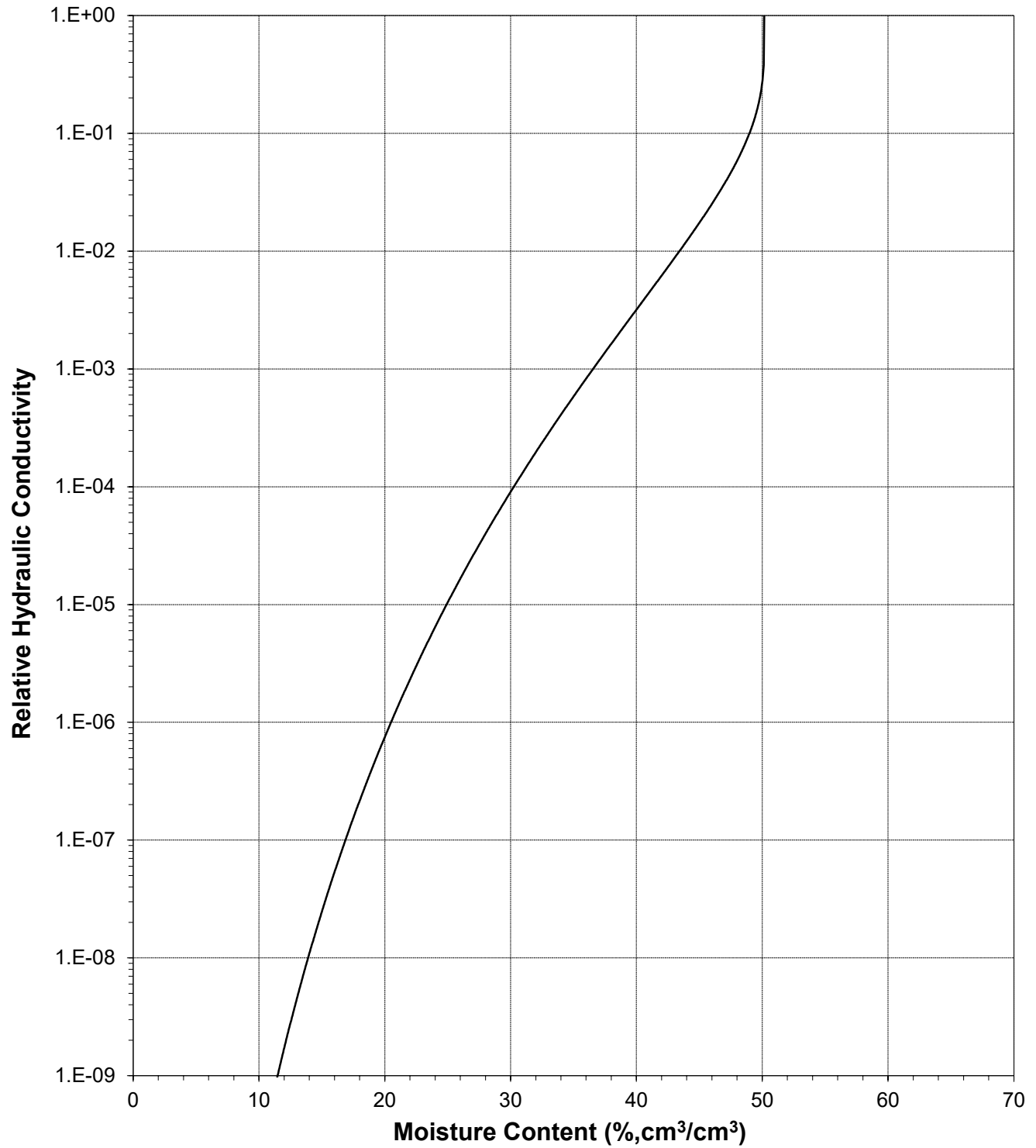




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: WD19-03 (Firm) (1300 kg/m³)

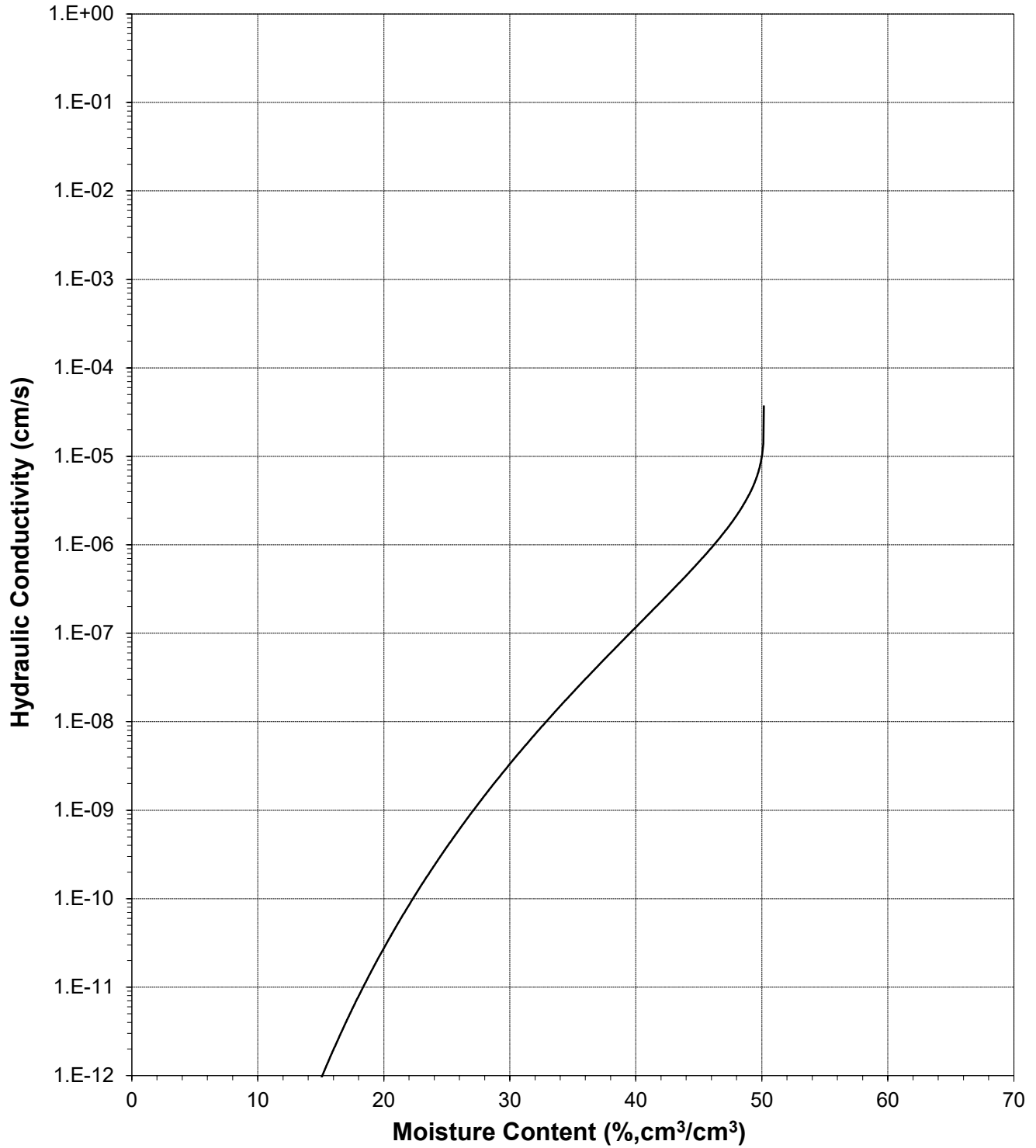




Daniel B. Stephens & Associates, Inc.

Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: WD19-03 (Firm) (1300 kg/m³)

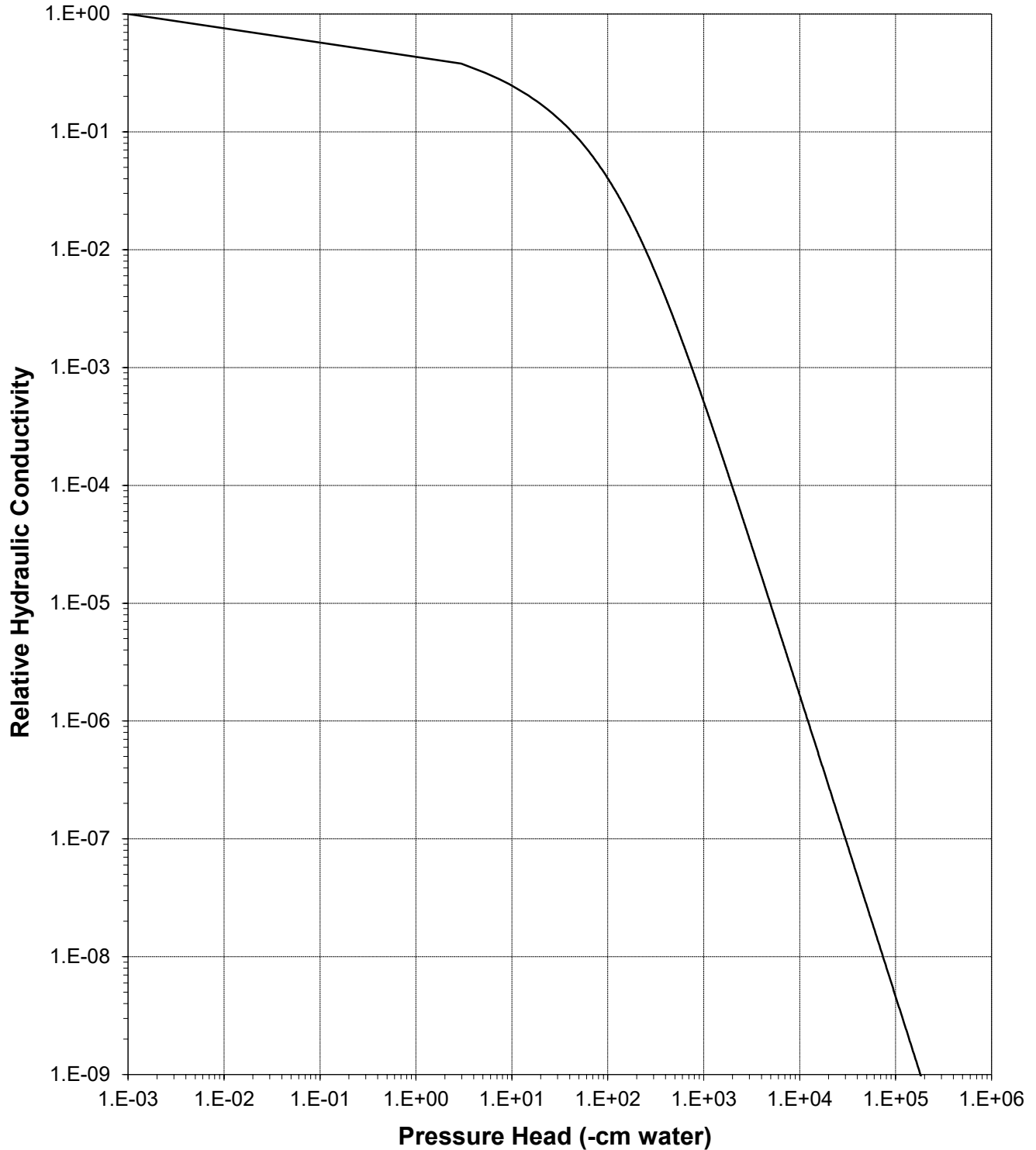




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Pressure Head

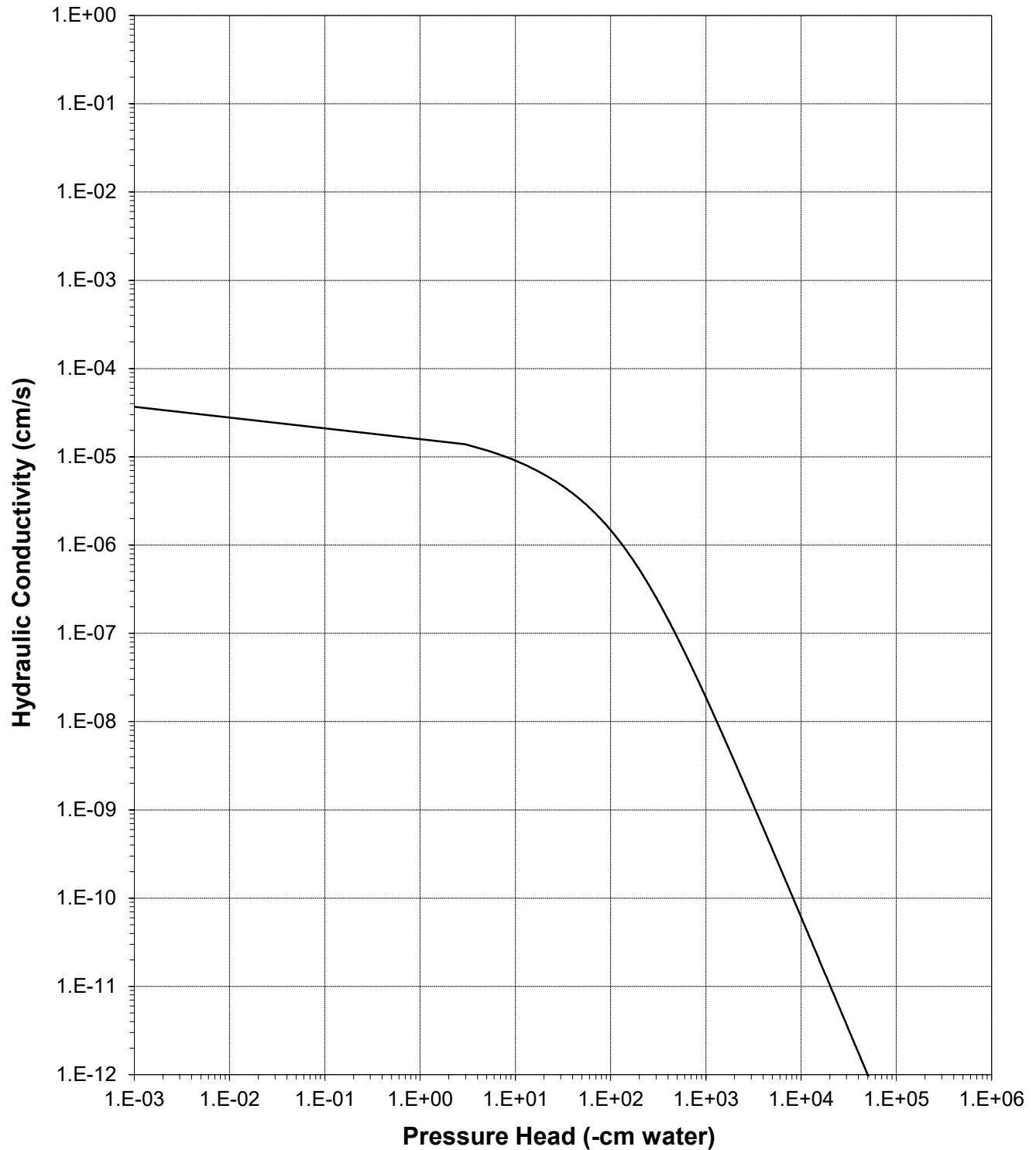
Sample Number: WD19-03 (Firm) (1300 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: WD19-03 (Firm) (1300 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-03 (Firm) (1300 kg/m³)
 Material Type: Waste Rock
 Depth: NA

Split (3/4", 3/8", #4): 3/4"

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	3.66	96.34	100.00
Mass Fraction (%):	3.66	96.34	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.30	1.33
Calculated Porosity (% vol):	0.00	50.79	49.86
Volume of Solids (cm ³):	1.38	36.35	37.74
Volume of Voids (cm ³):	0.00	37.53	37.53
Total Volume (cm ³):	1.38	73.88	75.26
Volumetric Fraction (%):	1.84	98.16	100.00
Initial Moisture Content (% vol):	0.00	36.47	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.25	1.28
Calculated Porosity (% vol):	0.00	52.72	51.79
Volume of Solids (cm ³):	1.38	36.35	37.74
Volume of Voids (cm ³):	0.00	40.54	40.54
Total Volume (cm ³):	1.38	76.89	78.27
Volumetric Fraction (%):	1.77	98.23	100.00
Saturated Moisture Content (% vol):	0.00	50.17	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.25	1.28
Calculated Porosity (% vol):	0.00	52.72	51.79
Volume of Solids (cm ³):	1.38	36.35	37.74
Volume of Voids (cm ³):	0.00	40.54	40.54
Total Volume (cm ³):	1.38	76.89	78.27
Volumetric Fraction (%):	1.77	98.23	100.00
Residual Moisture Content (% vol):	0.00	0.63	---
Ksat (cm/sec):	NM	3.7E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)
Material Type: Growth Media
Depth: NA

Dry wt. of sample (g): 333.97
Tare wt., ring (g): 141.30
Tare wt., screen & clamp (g): 25.84
Initial sample volume (cm³): 225.05
Initial dry bulk density (g/cm³): 1.48
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 44.00

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	10:50	595.53	0	41.95
	20-Sep-19	9:00	595.10	18.0	41.76
	27-Sep-19	9:30	593.12	58.0	40.88
	10-Oct-19	13:00	581.35	128.0	35.65
<i>Pressure plate:</i>	18-Oct-19	15:00	570.29	337	30.74

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	18.0	---	---	---	---
	58.0	---	---	---	---
	128.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-01 (Firm) (1480 kg/m³)

Initial sample bulk density (g/cm³): 1.48

Fraction of test sample used (<2.00mm fraction) (%): 94.89

Dry weight* of dew point potentiometer sample (g): 162.42

Tare weight, jar (g): 114.82

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	25-Sep-19	10:07	170.50	1632	23.90
	23-Sep-19	9:22	167.79	9790	15.89
	18-Sep-19	9:13	165.76	57211	9.88
	16-Sep-19	14:00	164.93	240163	7.43

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	1632	---	---	---	---
	9790	---	---	---	---
	57211	---	---	---	---
	240163	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '-' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-01 (Firm) (1480 kg/m³)

Initial sample bulk density (g/cm³): 1.48

Fraction of test sample used (<2.00mm fraction) (%): 94.89

Dry weight* of relative humidity box sample (g): 69.55

Tare weight (g): 31.75

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	19-Sep-19	7:30	70.99	848426	5.38

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

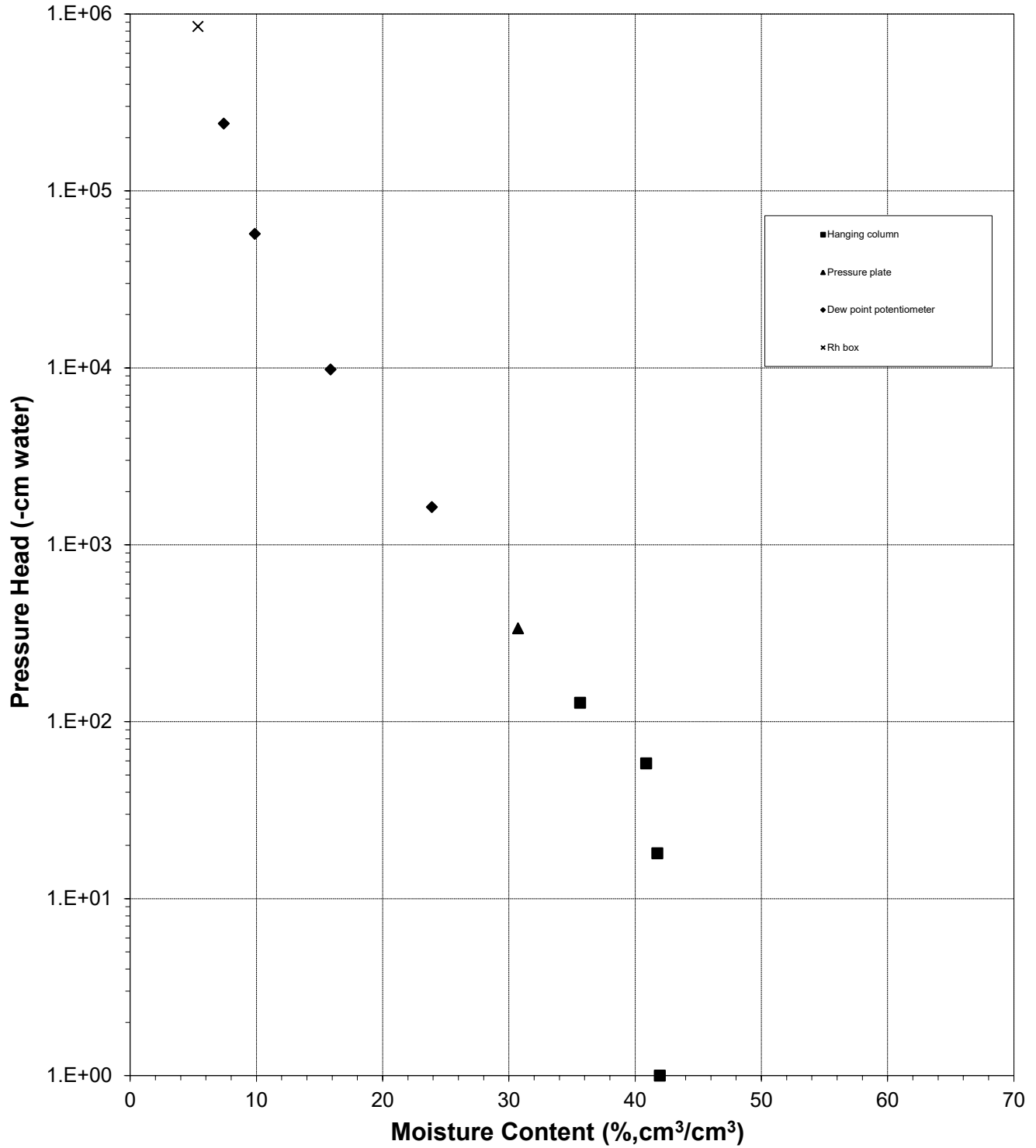
Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



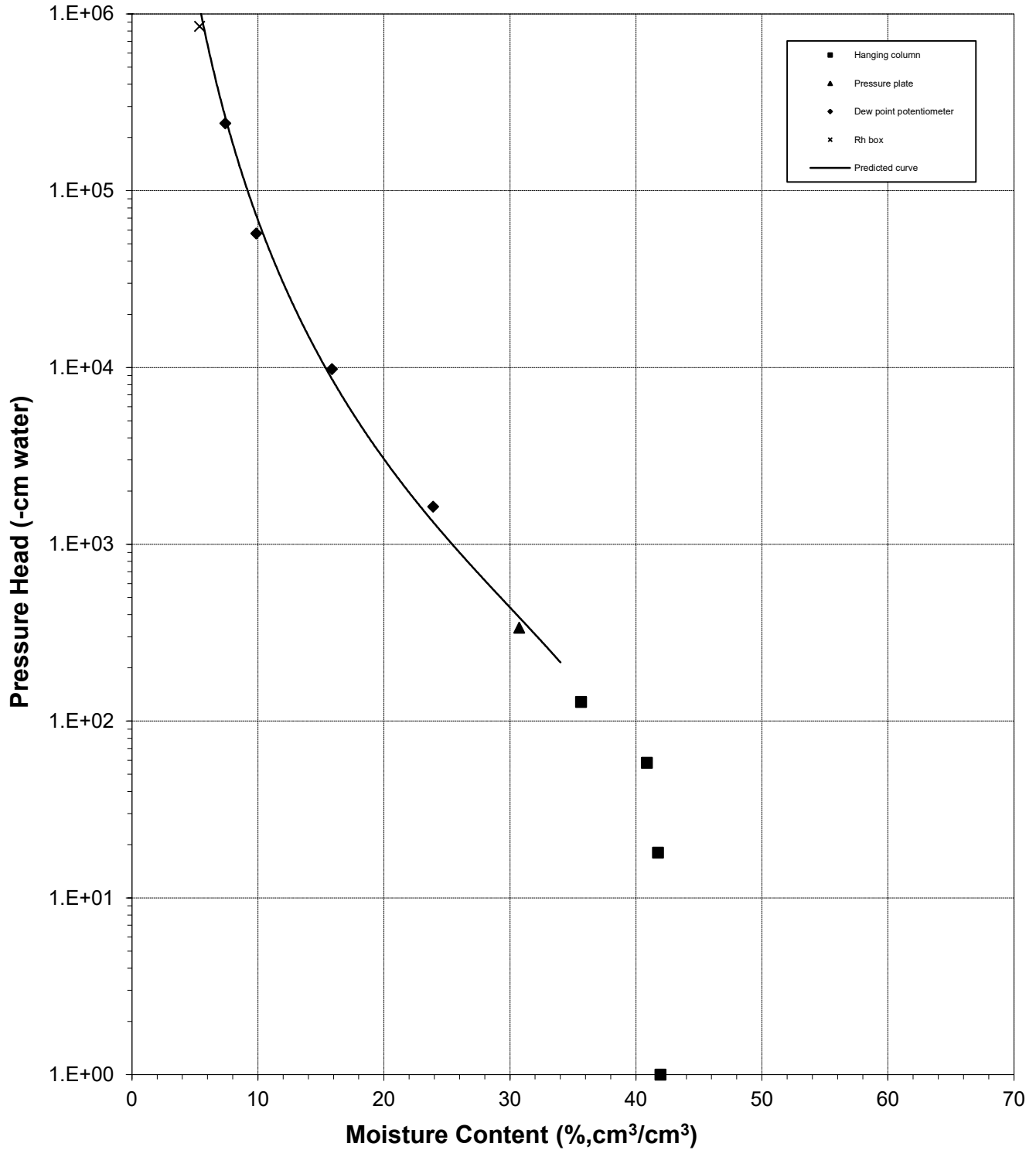
Water Retention Data Points
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Predicted Calibration Curve and Data Points

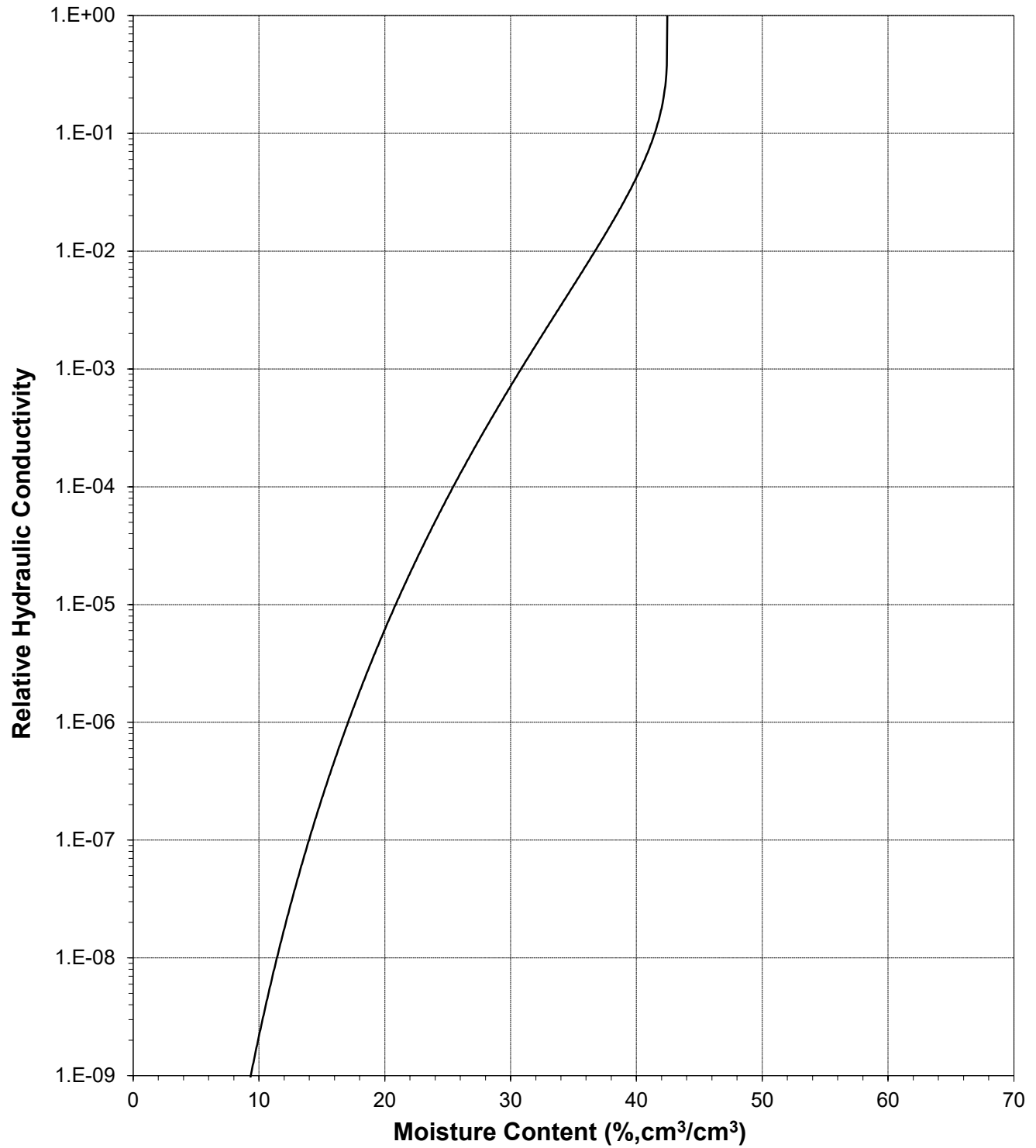
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

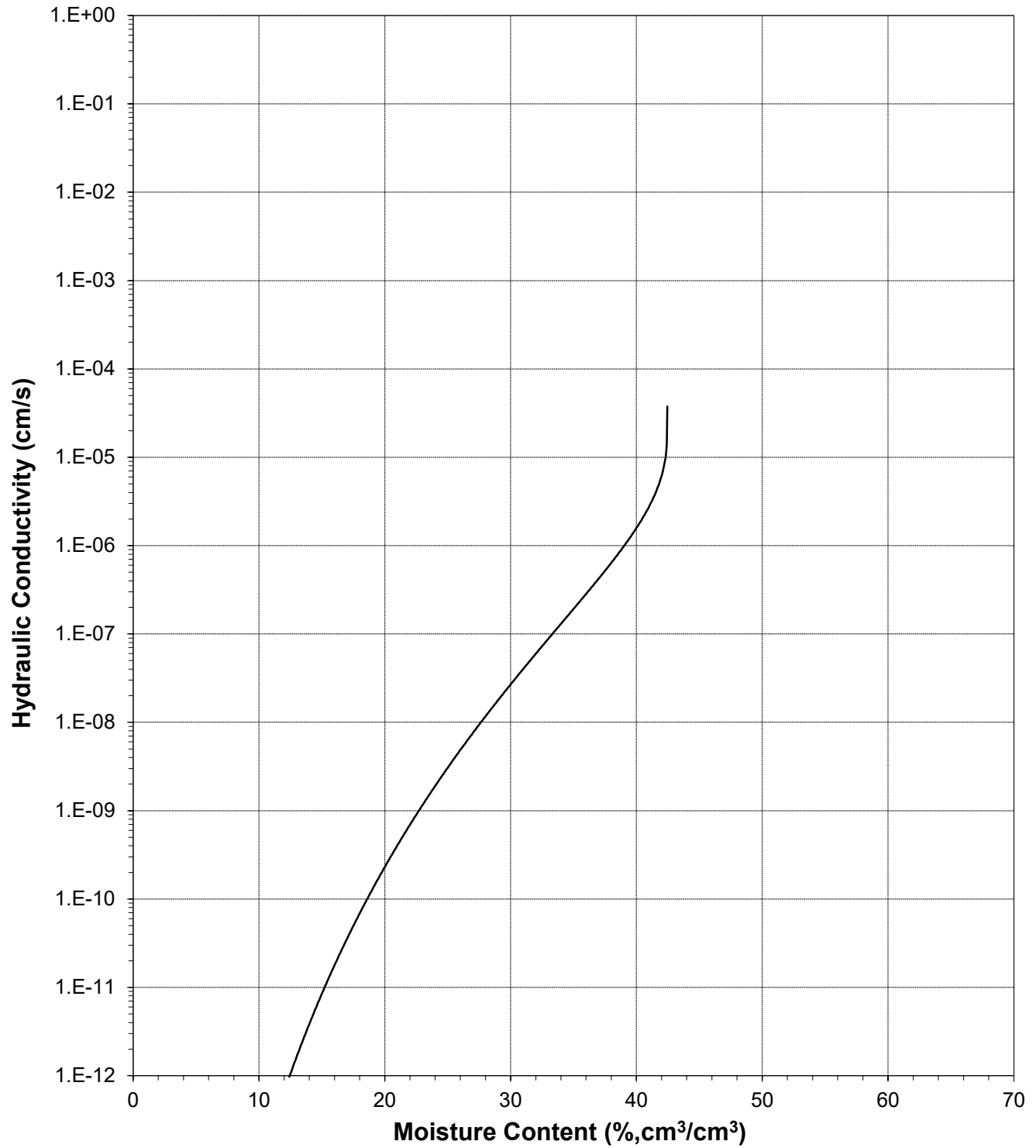
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

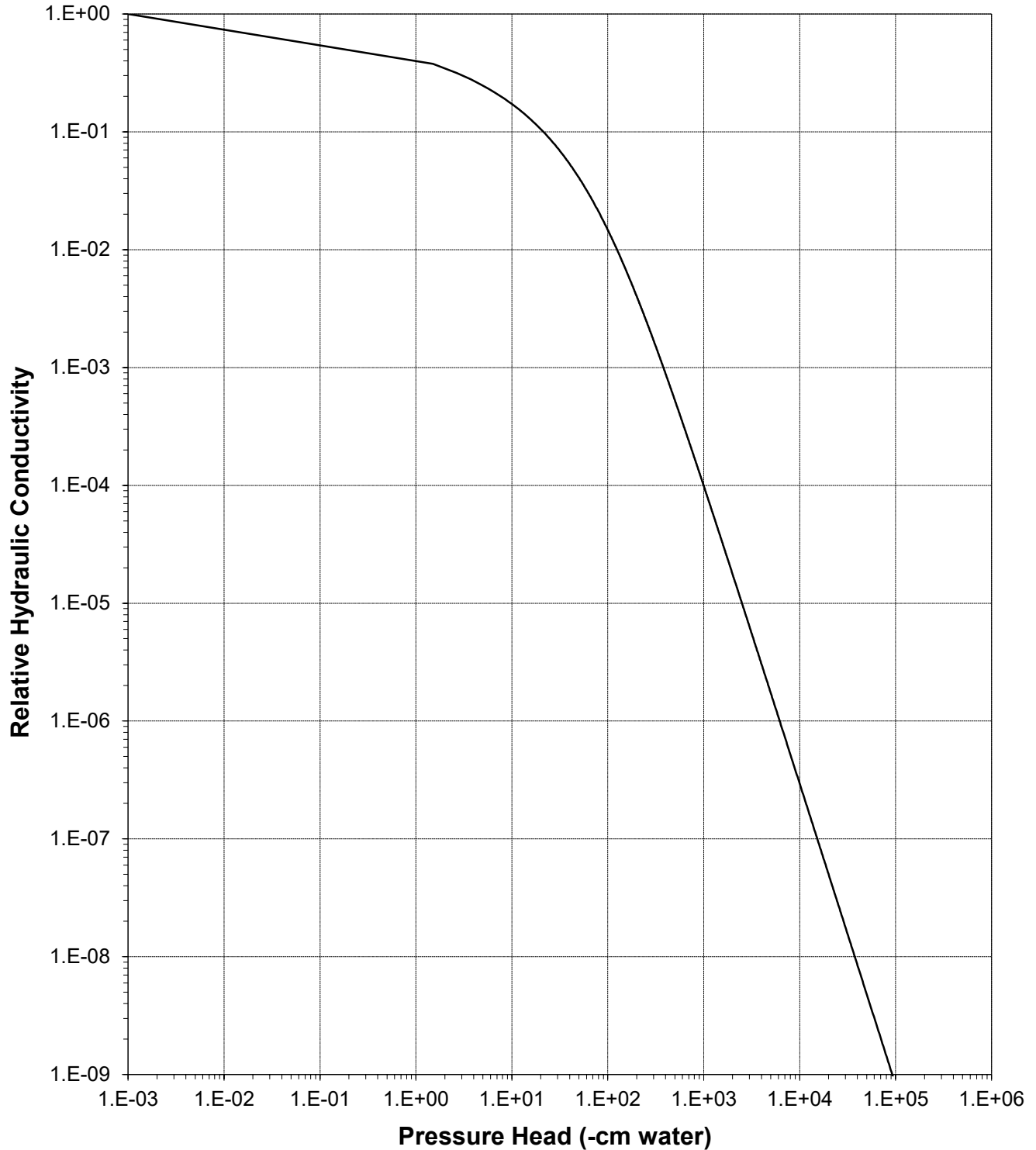
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Plot of Relative Hydraulic Conductivity vs Pressure Head

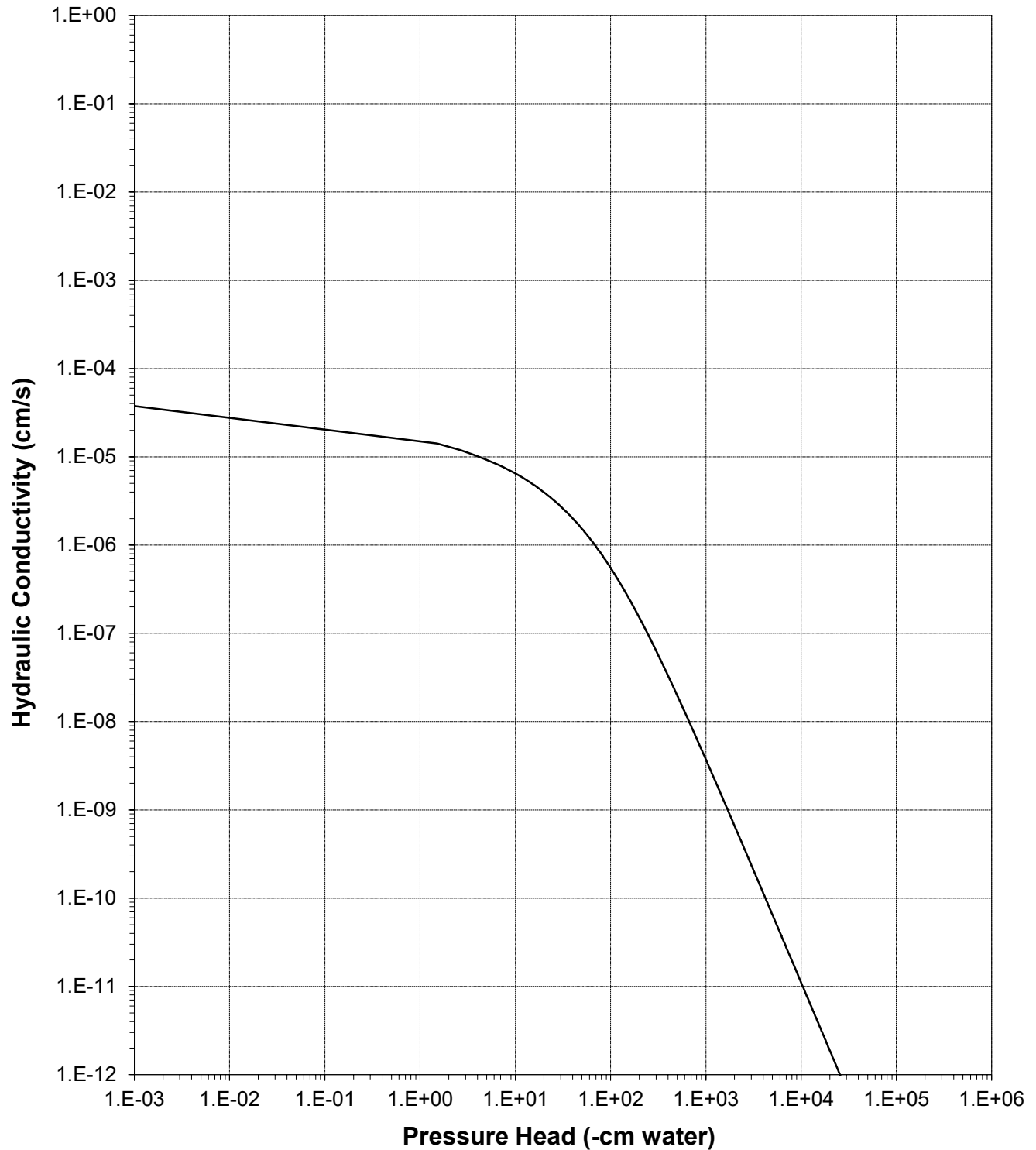
Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: Growth 19-01 (Firm) (1480 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-01 (Firm) (1480 kg/m³)
 Material Type: Growth Media
 Depth: NA

Split (3/4", 3/8", #4): #4

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	2.12	97.88	100.00
Mass Fraction (%):	2.12	97.88	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.48	1.50
Calculated Porosity (% vol):	0.00	44.00	43.47
Volume of Solids (cm ³):	0.80	36.94	37.74
Volume of Voids (cm ³):	0.00	29.02	29.02
Total Volume (cm ³):	0.80	65.96	66.76
Volumetric Fraction (%):	1.20	98.80	100.00
Initial Moisture Content (% vol):	0.00	26.81	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.48	1.50
Calculated Porosity (% vol):	0.00	44.00	43.47
Volume of Solids (cm ³):	0.80	36.94	37.74
Volume of Voids (cm ³):	0.00	29.02	29.02
Total Volume (cm ³):	0.80	65.96	66.76
Volumetric Fraction (%):	1.20	98.80	100.00
Saturated Moisture Content (% vol):	0.00	42.46	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.48	1.50
Calculated Porosity (% vol):	0.00	44.00	43.47
Volume of Solids (cm ³):	0.80	36.94	37.74
Volume of Voids (cm ³):	0.00	29.02	29.02
Total Volume (cm ³):	0.80	65.96	66.76
Volumetric Fraction (%):	1.20	98.80	100.00
Residual Moisture Content (% vol):	0.00	0.00	---
Ksat (cm/sec):	NM	3.8E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)
Material Type: Growth Media
Depth: NA

Dry wt. of sample (g): 332.78
Tare wt., ring (g): 139.98
Tare wt., screen & clamp (g): 29.79
Initial sample volume (cm³): 223.49
Initial dry bulk density (g/cm³): 1.49
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 43.81

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	12:05	596.51	0	42.04
	20-Sep-19	9:00	596.49	10.0	42.03
	27-Sep-19	9:30	595.96	30.0	41.80
	10-Oct-19	13:10	584.91	95.0	36.85
<i>Pressure plate:</i>	18-Oct-19	15:00	563.63	337	27.33

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	10.0	---	---	---	---
	30.0	---	---	---	---
	95.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)

Initial sample bulk density (g/cm³): 1.49

Fraction of test sample used (<2.00mm fraction) (%): 55.45

Dry weight* of dew point potentiometer sample (g): 174.91

Tare weight, jar (g): 124.08

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	24-Sep-19	8:15	181.33	2651	10.43
	20-Sep-19	7:44	179.34	8872	7.20
	17-Sep-19	8:30	177.65	52316	4.45
	13-Sep-19	12:48	176.95	247811	3.31

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	2651	---	---	---	---
	8872	---	---	---	---
	52316	---	---	---	---
	247811	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '-' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)

Initial sample bulk density (g/cm³): 1.49

Fraction of test sample used (<2.00mm fraction) (%): 55.45

Dry weight* of relative humidity box sample (g): 65.73

Tare weight (g): 40.79

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	19-Sep-19	7:30	66.46	848426	2.41

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

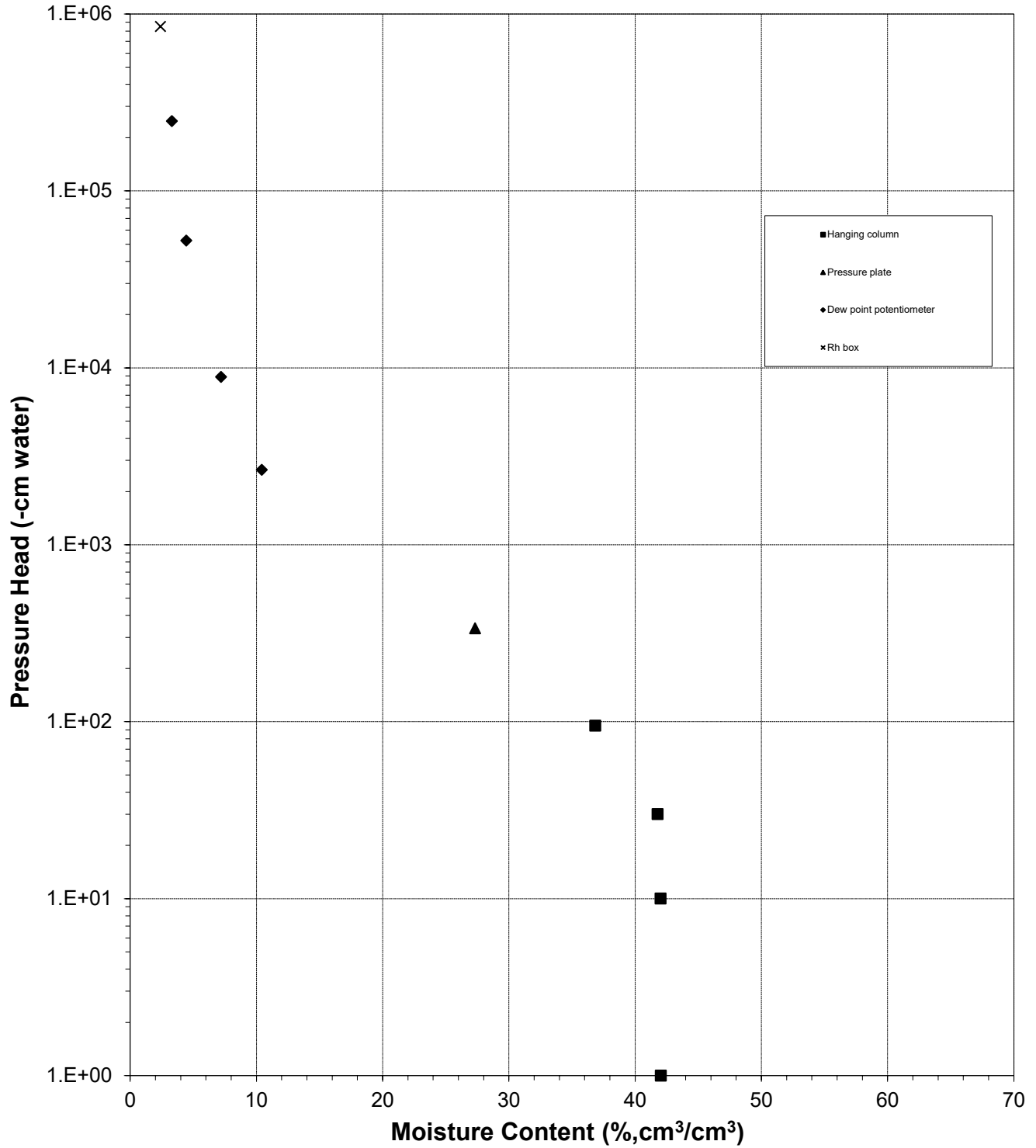
Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



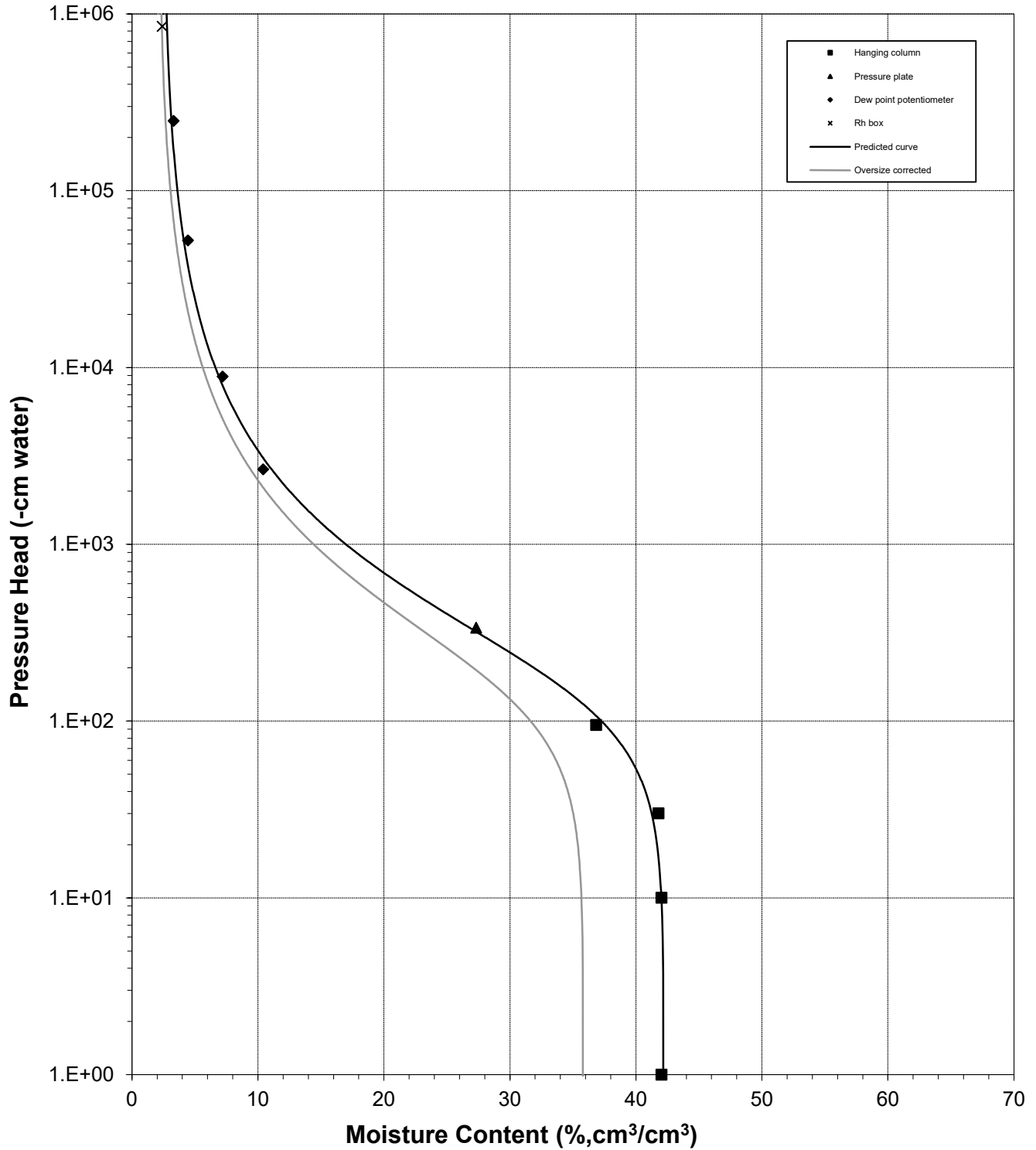
Water Retention Data Points
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)





Predicted Calibration Curve and Data Points

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)

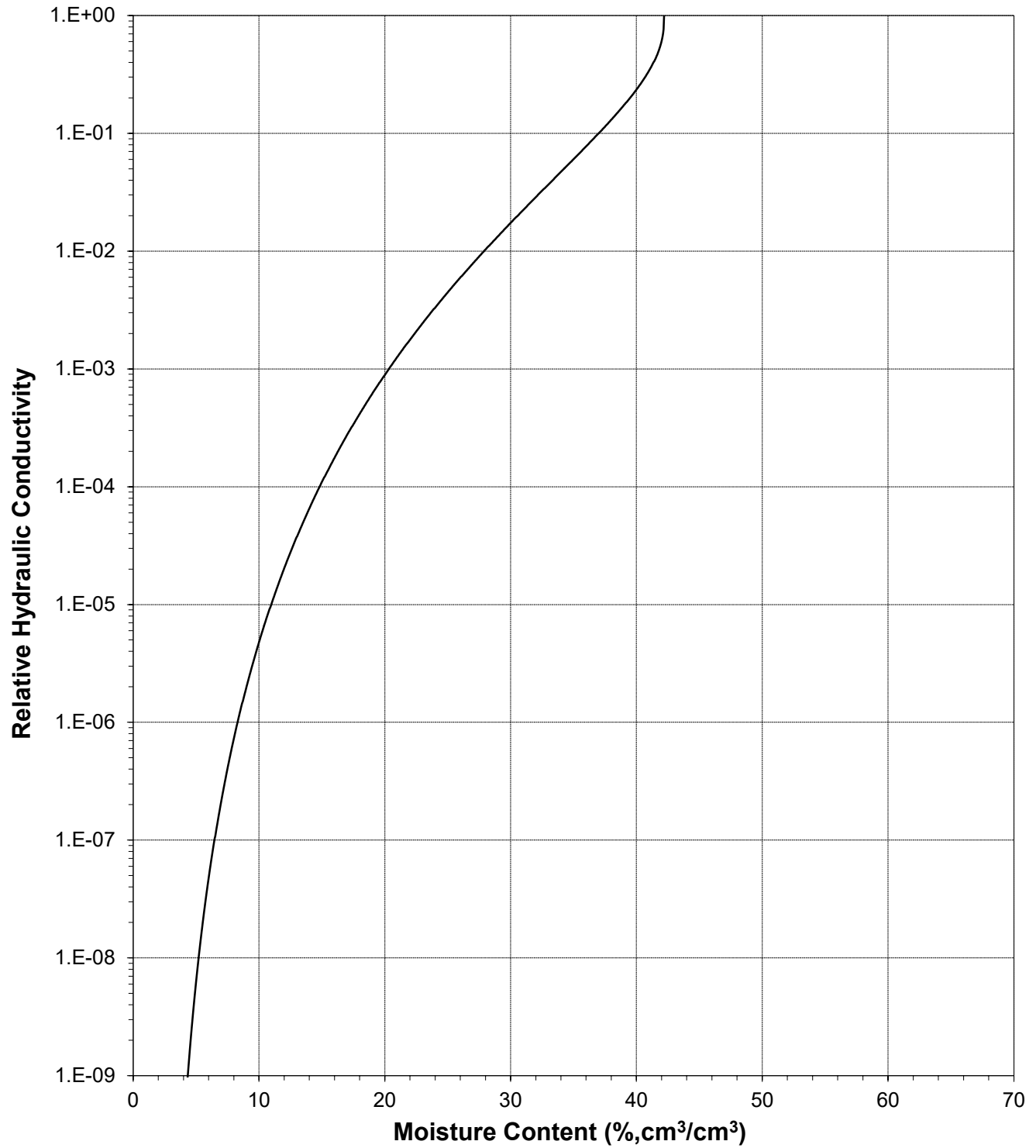




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Moisture Content

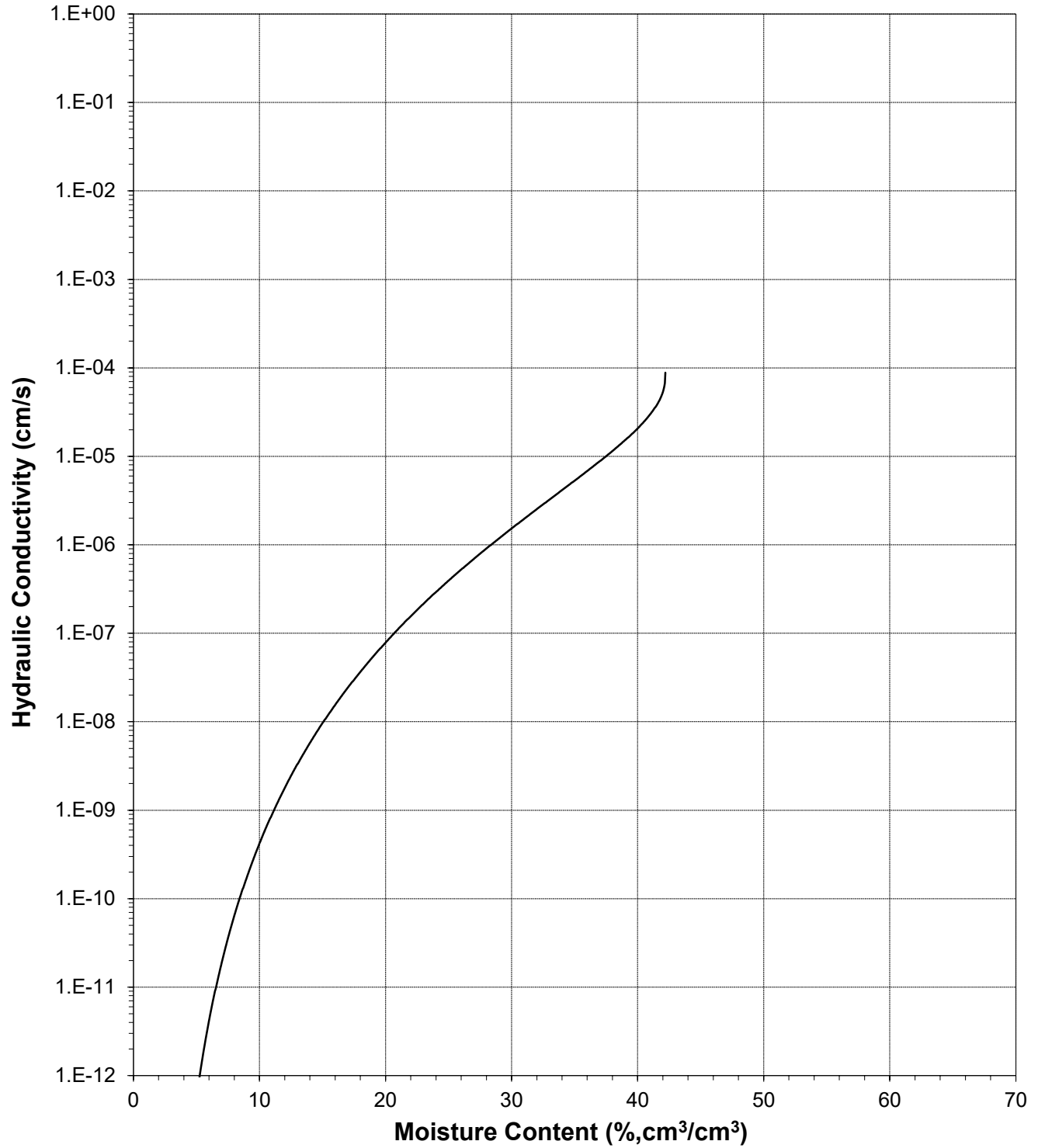
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)

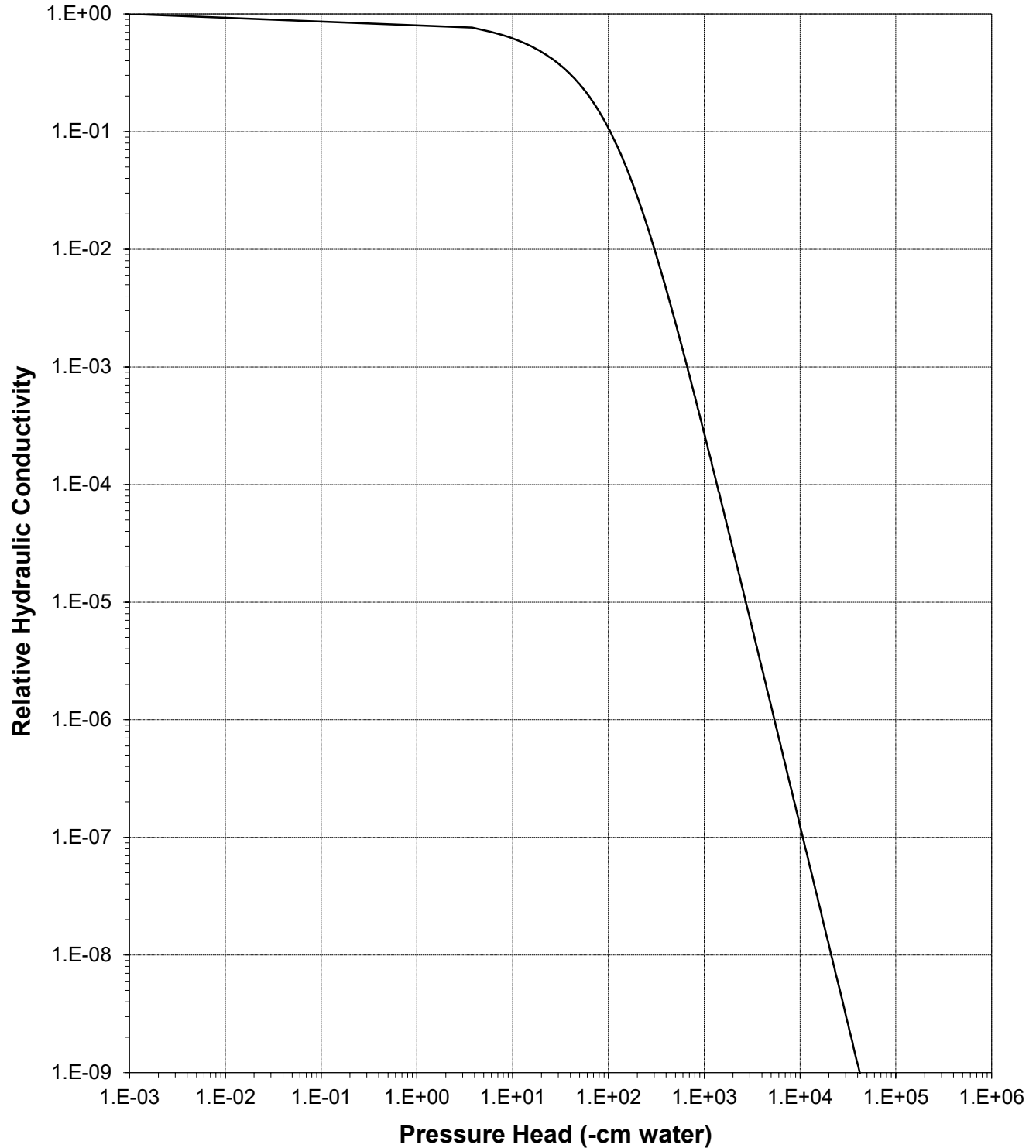




Daniel B. Stephens & Associates, Inc.

Plot of Relative Hydraulic Conductivity vs Pressure Head

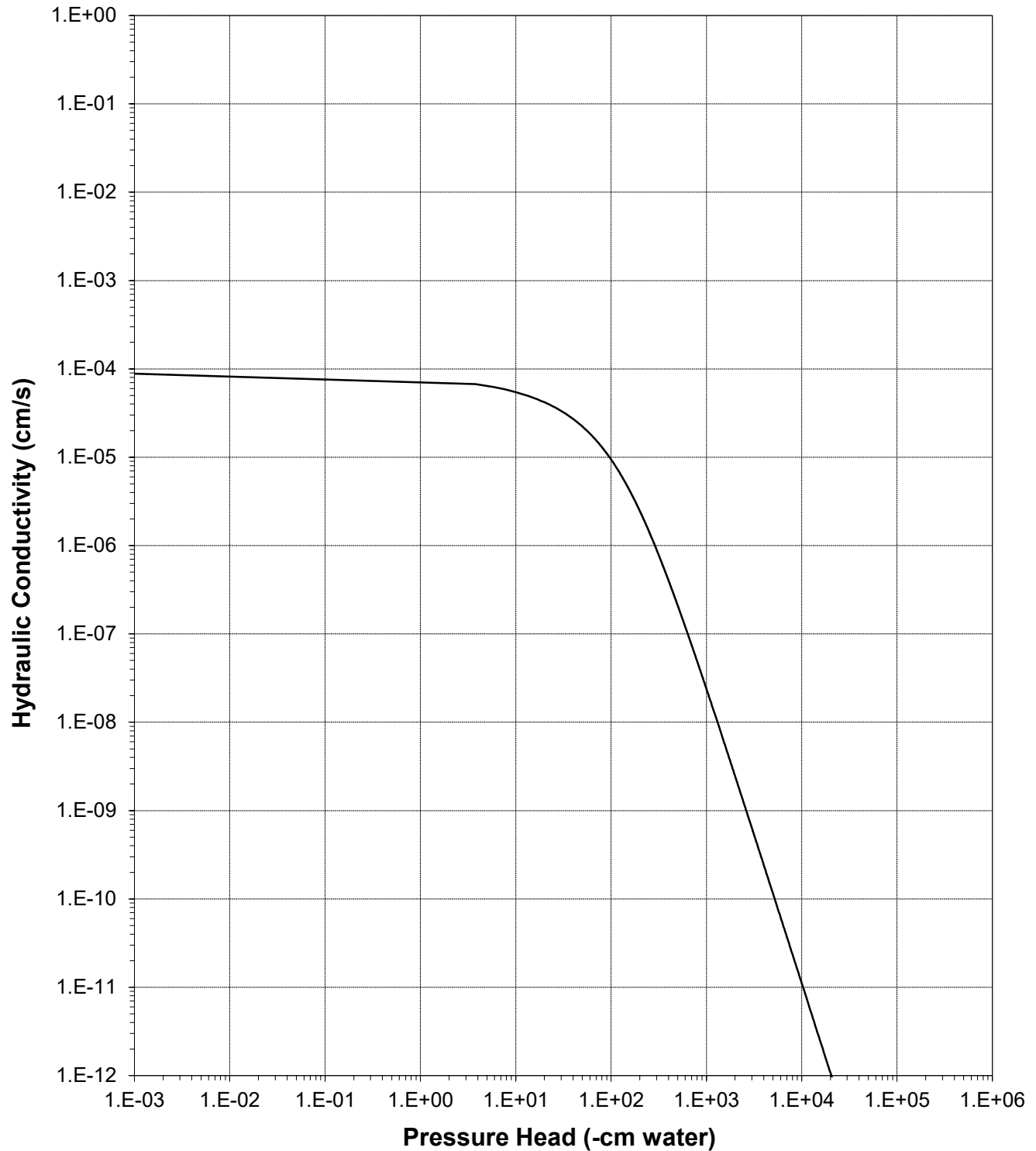
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: Growth 19-02 (Firm) (1490 kg/m³)





Daniel B. Stephens & Associates, Inc.

Oversize Correction Data Sheet

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02 (Firm) (1490 kg/m³)
Material Type: Growth Media
Depth: NA

Split (3/4", 3/8", #4): #4

	<u>Coarse Fraction*</u>	<u>Fines Fraction**</u>	<u>Composite</u>
Subsample Mass (g):	24.04	75.96	100.00
Mass Fraction (%):	24.04	75.96	100.00
<u>Initial Sample θ_i</u>			
Bulk Density (g/cm ³):	2.65	1.49	1.66
Calculated Porosity (% vol):	0.00	43.81	37.20
Volume of Solids (cm ³):	9.07	28.66	37.74
Volume of Voids (cm ³):	0.00	22.35	22.35
Total Volume (cm ³):	9.07	51.01	60.09
Volumetric Fraction (%):	15.10	84.90	100.00
Initial Moisture Content (% vol):	0.00	23.06	19.58
<u>Saturated Sample θ_s</u>			
Bulk Density (g/cm ³):	2.65	1.49	1.66
Calculated Porosity (% vol):	0.00	43.81	37.20
Volume of Solids (cm ³):	9.07	28.66	37.74
Volume of Voids (cm ³):	0.00	22.35	22.35
Total Volume (cm ³):	9.07	51.01	60.09
Volumetric Fraction (%):	15.10	84.90	100.00
Saturated Moisture Content (% vol):	0.00	42.20	35.83
<u>Residual Sample θ_r</u>			
Bulk Density (g/cm ³):	2.65	1.49	1.66
Calculated Porosity (% vol):	0.00	43.81	37.20
Volume of Solids (cm ³):	9.07	28.66	37.74
Volume of Voids (cm ³):	0.00	22.35	22.35
Total Volume (cm ³):	9.07	51.01	60.09
Volumetric Fraction (%):	15.10	84.90	100.00
Residual Moisture Content (% vol):	0.00	2.42	2.05
Ksat (cm/sec):	NM	8.8E-05	6.7E-05

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)
Material Type: Growth Media
Depth: NA

Dry wt. of sample (g): 312.27
Tare wt., ring (g): 139.35
Tare wt., screen & clamp (g): 26.55
Initial sample volume (cm³): 223.89
Initial dry bulk density (g/cm³): 1.39
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 47.37

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)	
<i>Hanging column:</i>	13-Sep-19	12:15	580.63	0	45.07	##
	20-Sep-19	9:00	580.27	10.0	44.91	##
	27-Sep-19	9:30	579.35	30.0	44.51	##
	10-Oct-19	13:10	570.01	95.0	40.40	##
<i>Pressure plate:</i>	18-Oct-19	15:00	552.62	337	32.75	##

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	227.33	+1.54%	1.37	48.16
	10.0	227.33	+1.54%	1.37	48.16
	30.0	227.33	+1.54%	1.37	48.16
	95.0	227.33	+1.54%	1.37	48.16
<i>Pressure plate:</i>	337	227.33	+1.54%	1.37	48.16

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data
Dew Point Potentiometer / Relative Humidity Box
 (Soil-Water Characteristic Curve)

Sample Number: Growth 19-03 (Firm) (1390 kg/m³)

Initial sample bulk density (g/cm³): 1.39

Fraction of test sample used (<2.00mm fraction) (%): 93.69

Dry weight of dew point potentiometer sample (g):* 159.17

Tare weight, jar (g): 111.79

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
<i>Dew point potentiometer:</i>	24-Sep-19	8:26	167.02	1836	21.32	##
	20-Sep-19	8:03	164.42	12849	14.26	##
	17-Sep-19	8:35	162.81	55069	9.89	##
	13-Sep-19	13:01	161.72	336432	6.93	##

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
<i>Dew point potentiometer:</i>	1836	227.33	+1.54%	1.37	48.16
	12849	227.33	+1.54%	1.37	48.16
	55069	227.33	+1.54%	1.37	48.16
	336432	227.33	+1.54%	1.37	48.16

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-03 (Firm) (1390 kg/m³)

Initial sample bulk density (g/cm³): 1.39

Fraction of test sample used (<2.00mm fraction) (%): 93.69

Dry weight* of relative humidity box sample (g): 60.83

Tare weight (g): 38.34

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)	
Relative humidity box:	19-Sep-19	7:30	61.79	848426	5.46	††

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	227.33	+1.54%	1.37	48.16

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '----' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

†† Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

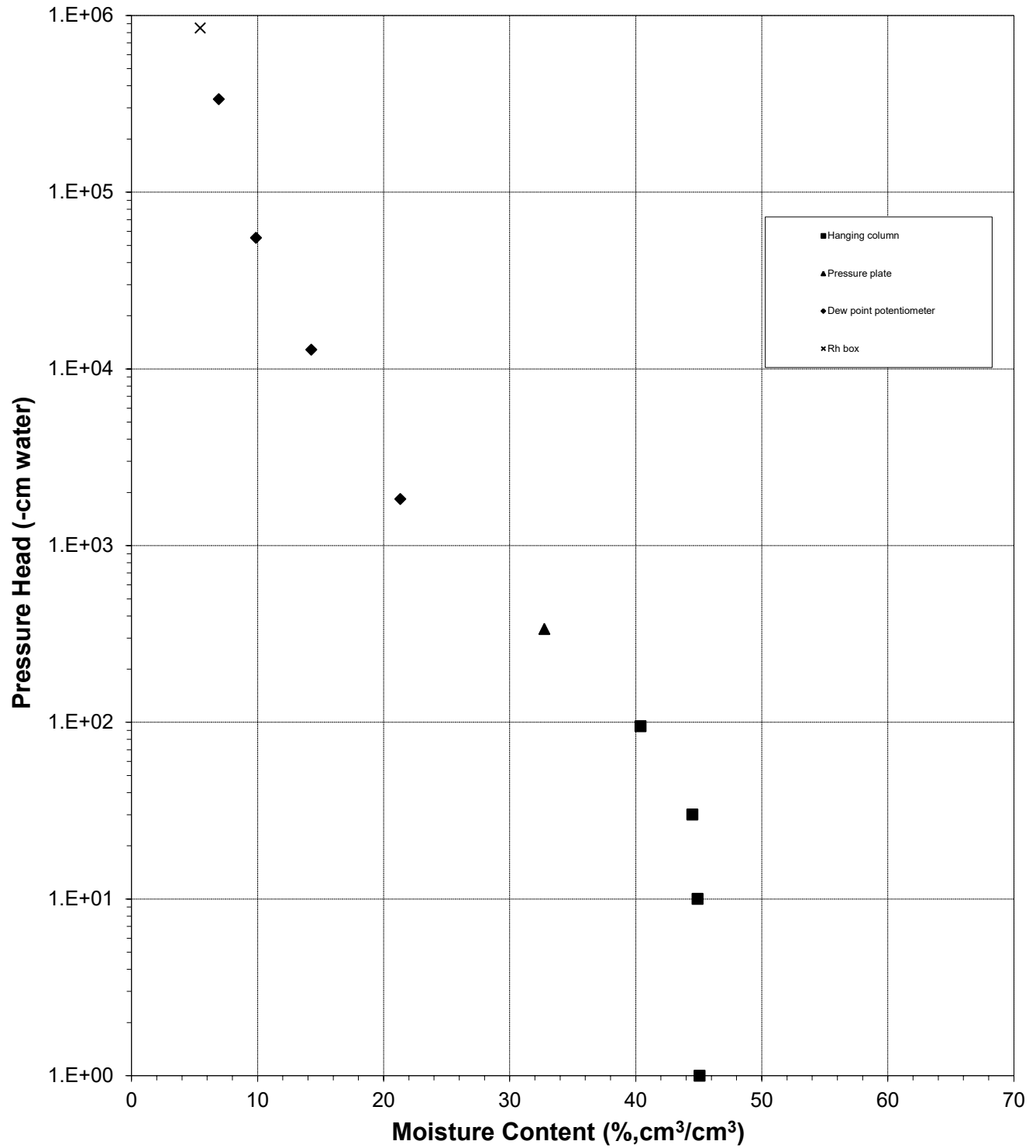
Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



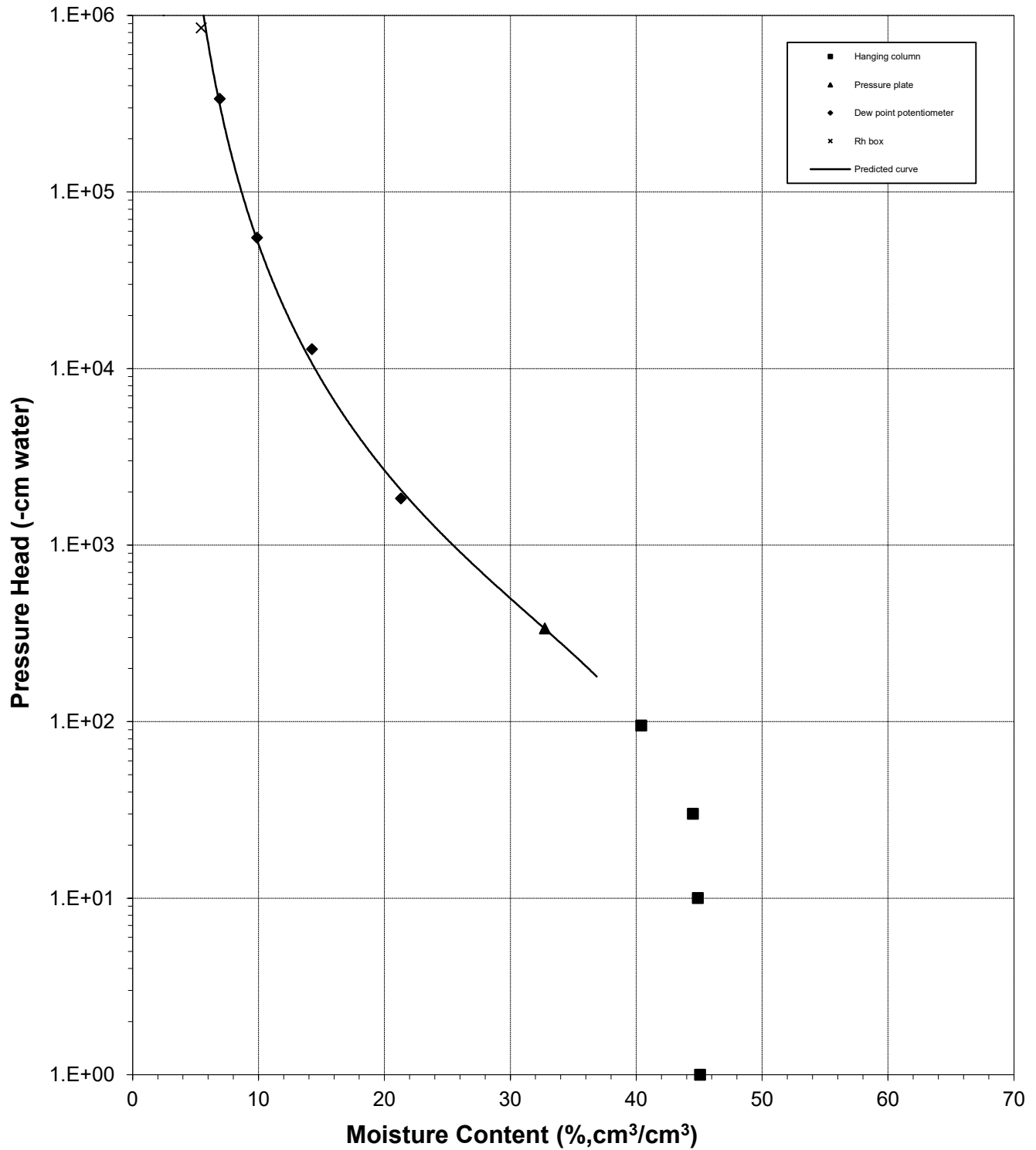
Water Retention Data Points
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)





Predicted Calibration Curve and Data Points

Sample Number: Growth 19-03 (Firm) (1390 kg/m³)

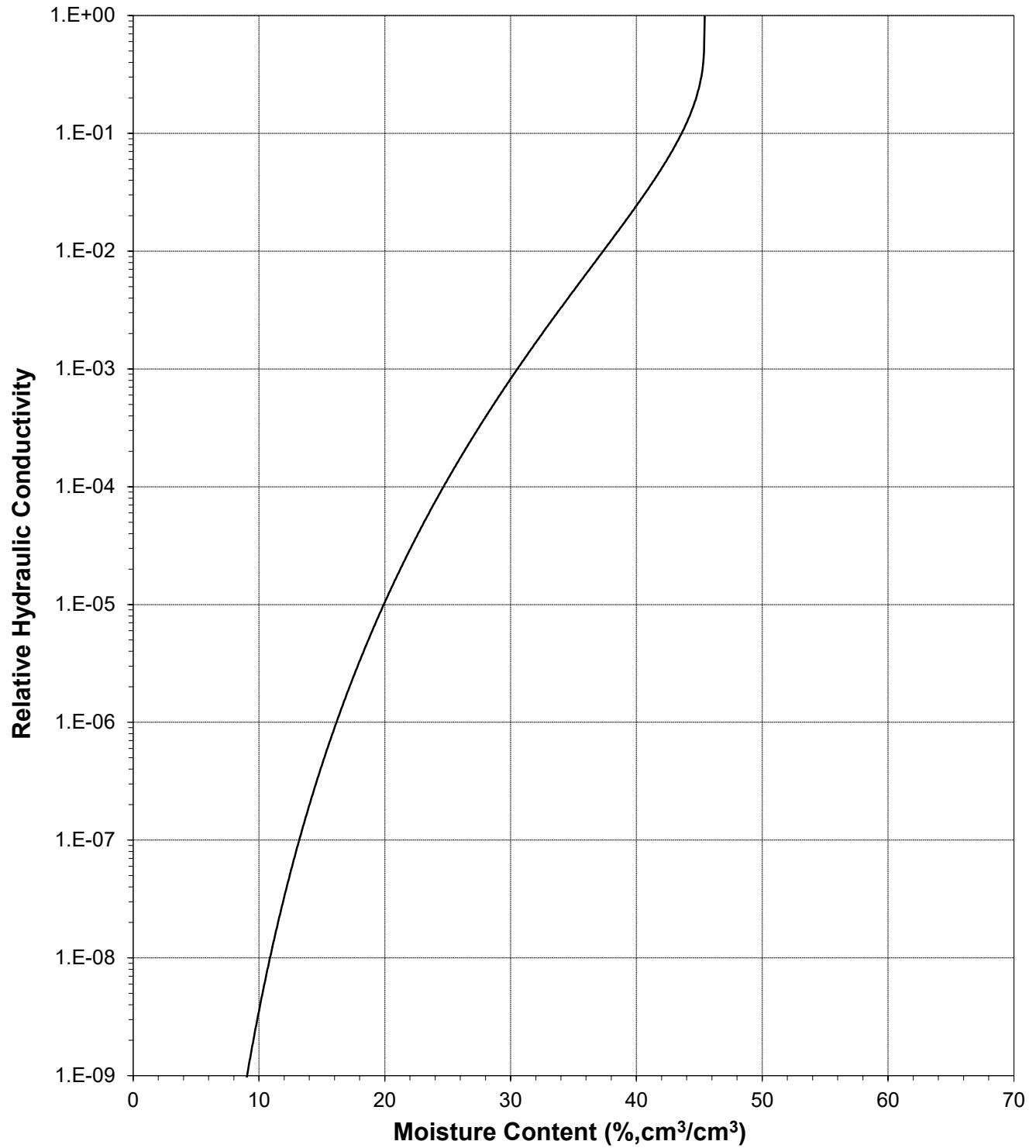




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Plot of Relative Hydraulic Conductivity vs Moisture Content

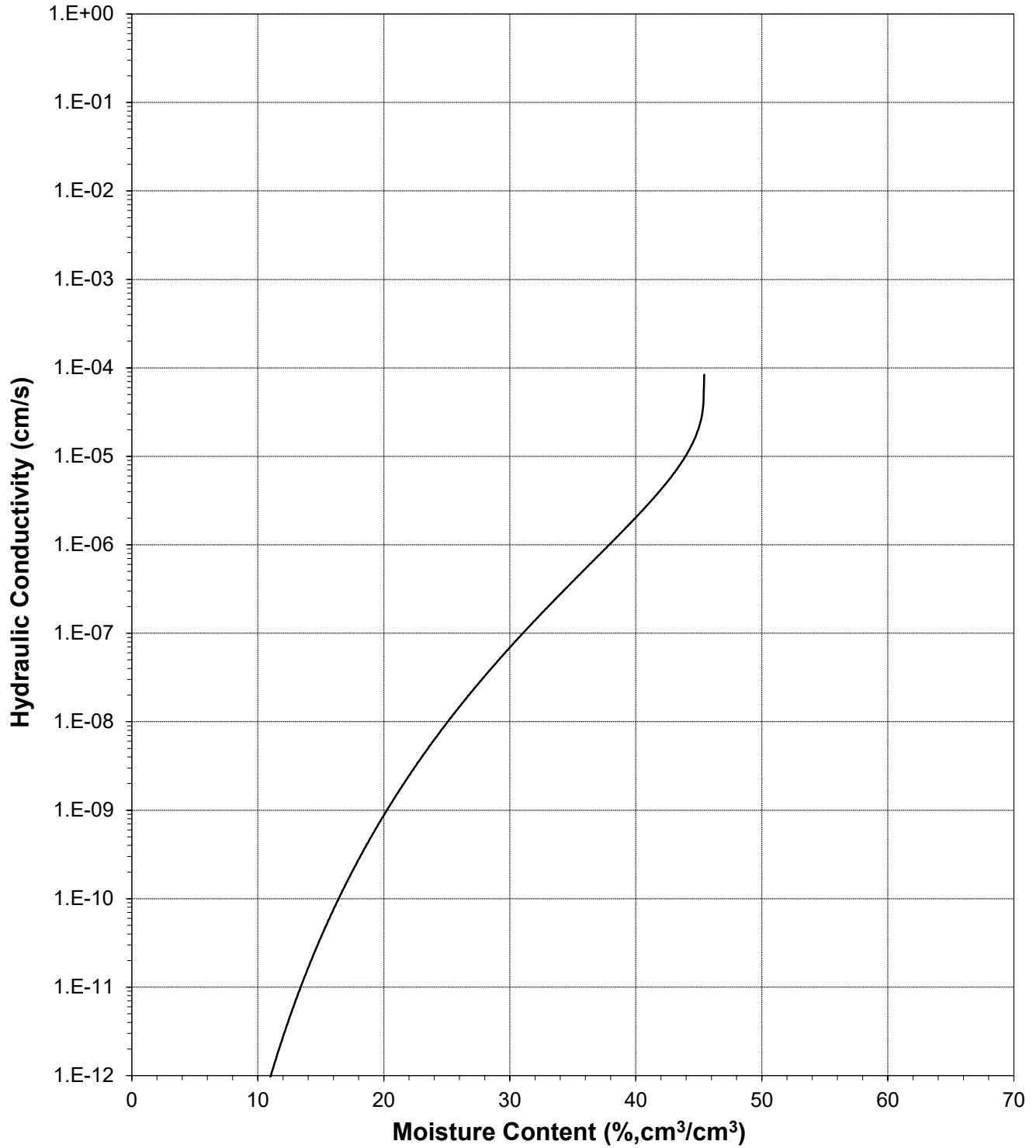
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

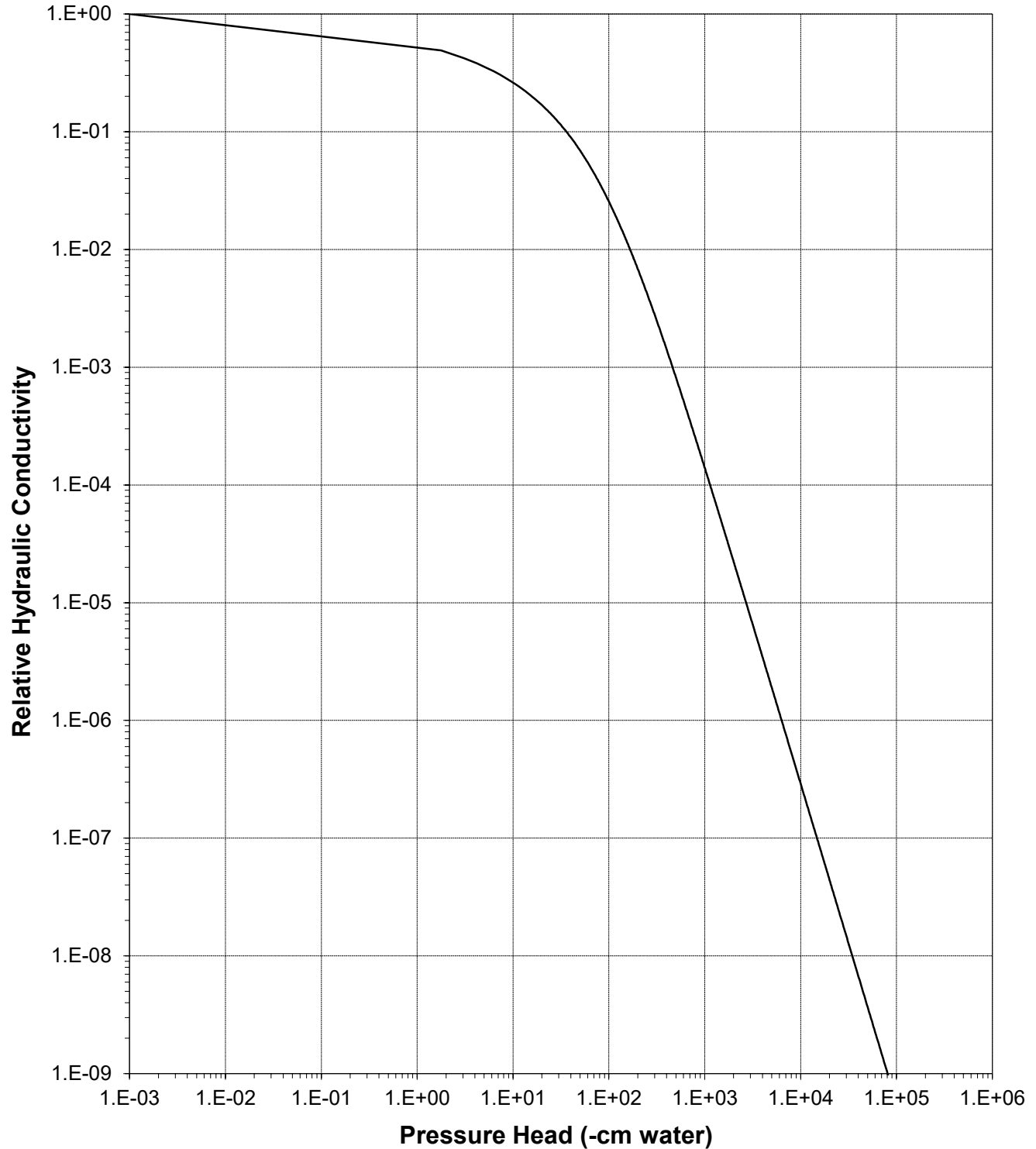
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)





Plot of Relative Hydraulic Conductivity vs Pressure Head

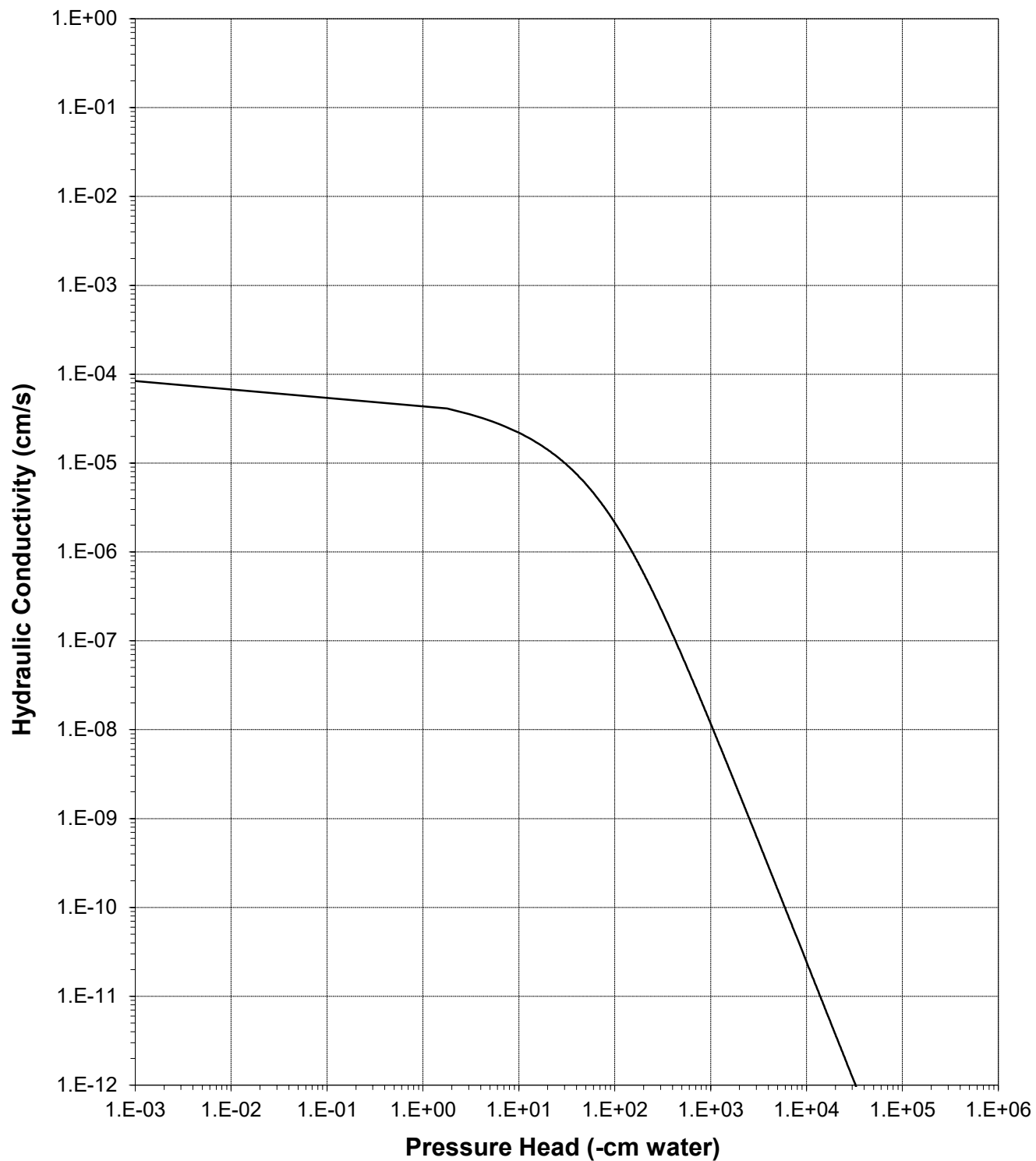
Sample Number: Growth 19-03 (Firm) (1390 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: Growth 19-03 (Firm) (1390 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-03 (Firm) (1390 kg/m³)
 Material Type: Growth Media
 Depth: NA

Split (3/4", 3/8", #4): #4

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	2.75	97.25	100.00
Mass Fraction (%):	2.75	97.25	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.39	1.41
Calculated Porosity (% vol):	0.00	47.37	46.67
Volume of Solids (cm ³):	1.04	36.70	37.74
Volume of Voids (cm ³):	0.00	33.03	33.03
Total Volume (cm ³):	1.04	69.73	70.76
Volumetric Fraction (%):	1.47	98.53	100.00
Initial Moisture Content (% vol):	0.00	22.09	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.37	1.39
Calculated Porosity (% vol):	0.00	48.16	47.47
Volume of Solids (cm ³):	1.04	36.70	37.74
Volume of Voids (cm ³):	0.00	34.10	34.10
Total Volume (cm ³):	1.04	70.80	71.84
Volumetric Fraction (%):	1.44	98.56	100.00
Saturated Moisture Content (% vol):	0.00	45.42	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.37	1.39
Calculated Porosity (% vol):	0.00	48.16	47.47
Volume of Solids (cm ³):	1.04	36.70	37.74
Volume of Voids (cm ³):	0.00	34.10	34.10
Total Volume (cm ³):	1.04	70.80	71.84
Volumetric Fraction (%):	1.44	98.56	100.00
Residual Moisture Content (% vol):	0.00	2.42	---
Ksat (cm/sec):	NM	8.4E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Moisture Retention Data
Hanging Column / Pressure Plate
 (Soil-Water Characteristic Curve)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)
Material Type: Growth Media
Depth: NA

Dry wt. of sample (g): 314.60
Tare wt., ring (g): 139.98
Tare wt., screen & clamp (g): 27.78
Initial sample volume (cm³): 223.27
Initial dry bulk density (g/cm³): 1.41
Assumed particle density (g/cm³): 2.65
Initial calculated total porosity (%): 46.83

	Date	Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content [†] (% vol)
<i>Hanging column:</i>	13-Sep-19	10:45	582.80	0	44.99
	20-Sep-19	9:00	581.43	18.0	44.37
	27-Sep-19	9:30	580.38	58.0	43.90
	10-Oct-19	13:00	578.75	128.0	43.17
<i>Pressure plate:</i>	18-Oct-19	15:00	552.21	337	31.28

Volume Adjusted Data¹

	Matric Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calculated Porosity (%)
<i>Hanging column:</i>	0.0	---	---	---	---
	18.0	---	---	---	---
	58.0	---	---	---	---
	128.0	---	---	---	---
<i>Pressure plate:</i>	337	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent each of the volume change measurements obtained after saturated hydraulic conductivity testing and throughout hanging column/pressure plate testing. "---" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Assumed density of water is 1.0 g/cm³

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

Technician Notes:

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-04 (Firm) (1410 kg/m³)

Initial sample bulk density (g/cm³): 1.41

Fraction of test sample used (<2.00mm fraction) (%): 99.93

Dry weight* of dew point potentiometer sample (g): 159.99

Tare weight, jar (g): 116.44

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Dew point potentiometer:	23-Sep-19	9:05	165.75	3875	18.62
	19-Sep-19	7:45	164.32	11932	14.00
	17-Sep-19	8:25	163.38	42730	10.96
	13-Sep-19	12:47	162.52	193456	8.18

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Dew point potentiometer:	3875	---	---	---	---
	11932	---	---	---	---
	42730	---	---	---	---
	193456	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1).

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Moisture Retention Data

Dew Point Potentiometer / Relative Humidity Box (Soil-Water Characteristic Curve)

Sample Number: Growth 19-04 (Firm) (1410 kg/m³)

Initial sample bulk density (g/cm³): 1.41

Fraction of test sample used (<2.00mm fraction) (%): 99.93

Dry weight* of relative humidity box sample (g): 60.22

Tare weight (g): 36.82

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content [†] (% vol)
Relative humidity box:	19-Sep-19	7:30	61.08	848426	5.22

Volume Adjusted Data¹

	Water Potential (-cm water)	Adjusted Volume (cm ³)	% Volume Change ² (%)	Adjusted Density (g/cm ³)	Adjusted Calc. Porosity (%)
Relative humidity box:	848426	---	---	---	---

Comments:

¹ Applicable if the sample experienced volume changes during testing. 'Volume Adjusted' values represent the volume change measurements obtained after the last hanging column or pressure plate point. "----" indicates no volume changes occurred.

² Represents percent volume change from original sample volume. A '+' denotes measured sample swelling, a '-' denotes measured sample settling, and '---' denotes no volume change occurred.

* Weight including tares

[†] Adjusted for >2.00mm (#10 sieve) material not used in DPP/RH testing. Assumed moisture content of material >2.00mm is zero, and assumed density of water is 1.0 g/cm³.

[‡] Volume adjustments are applicable at this matric potential (see comment #1). Changes in volume, if applicable, are estimated based on obtainable measurements of changes in sample length and diameter.

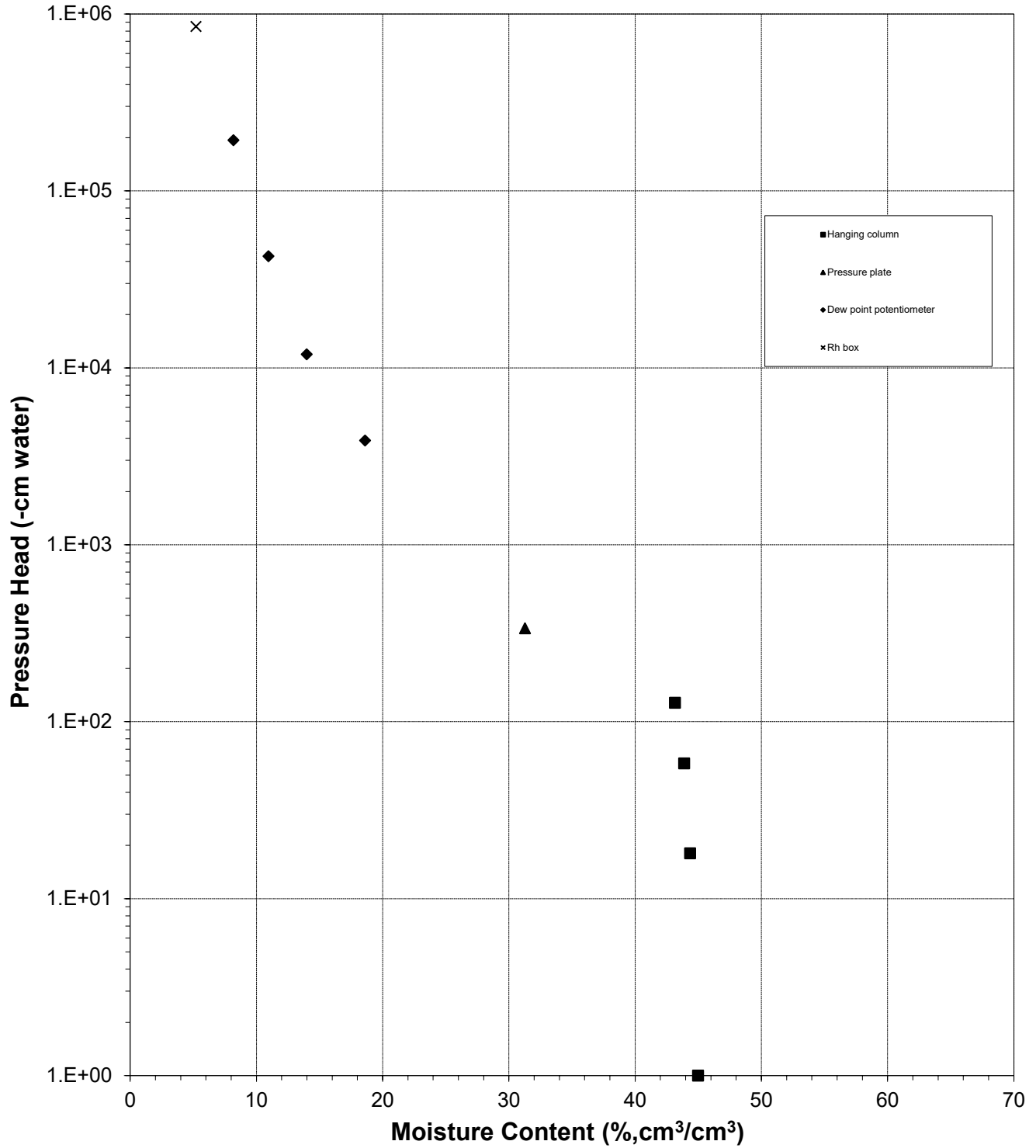
Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



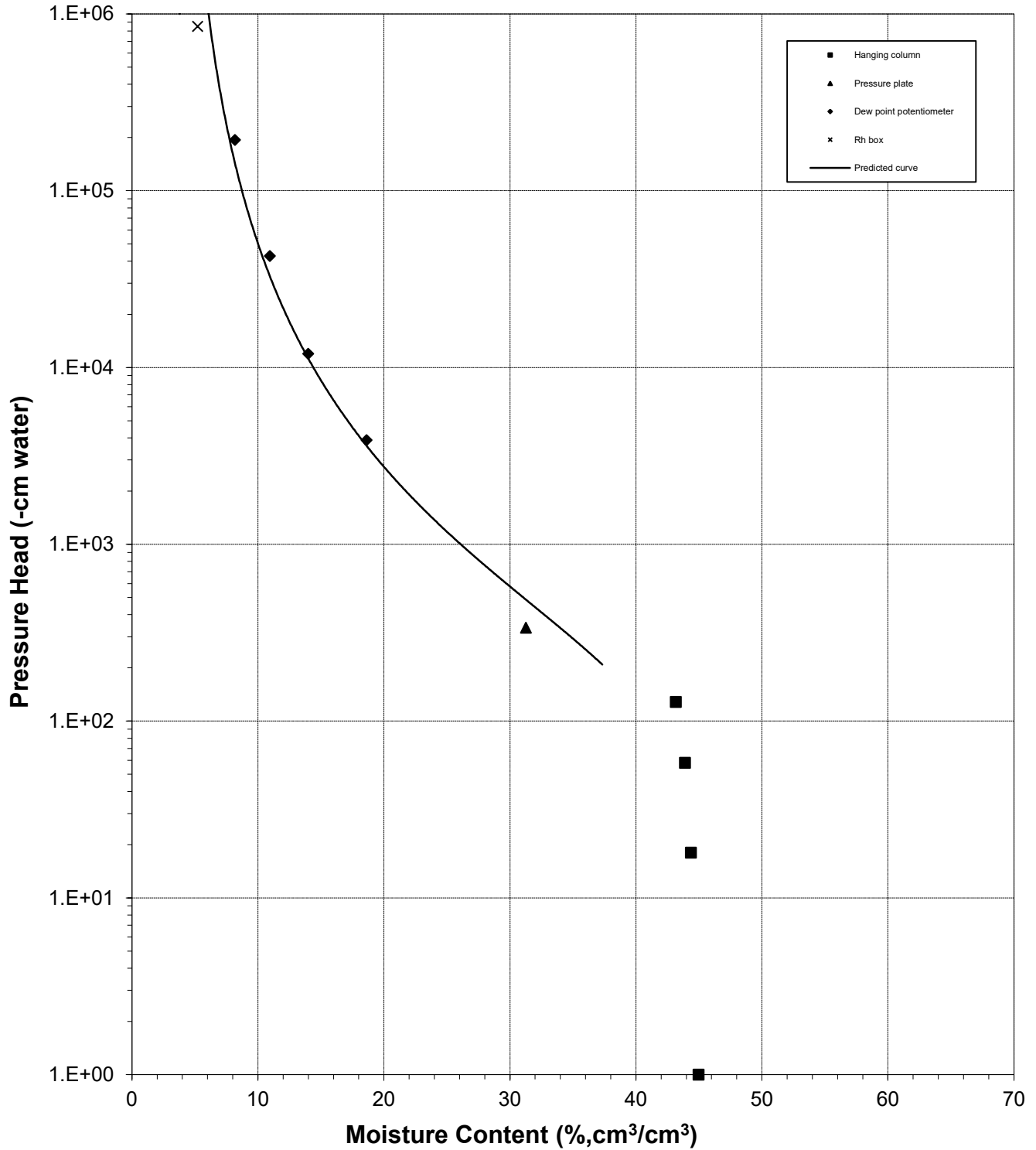
Water Retention Data Points
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)





Predicted Calibration Curve and Data Points

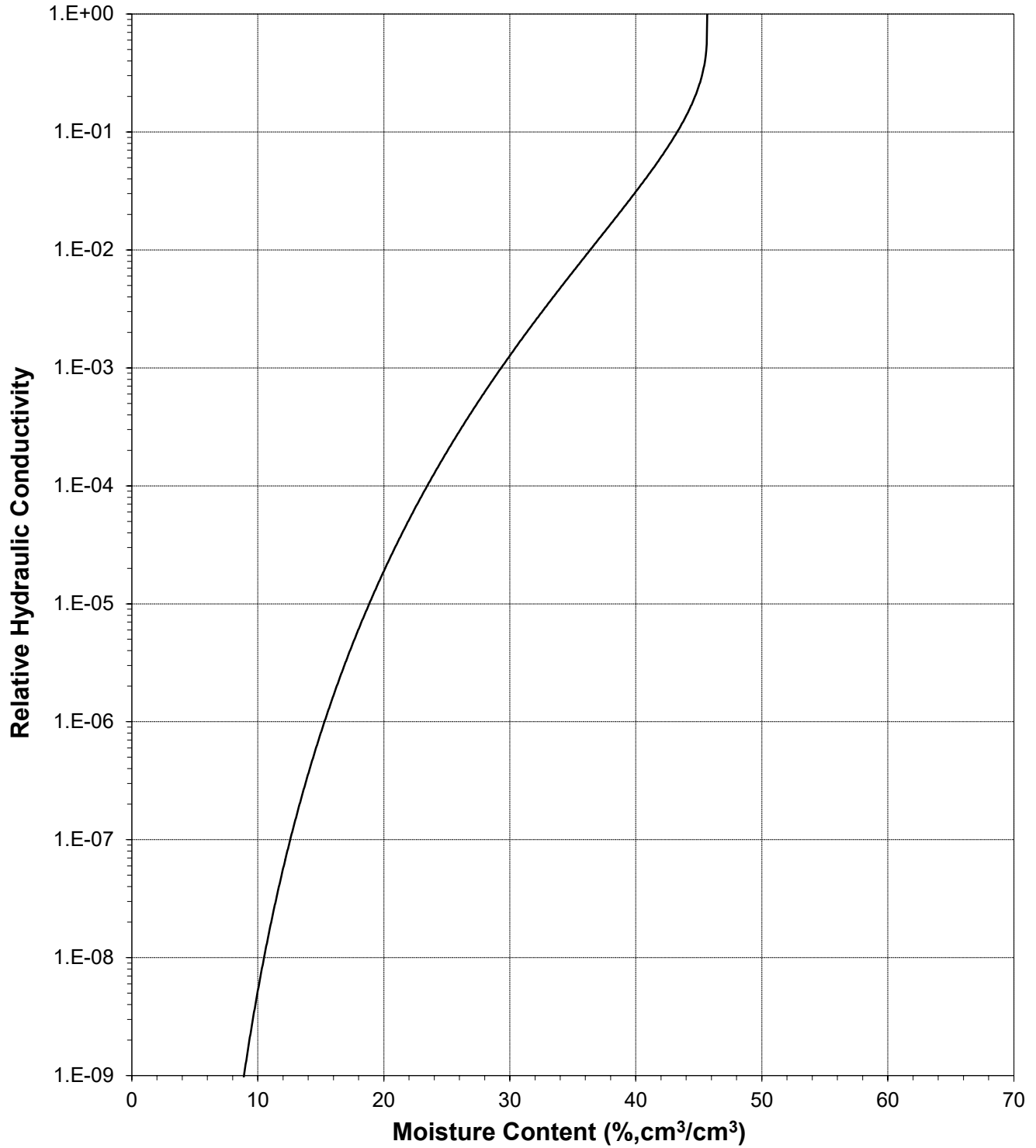
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)





Plot of Relative Hydraulic Conductivity vs Moisture Content

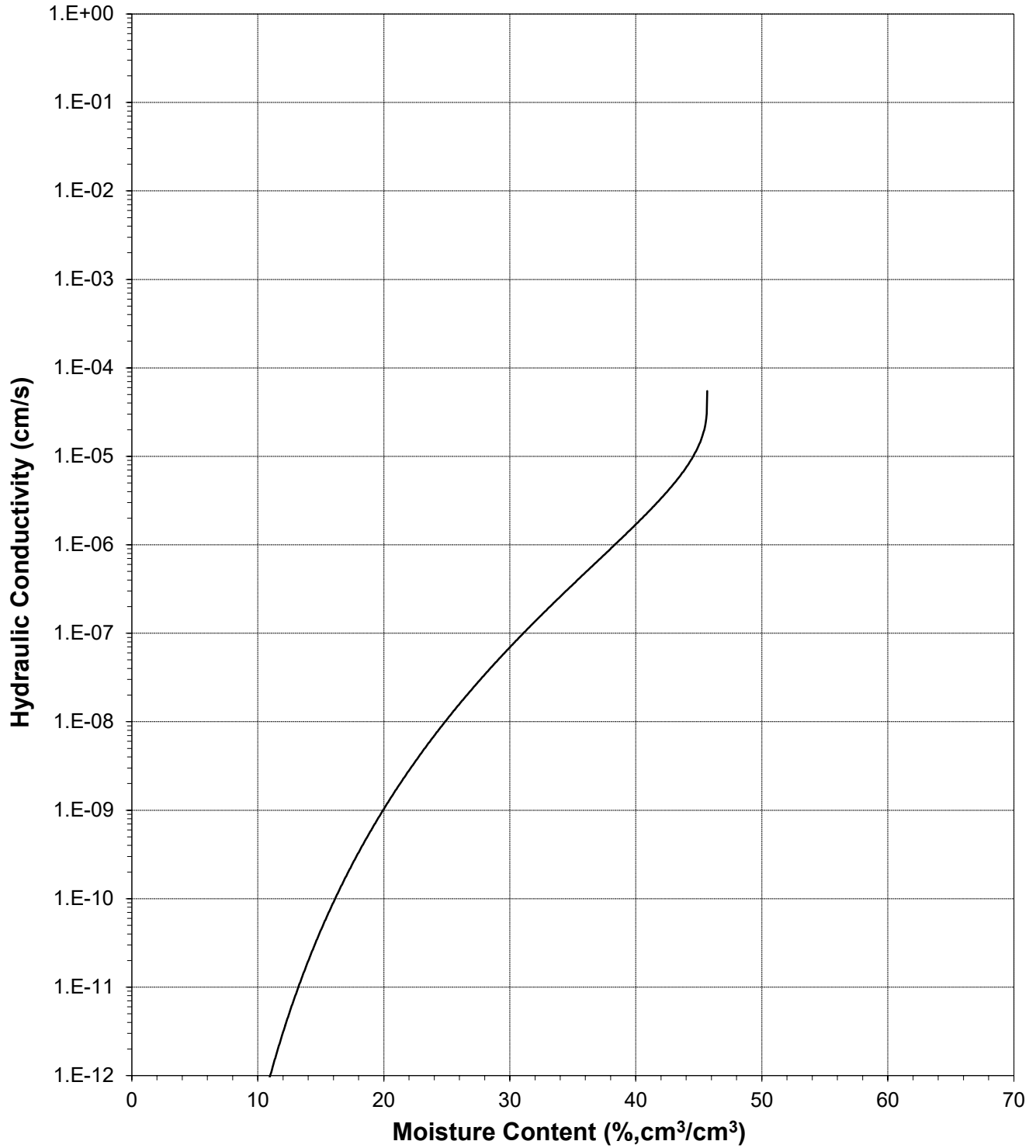
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)





Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: Growth 19-04 (Firm) (1410 kg/m³)

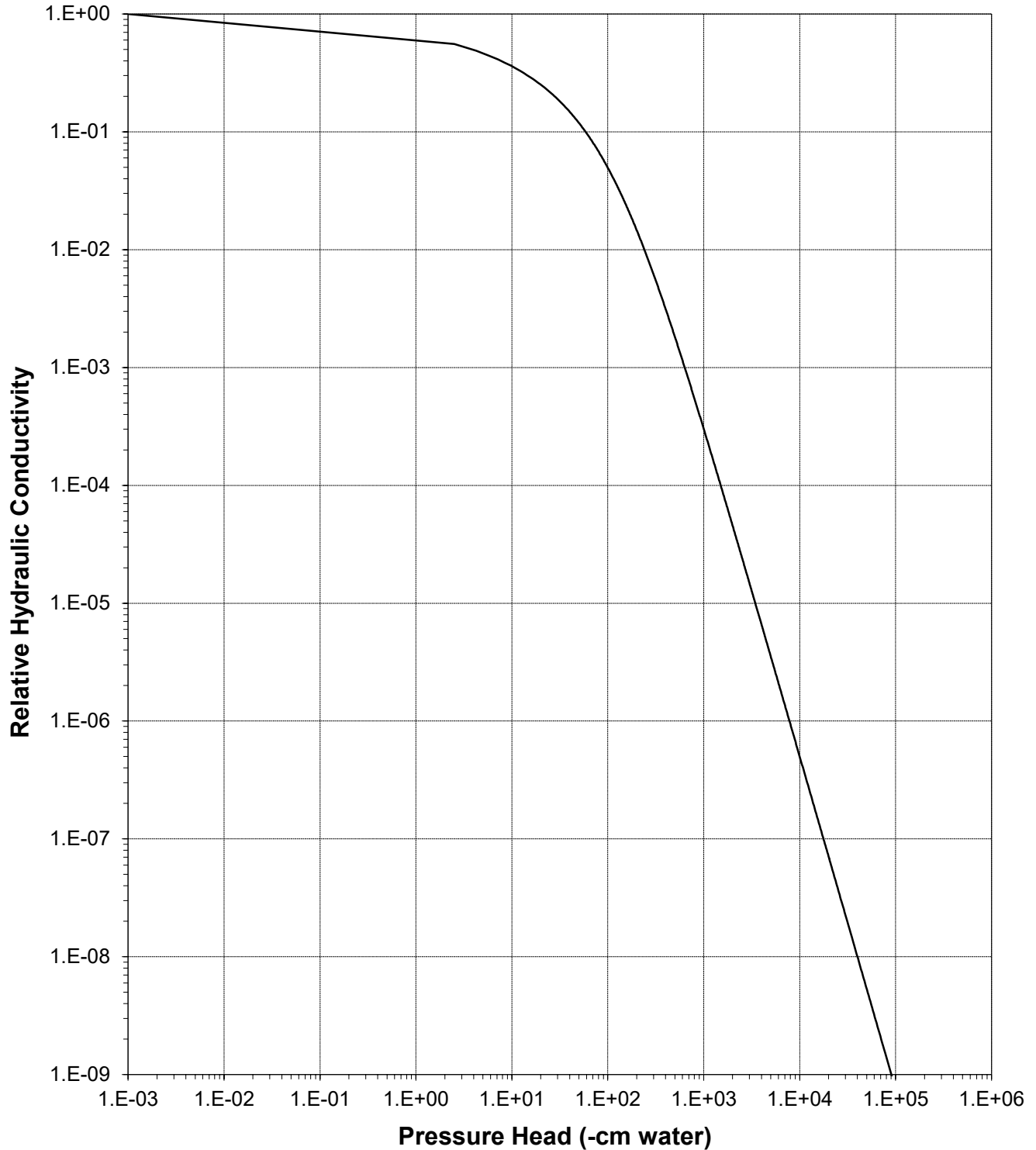




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Plot of Relative Hydraulic Conductivity vs Pressure Head

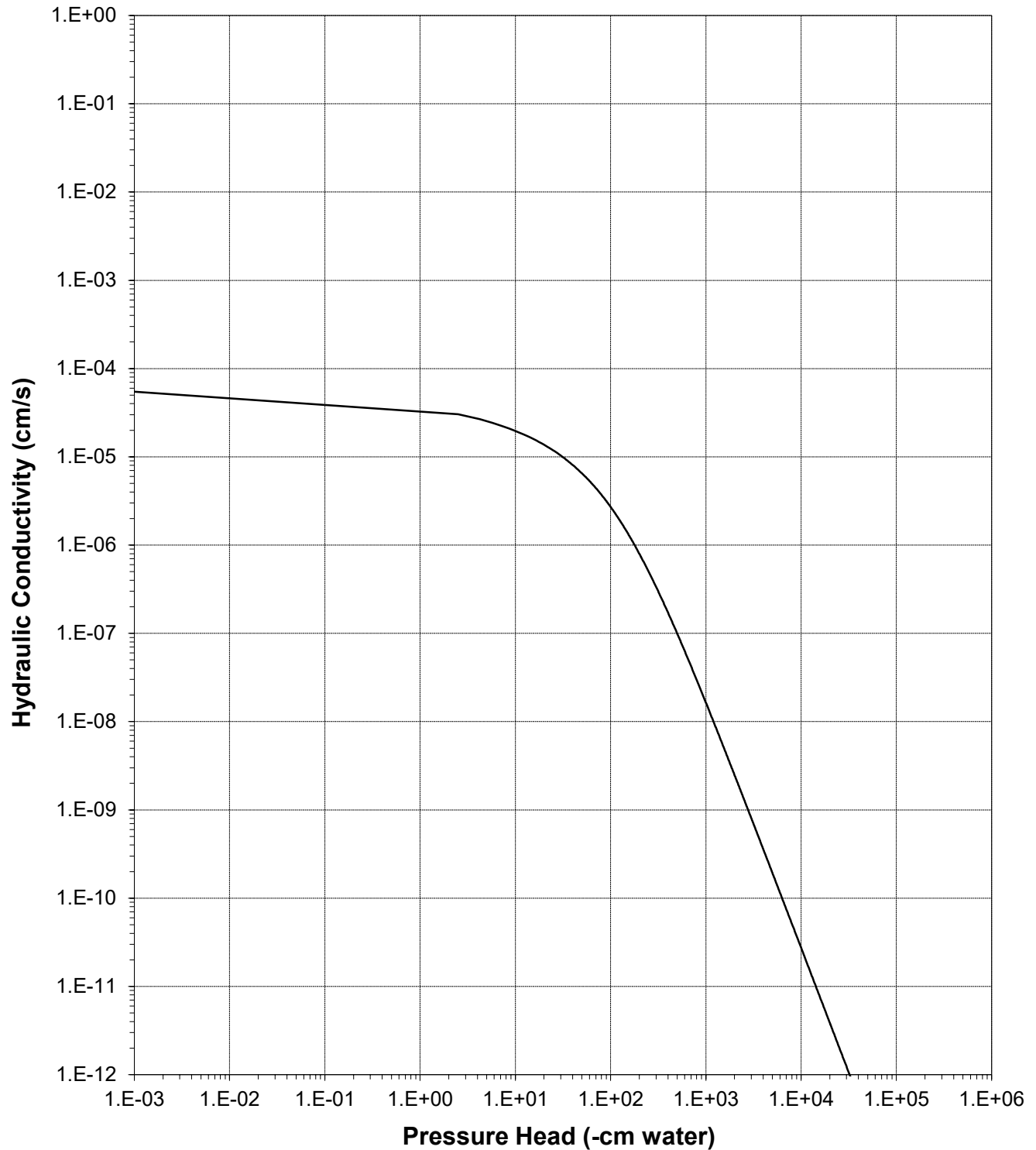
Sample Number: Growth 19-04 (Firm) (1410 kg/m³)





Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: Growth 19-04 (Firm) (1410 kg/m³)





Oversize Correction Data Sheet

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-04 (Firm) (1410 kg/m³)
 Material Type: Growth Media
 Depth: NA

Split (3/4", 3/8", #4): #4

	Coarse Fraction*	Fines Fraction**	Composite
Subsample Mass (g):	0.00	100.00	100.00
Mass Fraction (%):	0.00	100.00	100.00
<i>Initial Sample θ_i</i>			
Bulk Density (g/cm ³):	2.65	1.41	1.41
Calculated Porosity (% vol):	0.00	46.83	46.83
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	33.23	33.23
Total Volume (cm ³):	0.00	70.97	70.97
Volumetric Fraction (%):	0.00	100.00	100.00
Initial Moisture Content (% vol):	0.00	21.64	---
<i>Saturated Sample θ_s</i>			
Bulk Density (g/cm ³):	2.65	1.41	1.41
Calculated Porosity (% vol):	0.00	46.83	46.83
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	33.23	33.23
Total Volume (cm ³):	0.00	70.97	70.97
Volumetric Fraction (%):	0.00	100.00	100.00
Saturated Moisture Content (% vol):	0.00	45.67	---
<i>Residual Sample θ_r</i>			
Bulk Density (g/cm ³):	2.65	1.41	1.41
Calculated Porosity (% vol):	0.00	46.83	46.83
Volume of Solids (cm ³):	0.00	37.74	37.74
Volume of Voids (cm ³):	0.00	33.23	33.23
Total Volume (cm ³):	0.00	70.97	70.97
Volumetric Fraction (%):	0.00	100.00	100.00
Residual Moisture Content (% vol):	0.00	3.76	---
Ksat (cm/sec):	NM	5.5E-05	---

* = Porosity and moisture content of coarse fraction assumed to be zero.

** = Volume adjusted, if applicable. See notes on Moisture Retention Data pages.

NM = Not measured

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines

Particle Size Analysis



Summary of Particle Size Characteristics

Sample Number	d ₁₀ (mm)	d ₅₀ (mm)	d ₆₀ (mm)	C _u	C _c	Method	ASTM Classification	USDA Classification	
49-SWECO+1.0-D25B-138	0.00022	0.044	0.065	295	1.5	WS/H	Sandy lean clay s(CL)	Loam [†]	(Est)
9-SWECO+1.0-E22B-348	6.6E-05	0.050	0.15	2273	2.0	WS/H	Sandy fat clay s(CH)	Clay Loam [†]	(Est)
4-LFILTCAKE-E05B-315	6.5E-09	0.41	0.82	1.3E+08	1.9E+04	WS/H	Silty sand (SM)	Sandy Clay Loam [†]	(Est)
4381-Blend	5.7E-52	0.11	0.26	4.6E+50	2.6E+27	WS/H	Silty sand (SM)	Sandy Clay	(Est)
WD19-01	0.0037	0.084	0.13	35	4.4	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
WD19-02	0.0022	0.089	0.17	77	4.9	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
WD19-03	0.00063	0.067	0.11	175	5.8	WS/H	Sandy elastic silt s(MH)	Loam [†]	(Est)
Growth 19-01	0.0015	0.052	0.063	42	8.3	WS/H	Silt with sand (ML)s	Loam	
Growth 19-02	0.0065	0.084	0.14	22	2.5	WS/H	Silty sand with gravel (SM)g	Sandy Loam [†]	
Growth 19-03	0.0012	0.039	0.050	42	1.1	WS/H	Silt with sand (ML)s	Loam	(Est)
Growth 19-04	0.0027	0.047	0.056	21	2.4	WS/H	Silt with sand (ML)s	Loam	

d₅₀ = Median particle diameter

Est = Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{(d_{30})^2}{(d_{10})(d_{60})}$$

DS = Dry sieve

H = Hydrometer

WS = Wet sieve

[†] Greater than 10% of sample is coarse material



Percent Gravel, Sand, Silt and Clay*

Sample Number	% Gravel (>4.75mm)	% Sand (<4.75mm, >0.075mm)	% Silt (<0.075mm, >0.002mm)	% Clay (<0.002mm)
49-SWECO+1.0-D25B-138	7.1	29.5	39.7	23.8
9-SWECO+1.0-E22B-348	14.6	30.5	29.3	25.6
4-LFILTCAKE-E05B-315	0.0	61.4	17.1	21.4
4381-Blend	1.6	51.2	12.3	34.9
WD19-01	15.9	37.0	38.5	8.6
WD19-02	19.7	34.3	36.4	9.6
WD19-03	13.9	34.1	36.3	15.7
Growth 19-01	2.1	27.7	59.4	10.8
Growth 19-02	24.0	28.5	41.9	5.6
Growth 19-03	2.7	19.0	64.2	14.1
Growth 19-04	0.0	23.1	68.1	8.8

*USCS classification does not classify clay fraction based on particle size. USDA definition of clay (<0.002mm) used in this table.



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138
Material Type: Gangue
Depth: NA

Test Date: 24-Oct-19

Initial Dry Weight of Sample (g): 2418.21
Weight Passing #10 (g): 2134.76
Weight Retained #10 (g): 283.45
Weight of Hydrometer Sample (g): 75.74
Calculated Weight of Sieve Sample (g): 85.80

Shape: Angular
Hardness: Weathered and friable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10						
	3"	75	0.00	0.00	2418.21	100.00
	2"	50	0.00	0.00	2418.21	100.00
	1.5"	38.1	0.00	0.00	2418.21	100.00
	1"	25	0.00	0.00	2418.21	100.00
	3/4"	19.0	8.01	8.01	2410.20	99.67
	3/8"	9.5	79.65	87.66	2330.55	96.38
	4	4.75	83.96	171.62	2246.59	92.90
	10	2.00	111.83	283.45	2134.76	88.28
-10			(Based on calculated sieve wt.)			
	20	0.85	3.70	13.76	72.04	83.97
	40	0.425	4.82	18.58	67.22	78.35
	60	0.250	4.23	22.81	62.99	73.42
	100	0.150	4.00	26.81	58.99	68.76
	140	0.106	2.37	29.18	56.62	65.99
	200	0.075	2.19	31.37	54.43	63.44
	dry pan		0.84	32.21	53.59	
	wet pan			53.59	0.00	

d₁₀ (mm): 0.00022 d₅₀ (mm): 0.044
d₁₆ (mm): 0.00057 d₆₀ (mm): 0.065
d₃₀ (mm): 0.0047 d₈₄ (mm): 0.86

Median Particle Diameter--d₅₀ (mm): 0.044
Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 295
Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 1.5
Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.30

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

Classification of fines: CL

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Sandy lean clay s(CL)
USDA Soil Classification: Loam[†]

Laboratory analysis by: L. Daniell
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138
Material Type: Gangue
Depth: NA

Test Date: 22-Oct-19
Start Time: 9:00

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

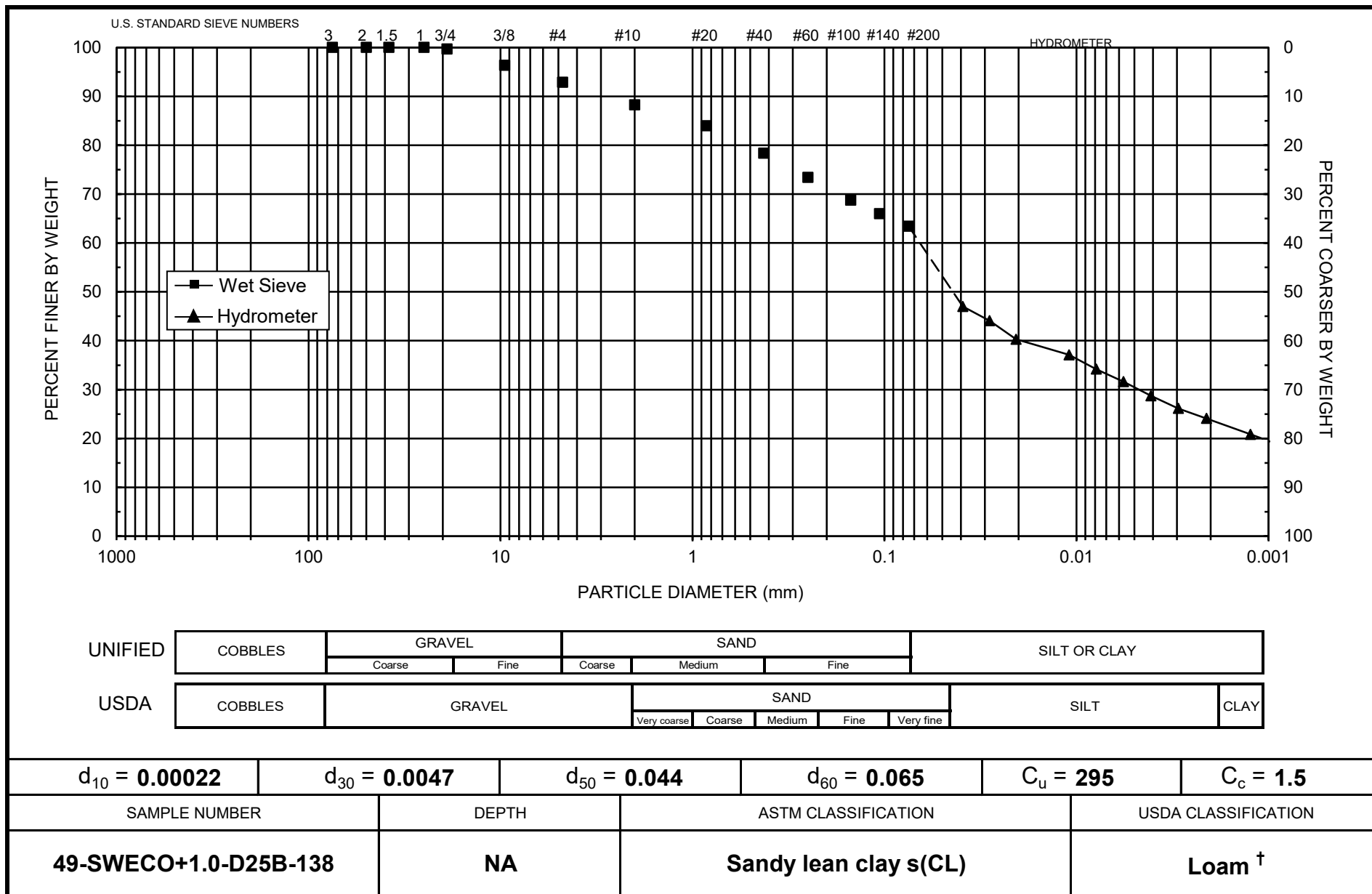
Initial Wt. (g): 75.74
Total Sample Wt. (g): 2418.21
Wt. Passing #10 (g): 2134.76

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
22-Oct-19	1	20.3	46.00	5.67	40.3	8	0.0391	53	47.0
	2	20.3	43.50	5.67	37.8	9	0.0283	50	44.1
	4	20.3	40.25	5.67	34.6	9	0.0206	46	40.3
	15	20.3	37.50	5.67	31.8	10	0.0109	42	37.1
	30	20.3	35.00	5.67	29.3	10	0.0079	39	34.2
	60	20.4	32.75	5.64	27.1	10	0.0057	36	31.6
	120	20.5	30.25	5.60	24.6	11	0.0041	33	28.7
	240	20.6	28.00	5.57	22.4	11	0.0029	30	26.1
	485	21.3	26.00	5.33	20.7	12	0.0021	27	24.1
23-Oct-19	1446	20.4	23.50	5.64	17.9	12	0.0012	24	20.8

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: A. Bland
Data entered by: A. Albay-Yenney
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material

Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348
Material Type: Gangue
Depth: NA

Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 5317.79
Weight Passing #10 (g): 4181.87
Weight Retained #10 (g): 1135.92
Weight of Hydrometer Sample (g): 85.52
Calculated Weight of Sieve Sample (g): 108.75

Shape: Angular
Hardness: Weathered and friable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	5317.79	100.00
	2"	50	0.00	0.00	5317.79	100.00
	1.5"	38.1	0.00	0.00	5317.79	100.00
	1"	25	0.00	0.00	5317.79	100.00
	3/4"	19.0	117.15	117.15	5200.64	97.80
	3/8"	9.5	370.53	487.68	4830.11	90.83
	4	4.75	288.80	776.48	4541.31	85.40
	10	2.00	359.44	1135.92	4181.87	78.64
-10	(Based on calculated sieve wt.)					
	20	0.85	7.00	30.23	78.52	72.20
	40	0.425	4.97	35.20	73.55	67.63
	60	0.250	4.05	39.25	69.50	63.91
	100	0.150	4.04	43.29	65.46	60.19
	140	0.106	2.98	46.27	62.48	57.45
	200	0.075	2.78	49.05	59.70	54.90
	dry pan		1.30	50.35	58.40	
	wet pan			58.40	0.00	

d₁₀ (mm): 6.6E-05 d₅₀ (mm): 0.050
d₁₆ (mm): 0.00024 d₆₀ (mm): 0.15
d₃₀ (mm): 0.0044 d₈₄ (mm): 4.0

Median Particle Diameter--d₅₀ (mm): 0.050
Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 2273
Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 2.0
Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 1.4

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

Classification of fines: CH

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Sandy fat clay s(CH)
USDA Soil Classification: Clay Loam †

Laboratory analysis by: J. Newcomer
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348
Material Type: Gangue
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:36

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

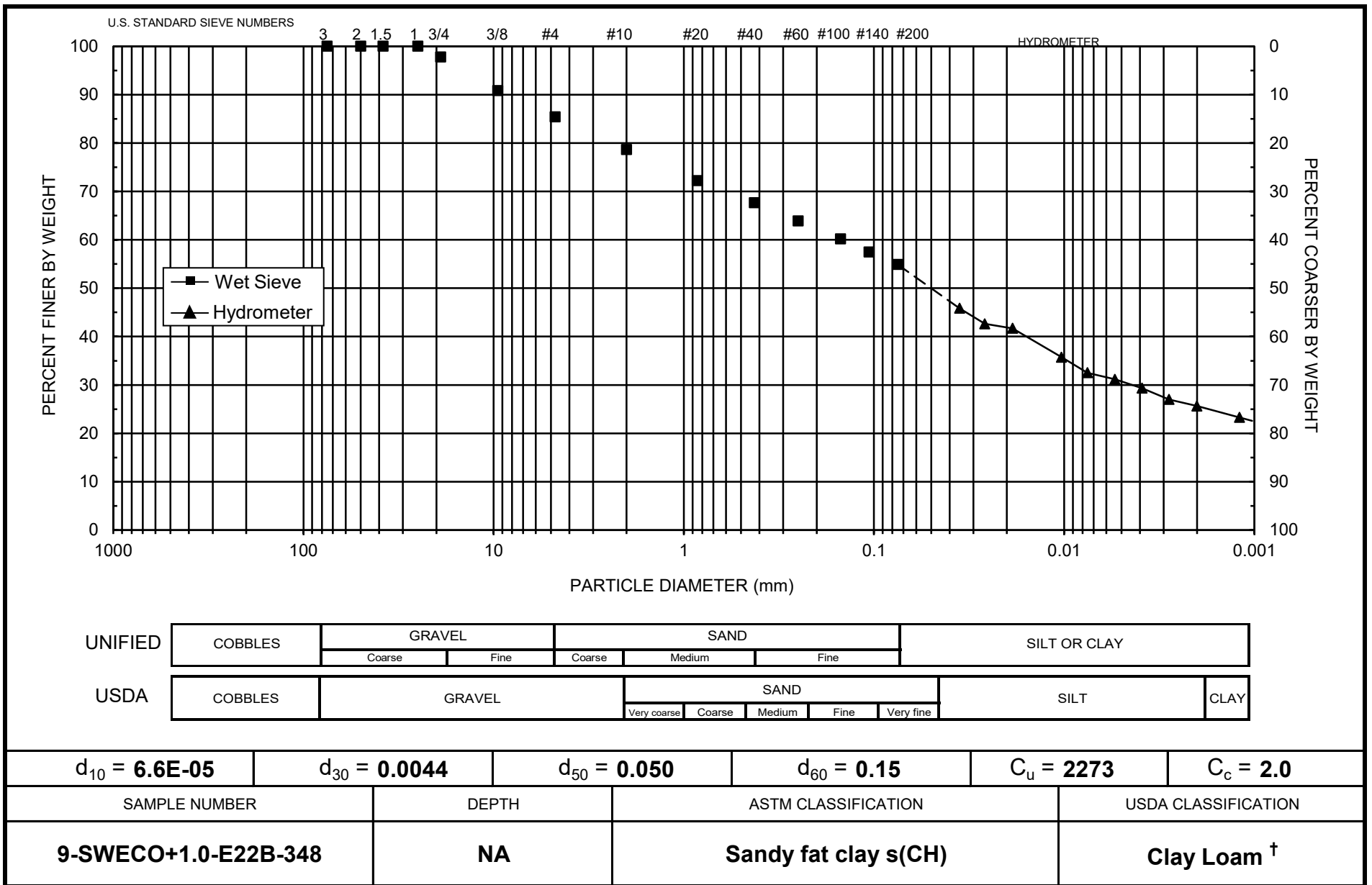
Initial Wt. (g): 85.52
Total Sample Wt. (g): 5317.79
Wt. Passing #10 (g): 4181.87

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.8	55.00	5.15	49.9	7	0.0355	58	45.8
	2	21.8	51.50	5.15	46.4	7	0.0261	54	42.6
	4	21.8	50.50	5.15	45.4	8	0.0187	53	41.7
	15	21.8	44.00	5.15	38.9	9	0.0103	45	35.7
	30	21.8	40.50	5.15	35.4	9	0.0075	41	32.5
	60	21.9	39.00	5.11	33.9	9	0.0054	40	31.2
	120	21.9	37.00	5.11	31.9	10	0.0039	37	29.3
	240	21.8	34.50	5.15	29.4	10	0.0028	34	27.0
	483	21.9	33.00	5.11	27.9	10	0.0020	33	25.6
18-Sep-19	1410	21.7	30.50	5.19	25.3	11	0.0012	30	23.3

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Thurgood
Data entered by: A. Albay-Yenney
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material

Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4-LFILTCAKE-E05B-315
Material Type: Tailings
Depth: NA

Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 2547.30
Weight Passing #10 (g): 2181.06
Weight Retained #10 (g): 366.24
Weight of Hydrometer Sample (g): 56.22
Calculated Weight of Sieve Sample (g): 65.66

Shape: Angular
Hardness: Hard and durable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	2547.30	100.00
	2"	50	0.00	0.00	2547.30	100.00
	1.5"	38.1	0.00	0.00	2547.30	100.00
	1"	25	0.00	0.00	2547.30	100.00
	3/4"	19.0	0.00	0.00	2547.30	100.00
	3/8"	9.5	0.00	0.00	2547.30	100.00
	4	4.75	0.00	0.00	2547.30	100.00
	10	2.00	366.24	366.24	2181.06	85.62
-10	(Based on calculated sieve wt.)					
	20	0.85	16.46	25.90	39.76	60.55
	40	0.425	6.78	32.68	32.98	50.23
	60	0.250	2.81	35.49	30.17	45.95
	100	0.150	2.12	37.61	28.05	42.72
	140	0.106	1.38	38.99	26.67	40.62
	200	0.075	1.34	40.33	25.33	38.58
	dry pan		0.33	40.66	25.00	
	wet pan			25.00	0.00	

d₁₀ (mm): 6.5E-09 d₅₀ (mm): 0.41

d₁₆ (mm): 4.9E-06 d₆₀ (mm): 0.82

d₃₀ (mm): 0.010 d₈₄ (mm): 1.9

Median Particle Diameter--d₅₀ (mm): 0.41

Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 1.3E+08

Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 1.9E+04

Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.77

Classification of fines (visual method): ML

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Silty sand (SM)

USDA Soil Classification: Sandy Clay Loam †

Laboratory analysis by: J. Newcomer/L. Daniell

Data entered by: L. Thurgood

Checked by: J. Hines

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4-LFILTCAKE-E05B-315
Material Type: Tailings
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:48

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

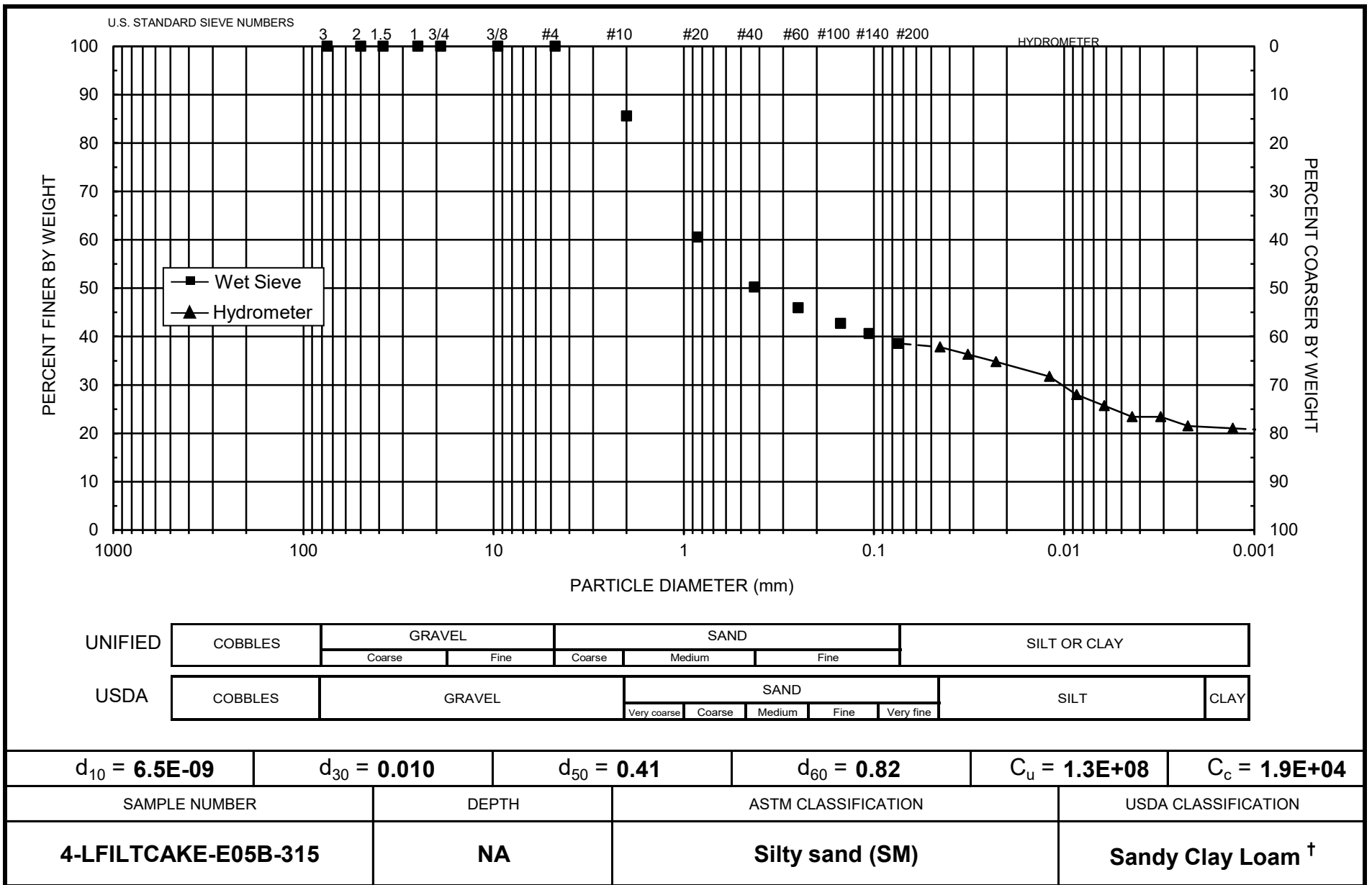
Initial Wt. (g): 56.22
Total Sample Wt. (g): 2547.30
Wt. Passing #10 (g): 2181.06

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.8	30.00	5.15	24.9	11	0.0449	44	37.8
	2	21.8	29.00	5.15	23.9	11	0.0320	42	36.3
	4	21.8	28.00	5.15	22.9	11	0.0228	41	34.8
	15	21.8	26.00	5.15	20.9	12	0.0119	37	31.8
	30	21.9	23.50	5.11	18.4	12	0.0086	33	28.0
	60	21.9	22.00	5.11	16.9	12	0.0061	30	25.7
	120	21.9	20.50	5.11	15.4	12	0.0044	27	23.4
	240	21.9	20.50	5.11	15.4	12	0.0031	27	23.4
	472	21.9	19.25	5.11	14.1	13	0.0022	25	21.5
18-Sep-19	1400	21.7	19.00	5.19	13.8	13	0.0013	25	21.0

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Daniell
Data entered by: L. Thurgood
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material

Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4381-Blend
Material Type: Tailings
Depth: NA
Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 3776.49
Weight Passing #10 (g): 3673.09
Weight Retained #10 (g): 103.39
Weight of Hydrometer Sample (g): 58.23
Calculated Weight of Sieve Sample (g): 59.87

Shape: Angular
Hardness: Soft

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	3776.49	100.00
	2"	50	0.00	0.00	3776.49	100.00
	1.5"	38.1	0.00	0.00	3776.49	100.00
	1"	25	0.00	0.00	3776.49	100.00
	3/4"	19.0	0.00	0.00	3776.49	100.00
	3/8"	9.5	30.95	30.95	3745.54	99.18
	4	4.75	29.91	60.86	3715.62	98.39
	10	2.00	42.53	103.39	3673.09	97.26
-10	(Based on calculated sieve wt.)					
	20	0.85	8.45	10.09	49.78	83.15
	40	0.425	8.83	18.92	40.95	68.40
	60	0.250	5.39	24.31	35.56	59.40
	100	0.150	3.64	27.95	31.92	53.32
	140	0.106	2.05	30.00	29.87	49.89
	200	0.075	1.63	31.63	28.24	47.17
	dry pan		0.49	32.12	27.75	
	wet pan			27.75	0.00	

d₁₀ (mm): 5.7E-52 d₅₀ (mm): 0.11
d₁₆ (mm): 2.9E-40 d₆₀ (mm): 0.26
d₃₀ (mm): 6.2E-13 d₈₄ (mm): 0.90

Median Particle Diameter--d₅₀ (mm): 0.11
Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 4.6E+50
Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 2.6E+27
Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.34

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

Classification of fines: ML

ASTM Soil Classification: Silty sand (SM)
USDA Soil Classification: Sandy Clay

Laboratory analysis by: J. Newcomer
Data entered by: L. Thurgood
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4381-Blend
Material Type: Tailings
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:42

Type of Water Used: DISTILLED
Reaction with H₂O₂: NA
Dispersant:* (NaPO₃)₆
Assumed particle density: 2.65

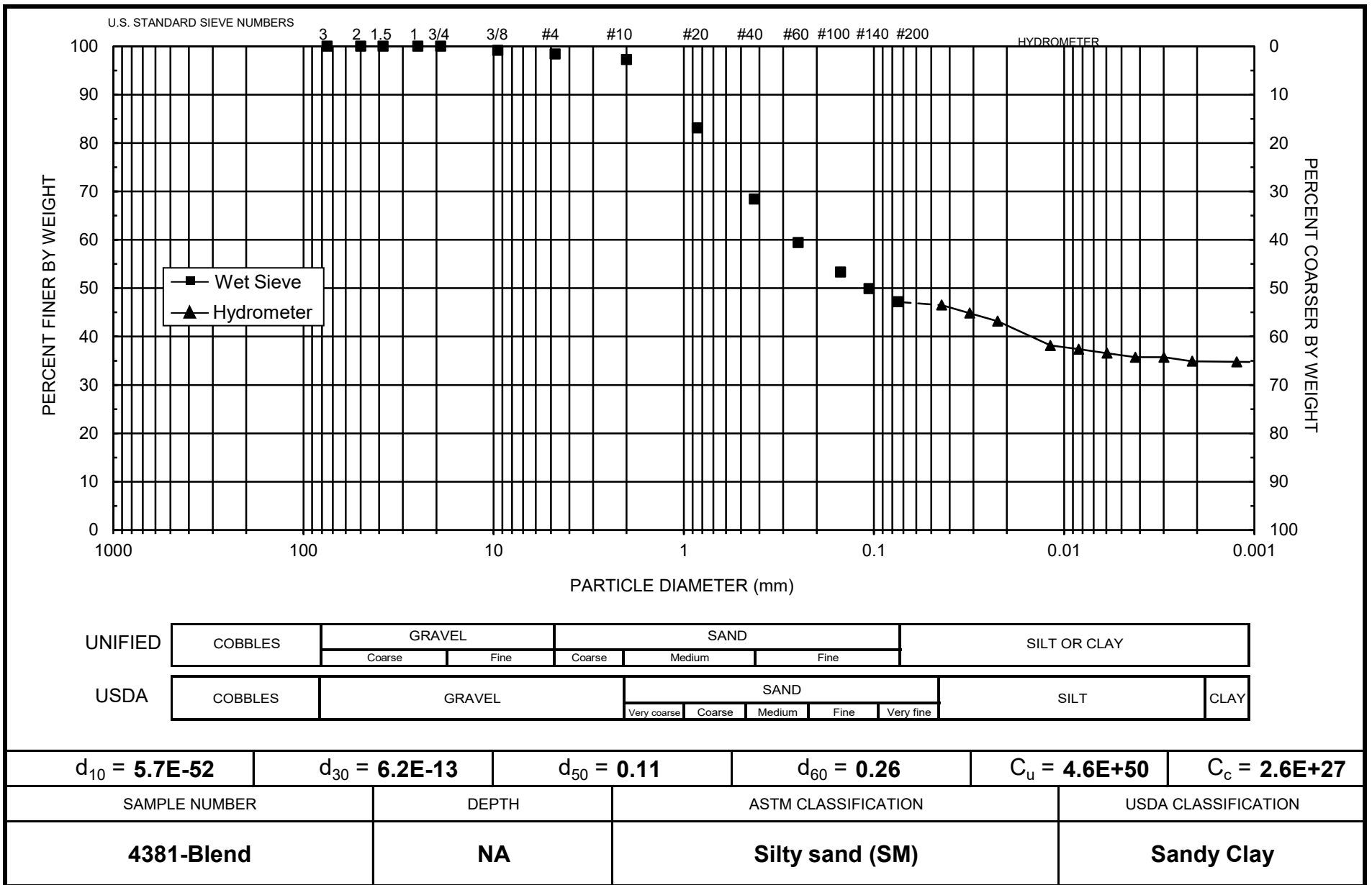
Initial Wt. (g): 58.23
Total Sample Wt. (g): 3776.49
Wt. Passing #10 (g): 3673.09

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.8	33.00	5.15	27.9	10	0.0440	48	46.5
	2	21.8	32.00	5.15	26.9	11	0.0313	46	44.8
	4	21.8	31.00	5.15	25.9	11	0.0223	44	43.2
	15	21.8	28.00	5.15	22.9	11	0.0118	39	38.2
	30	21.9	27.50	5.11	22.4	11	0.0084	38	37.4
	60	21.9	27.00	5.11	21.9	11	0.0059	38	36.6
	120	21.9	26.50	5.11	21.4	11	0.0042	37	35.7
	240	21.9	26.50	5.11	21.4	11	0.0030	37	35.7
	478	21.9	26.00	5.11	20.9	12	0.0021	36	34.9
18-Sep-19	1405	21.7	26.00	5.19	20.8	12	0.0012	36	34.8

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: J. Hines
Data entered by: L. Thurgood
Checked by: J. Hines



Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-01
 Material Type: Waste Rock
 Depth: NA
 Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 4957.68
 Weight Passing #10 (g): 4009.67
 Weight Retained #10 (g): 948.02
 Weight of Hydrometer Sample (g): 55.82
 Calculated Weight of Sieve Sample (g): 69.02

Shape: Angular
 Hardness: Weathered and friable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	4957.68	100.00
	2"	50	0.00	0.00	4957.68	100.00
	1.5"	38.1	244.68	244.68	4713.00	95.06
	1"	25	152.60	397.28	4560.40	91.99
	3/4"	19.0	59.57	456.85	4500.83	90.79
	3/8"	9.5	124.60	581.45	4376.23	88.27
	4	4.75	207.38	788.83	4168.85	84.09
	10	2.00	159.19	948.02	4009.67	80.88
-10	(Based on calculated sieve wt.)					
	20	0.85	5.17	18.37	50.65	73.39
	40	0.425	3.18	21.55	47.47	68.78
	60	0.250	2.07	23.62	45.40	65.78
	100	0.150	2.56	26.18	42.84	62.07
	140	0.106	4.01	30.19	38.83	56.26
	200	0.075	6.31	36.50	32.52	47.12
	dry pan		2.30	38.80	30.22	
	wet pan			30.22	0.00	

d₁₀ (mm): 0.0037 d₅₀ (mm): 0.084
 d₁₆ (mm): 0.0095 d₆₀ (mm): 0.13
 d₃₀ (mm): 0.046 d₈₄ (mm): 4.6

Median Particle Diameter--d₅₀ (mm): 0.084
 Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 35
 Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 4.4
 Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 1.6

Classification of fines (visual method): ML

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Silty sand with gravel (SM)g
 USDA Soil Classification: Sandy Loam †

Laboratory analysis by: J. Newcomer
 Data entered by: L. Thurgood
 Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-01
Material Type: Waste Rock
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:24

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

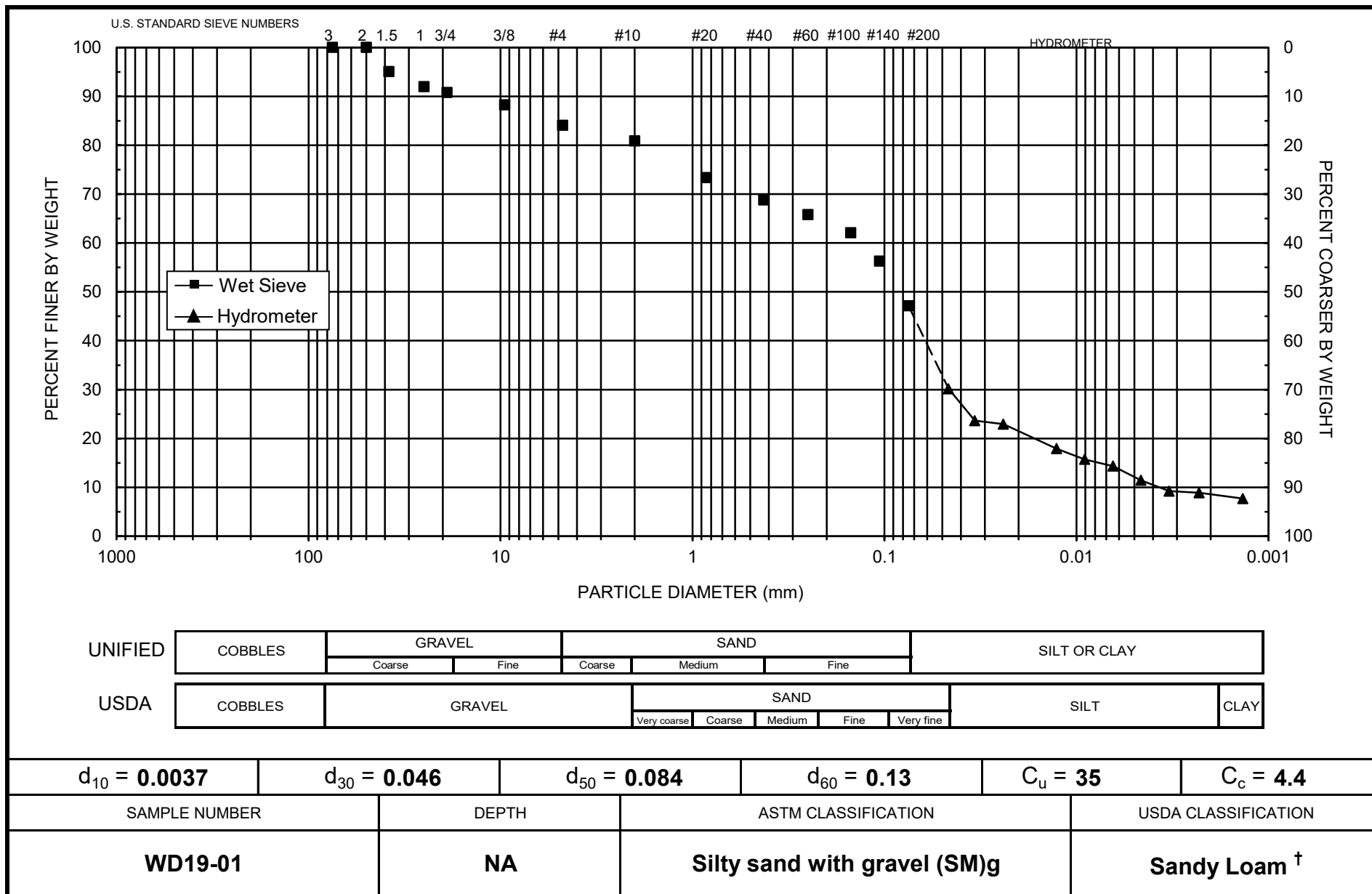
Initial Wt. (g): 55.82
Total Sample Wt. (g): 4957.68
Wt. Passing #10 (g): 4009.67

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	26.00	5.19	20.8	12	0.0464	37	30.2
	2	21.7	21.50	5.19	16.3	12	0.0338	29	23.6
	4	21.7	21.00	5.19	15.8	12	0.0240	28	22.9
	15	21.8	17.50	5.15	12.4	13	0.0127	22	17.9
	30	21.8	16.00	5.15	10.9	13	0.0091	19	15.7
	60	21.9	15.00	5.11	9.9	13	0.0064	18	14.3
	120	21.9	13.00	5.11	7.9	14	0.0046	14	11.4
	240	21.8	11.50	5.15	6.4	14	0.0033	11	9.2
	493	21.9	11.25	5.11	6.1	14	0.0023	11	8.9
18-Sep-19	1420	21.7	10.50	5.19	5.3	14	0.0014	10	7.7

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Daniell
Data entered by: L. Thurgood
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material



Daniel B. Stephens & Associates, Inc.



Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: WD19-02
 Material Type: Waste Rock
 Depth: NA
 Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 5502.23
 Weight Passing #10 (g): 4239.15
 Weight Retained #10 (g): 1263.08
 Weight of Hydrometer Sample (g): 73.74
 Calculated Weight of Sieve Sample (g): 95.71

Shape: Rounded
 Hardness: Hard and durable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	5502.23	100.00
	2"	50	0.00	0.00	5502.23	100.00
	1.5"	38.1	229.75	229.75	5272.48	95.82
	1"	25	322.70	552.45	4949.78	89.96
	3/4"	19.0	163.86	716.31	4785.92	86.98
	3/8"	9.5	178.18	894.49	4607.74	83.74
	4	4.75	189.96	1084.45	4417.77	80.29
	10	2.00	178.62	1263.08	4239.15	77.04
-10	(Based on calculated sieve wt.)					
	20	0.85	7.05	29.02	66.69	69.68
	40	0.425	4.17	33.19	62.52	65.32
	60	0.250	2.62	35.81	59.90	62.58
	100	0.150	3.13	38.94	56.77	59.31
	140	0.106	4.96	43.90	51.81	54.13
	200	0.075	7.76	51.66	44.05	46.02
	dry pan		1.77	53.43	42.28	
	wet pan			42.28	0.00	

d₁₀ (mm): 0.0022 d₅₀ (mm): 0.089
 d₁₆ (mm): 0.0072 d₆₀ (mm): 0.17
 d₃₀ (mm): 0.043 d₈₄ (mm): 10

Median Particle Diameter--d₅₀ (mm): 0.089
 Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 77
 Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 4.9
 Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 3.4

Classification of fines (visual method): ML

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Silty sand with gravel (SM)g
 USDA Soil Classification: Sandy Loam †

Laboratory analysis by: J. Newcomer/L. Daniell
 Data entered by: A. Albay-Yenney
 Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-02
Material Type: Waste Rock
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:30

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

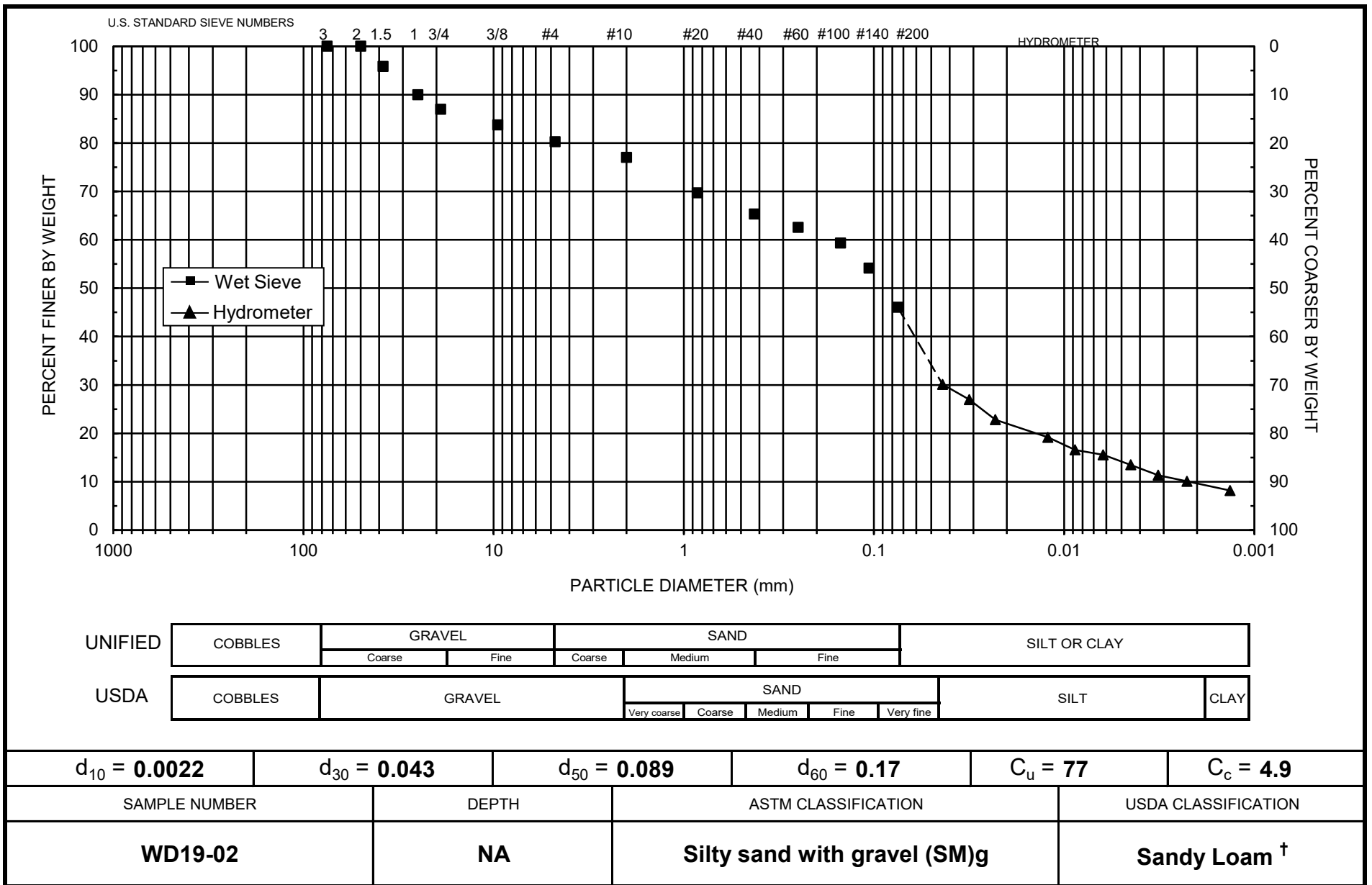
Initial Wt. (g): 73.74
Total Sample Wt. (g): 5502.23
Wt. Passing #10 (g): 4239.15

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	34.00	5.19	28.8	10	0.0436	39	30.1
	2	21.7	31.00	5.19	25.8	11	0.0315	35	27.0
	4	21.7	27.00	5.19	21.8	11	0.0230	30	22.8
	15	21.8	23.50	5.15	18.4	12	0.0122	25	19.2
	30	21.8	21.00	5.15	15.9	12	0.0088	21	16.6
	60	21.9	20.00	5.11	14.9	13	0.0062	20	15.6
	120	21.9	18.00	5.11	12.9	13	0.0045	17	13.5
	240	21.8	16.00	5.15	10.9	13	0.0032	15	11.3
	488	21.9	14.75	5.11	9.6	13	0.0023	13	10.1
18-Sep-19	1415	21.7	13.00	5.19	7.8	14	0.0013	11	8.2

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Daniell
Data entered by: A. Albay-Yenney
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material



Daniel B. Stephens & Associates, Inc.



Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-03
Material Type: Waste Rock
Depth: NA
Test Date: 24-Oct-19

Initial Dry Weight of Sample (g): 4463.24
Weight Passing #10 (g): 3622.39
Weight Retained #10 (g): 840.85
Weight of Hydrometer Sample (g): 78.61
Calculated Weight of Sieve Sample (g): 96.86

Shape: Angular
Hardness: Weathered and friable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	4463.24	100.00
	2"	50	0.00	0.00	4463.24	100.00
	1.5"	38.1	0.00	0.00	4463.24	100.00
	1"	25	74.00	74.00	4389.24	98.34
	3/4"	19.0	89.43	163.43	4299.81	96.34
	3/8"	9.5	246.55	409.98	4053.26	90.81
	4	4.75	209.11	619.09	3844.15	86.13
	10	2.00	221.76	840.85	3622.39	81.16
-10	(Based on calculated sieve wt.)					
	20	0.85	3.24	21.49	75.37	77.82
	40	0.425	4.13	25.62	71.24	73.55
	60	0.250	3.83	29.45	67.41	69.60
	100	0.150	4.82	34.27	62.59	64.62
	140	0.106	5.07	39.34	57.52	59.39
	200	0.075	7.15	46.49	50.37	52.00
	dry pan		2.47	48.96	47.90	
	wet pan			47.90	0.00	

d₁₀ (mm): 0.00063 d₅₀ (mm): 0.067
d₁₆ (mm): 0.0021 d₆₀ (mm): 0.11
d₃₀ (mm): 0.020 d₈₄ (mm): 3.3

Median Particle Diameter--d₅₀ (mm): 0.067
Uniformity Coefficient, C_u--[d₆₀/d₁₀] (mm): 175
Coefficient of Curvature, C_c--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 5.8
Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 1.1

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

Classification of fines: MH

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Sandy elastic silt s(MH)
USDA Soil Classification: Loam[†]

Laboratory analysis by: L. Daniell
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-03
Material Type: Waste Rock
Depth: NA

Test Date: 22-Oct-19
Start Time: 9:06

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

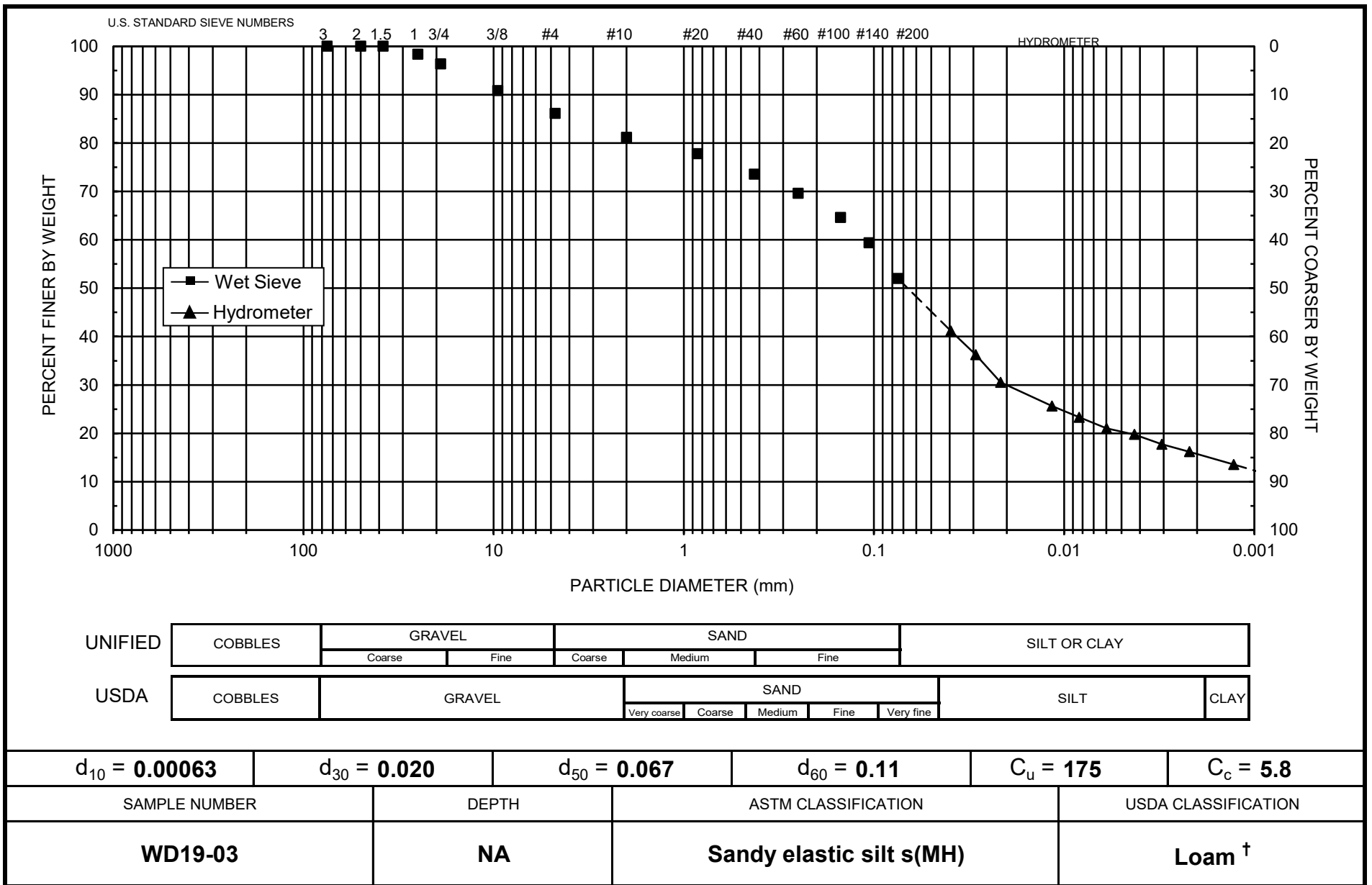
Initial Wt. (g): 78.61
Total Sample Wt. (g): 4463.24
Wt. Passing #10 (g): 3622.39

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
22-Oct-19	1	20.3	45.50	5.67	39.8	8	0.0393	51	41.1
	2	20.3	40.75	5.67	35.1	9	0.0291	45	36.2
	4	20.3	35.25	5.67	29.6	10	0.0216	38	30.5
	15	20.3	30.50	5.67	24.8	11	0.0116	32	25.6
	30	20.3	28.25	5.67	22.6	11	0.0083	29	23.3
	60	20.4	26.00	5.64	20.4	12	0.0060	26	21.0
	120	20.5	24.75	5.60	19.1	12	0.0043	24	19.8
	240	20.6	22.75	5.57	17.2	12	0.0031	22	17.7
	480	21.3	21.00	5.33	15.7	12	0.0022	20	16.2
23-Oct-19	1441	20.4	18.75	5.64	13.1	13	0.0013	17	13.5

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: A. Bland
Data entered by: A. Albay-Yenney
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material

Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-01
 Material Type: Growth Media
 Depth: NA
 Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 5855.28
 Weight Passing #10 (g): 5676.77
 Weight Retained #10 (g): 178.50
 Weight of Hydrometer Sample (g): 62.59
 Calculated Weight of Sieve Sample (g): 64.56

Shape: Angular
 Hardness: Soft

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	5855.28	100.00
	2"	50	0.00	0.00	5855.28	100.00
	1.5"	38.1	0.00	0.00	5855.28	100.00
	1"	25	35.16	35.16	5820.12	99.40
	3/4"	19.0	12.80	47.96	5807.32	99.18
	3/8"	9.5	39.36	87.32	5767.96	98.51
	4	4.75	36.90	124.22	5731.06	97.88
	10	2.00	54.28	178.50	5676.77	96.95
-10	(Based on calculated sieve wt.)					
	20	0.85	0.96	2.93	61.63	95.46
	40	0.425	1.56	4.49	60.07	93.05
	60	0.250	1.34	5.83	58.73	90.97
	100	0.150	2.11	7.94	56.62	87.70
	140	0.106	4.19	12.13	52.43	81.21
	200	0.075	7.12	19.25	45.31	70.18
	dry pan		0.54	19.79	44.77	
	wet pan			44.77	0.00	

d₁₀ (mm): 0.0015 d₅₀ (mm): 0.052
 d₁₆ (mm): 0.0048 d₆₀ (mm): 0.063
 d₃₀ (mm): 0.028 d₈₄ (mm): 0.12

Median Particle Diameter--d₅₀ (mm): 0.052
 Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 42
 Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 8.3
 Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.059

Classification of fines (visual method): ML

ASTM Soil Classification: Silt with sand (ML)s
 USDA Soil Classification: Loam

Laboratory analysis by: J. Newcomer
 Data entered by: L. Thurgood
 Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-01
Material Type: Growth Media
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:00

Type of Water Used: DISTILLED
Reaction with H₂O₂: NA
Dispersant:* (NaPO₃)₆
Assumed particle density: 2.65

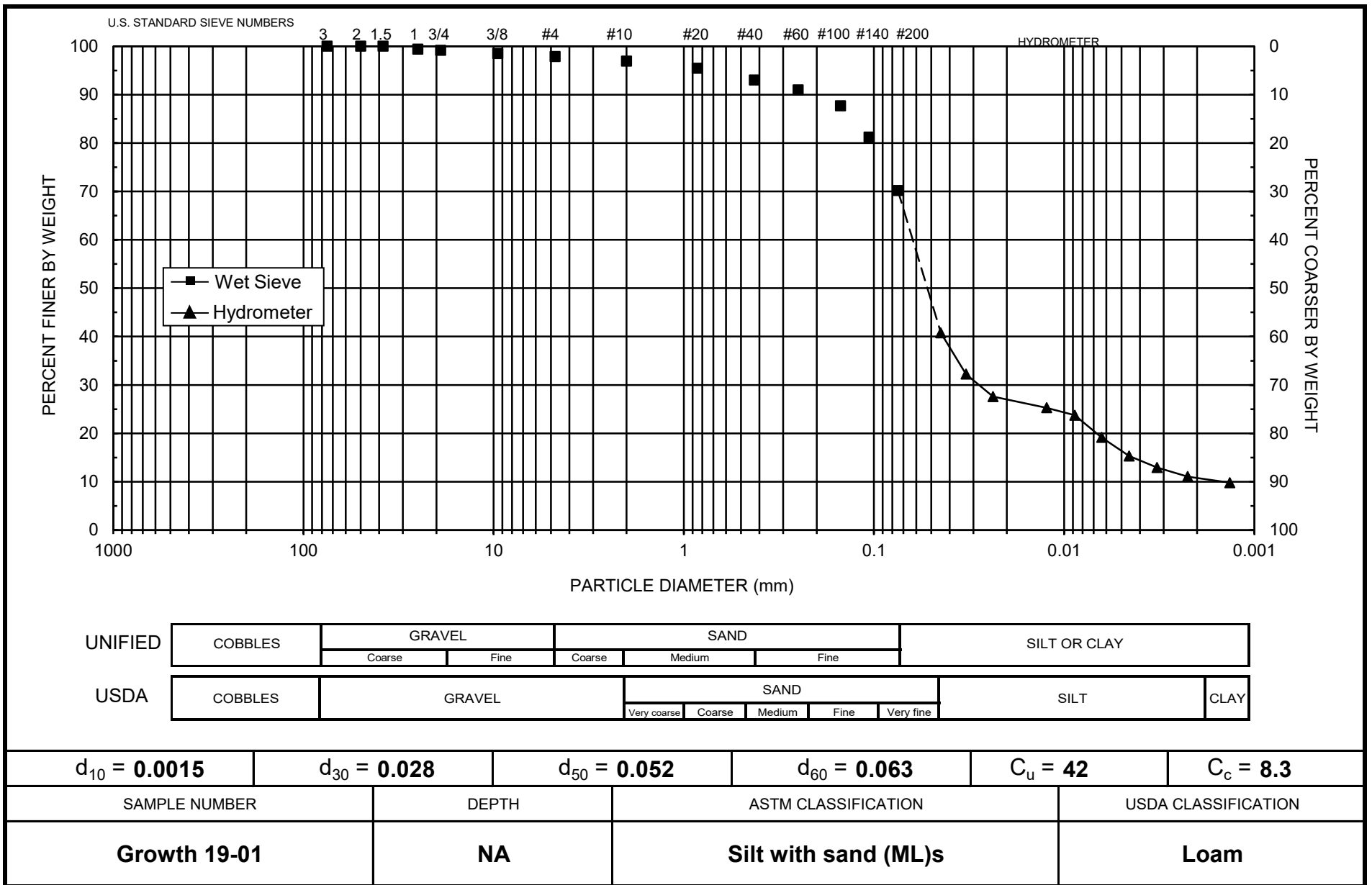
Initial Wt. (g): 62.59
Total Sample Wt. (g): 5855.28
Wt. Passing #10 (g): 5676.77

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	31.50	5.19	26.3	11	0.0445	42	40.8
	2	21.7	26.00	5.19	20.8	12	0.0328	33	32.2
	4	21.7	23.00	5.19	17.8	12	0.0237	28	27.6
	15	21.7	21.50	5.19	16.3	12	0.0124	26	25.3
	30	21.7	20.50	5.19	15.3	12	0.0088	24	23.7
	60	21.8	17.50	5.15	12.4	13	0.0063	20	19.1
	120	21.9	15.00	5.11	9.9	13	0.0046	16	15.3
	240	21.8	13.50	5.15	8.4	14	0.0032	13	12.9
	513	21.9	12.25	5.11	7.1	14	0.0022	11	11.1
18-Sep-19	1440	21.7	11.50	5.19	6.3	14	0.0013	10	9.8

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Daniell
Data entered by: L. Thurgood
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02
Material Type: Growth Media
Depth: NA
Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 5828.40
Weight Passing #10 (g): 4254.93
Weight Retained #10 (g): 1573.46
Weight of Hydrometer Sample (g): 53.13
Calculated Weight of Sieve Sample (g): 72.78

Shape: Rounded
Hardness: Hard and durable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	5828.40	100.00
	2"	50	0.00	0.00	5828.40	100.00
	1.5"	38.1	70.77	70.77	5757.63	98.79
	1"	25	678.03	748.80	5079.60	87.15
	3/4"	19.0	215.13	963.93	4864.47	83.46
	3/8"	9.5	269.96	1233.89	4594.51	78.83
	4	4.75	167.27	1401.16	4427.24	75.96
	10	2.00	172.30	1573.46	4254.93	73.00
-10	(Based on calculated sieve wt.)					
	20	0.85	2.29	21.94	50.84	69.86
	40	0.425	2.04	23.98	48.80	67.05
	60	0.250	1.70	25.68	47.10	64.72
	100	0.150	2.70	28.38	44.40	61.01
	140	0.106	4.24	32.62	40.16	55.18
	200	0.075	5.60	38.22	34.56	47.49
	dry pan		0.34	38.56	34.22	
	wet pan			34.22	0.00	

d₁₀ (mm): 0.0065 d₅₀ (mm): 0.084
d₁₆ (mm): 0.018 d₆₀ (mm): 0.14
d₃₀ (mm): 0.048 d₈₄ (mm): 20

Median Particle Diameter--d₅₀ (mm): 0.084
Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 22
Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 2.5
Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 6.7

Classification of fines (visual method): ML

† Greater than 10% of sample is coarse material

ASTM Soil Classification: Silty sand with gravel (SM)g
USDA Soil Classification: Sandy Loam †

Laboratory analysis by: J. Newcomer
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02
Material Type: Growth Media
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:06

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

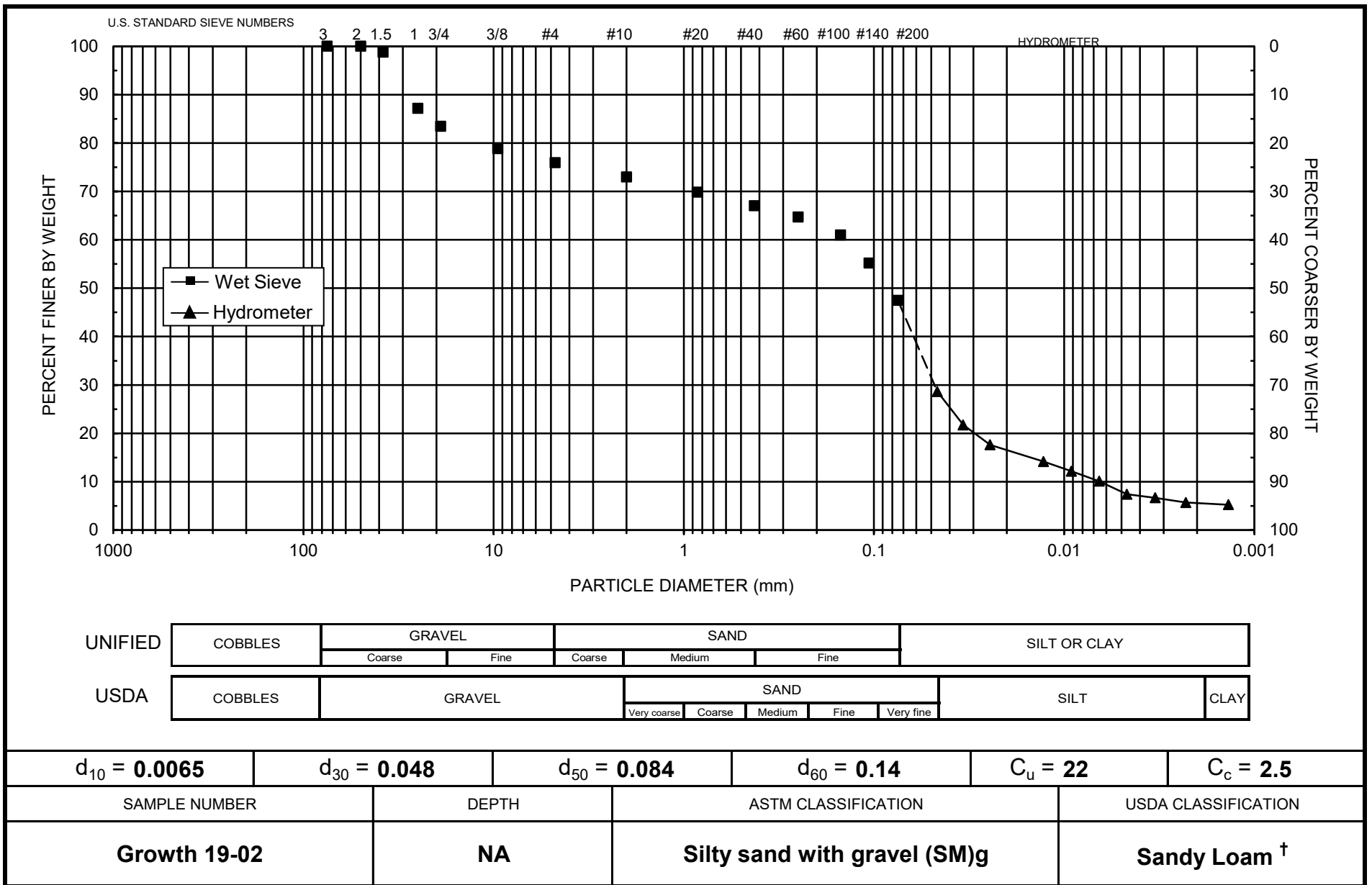
Initial Wt. (g): 53.13
Total Sample Wt. (g): 5828.40
Wt. Passing #10 (g): 4254.93

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	26.00	5.19	20.8	12	0.0464	39	28.6
	2	21.7	21.00	5.19	15.8	12	0.0340	30	21.7
	4	21.7	18.00	5.19	12.8	13	0.0245	24	17.6
	15	21.7	15.50	5.19	10.3	13	0.0128	19	14.2
	30	21.8	14.00	5.15	8.9	14	0.0092	17	12.2
	60	21.8	12.50	5.15	7.4	14	0.0065	14	10.1
	120	21.9	10.50	5.11	5.4	14	0.0047	10	7.4
	240	21.8	10.00	5.15	4.9	14	0.0033	9	6.7
	508	21.9	9.25	5.11	4.1	14	0.0023	8	5.7
18-Sep-19	1435	21.7	9.00	5.19	3.8	14	0.0014	7	5.2

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Thurgood
Data entered by: A. Albay-Yenney
Checked by: J. Hines



[†] Greater than 10% of sample is coarse material



Daniel B. Stephens & Associates, Inc.



Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-03
 Material Type: Growth Media
 Depth: NA
 Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 4962.44
 Weight Passing #10 (g): 4780.79
 Weight Retained #10 (g): 181.65
 Weight of Hydrometer Sample (g): 65.05
 Calculated Weight of Sieve Sample (g): 67.52

Shape: Angular
 Hardness: Hard and durable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	4962.44	100.00
	2"	50	0.00	0.00	4962.44	100.00
	1.5"	38.1	0.00	0.00	4962.44	100.00
	1"	25	0.00	0.00	4962.44	100.00
	3/4"	19.0	52.44	52.44	4910.00	98.94
	3/8"	9.5	32.93	85.37	4877.07	98.28
	4	4.75	51.02	136.39	4826.05	97.25
	10	2.00	45.26	181.65	4780.79	96.34
-10	(Based on calculated sieve wt.)					
	20	0.85	0.84	3.31	64.21	95.10
	40	0.425	0.83	4.14	63.38	93.87
	60	0.250	0.71	4.85	62.67	92.81
	100	0.150	1.47	6.32	61.20	90.64
	140	0.106	3.12	9.44	58.08	86.02
	200	0.075	5.21	14.65	52.87	78.30
	dry pan		0.56	15.21	52.31	
	wet pan			52.31	0.00	

d₁₀ (mm): 0.0012 d₅₀ (mm): 0.039
 d₁₆ (mm): 0.0026 d₆₀ (mm): 0.050
 d₃₀ (mm): 0.0083 d₈₄ (mm): 0.097

Median Particle Diameter--d₅₀ (mm): 0.039
 Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 42
 Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 1.1
 Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.046

Note: Reported values for d₁₀, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d₁₀ diameter

Classification of fines (visual method): ML

ASTM Soil Classification: Silt with sand (ML)s
 USDA Soil Classification: Loam

Laboratory analysis by: J. Newcomer
 Data entered by: A. Albay-Yenney
 Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-03
Material Type: Growth Media
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:12

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

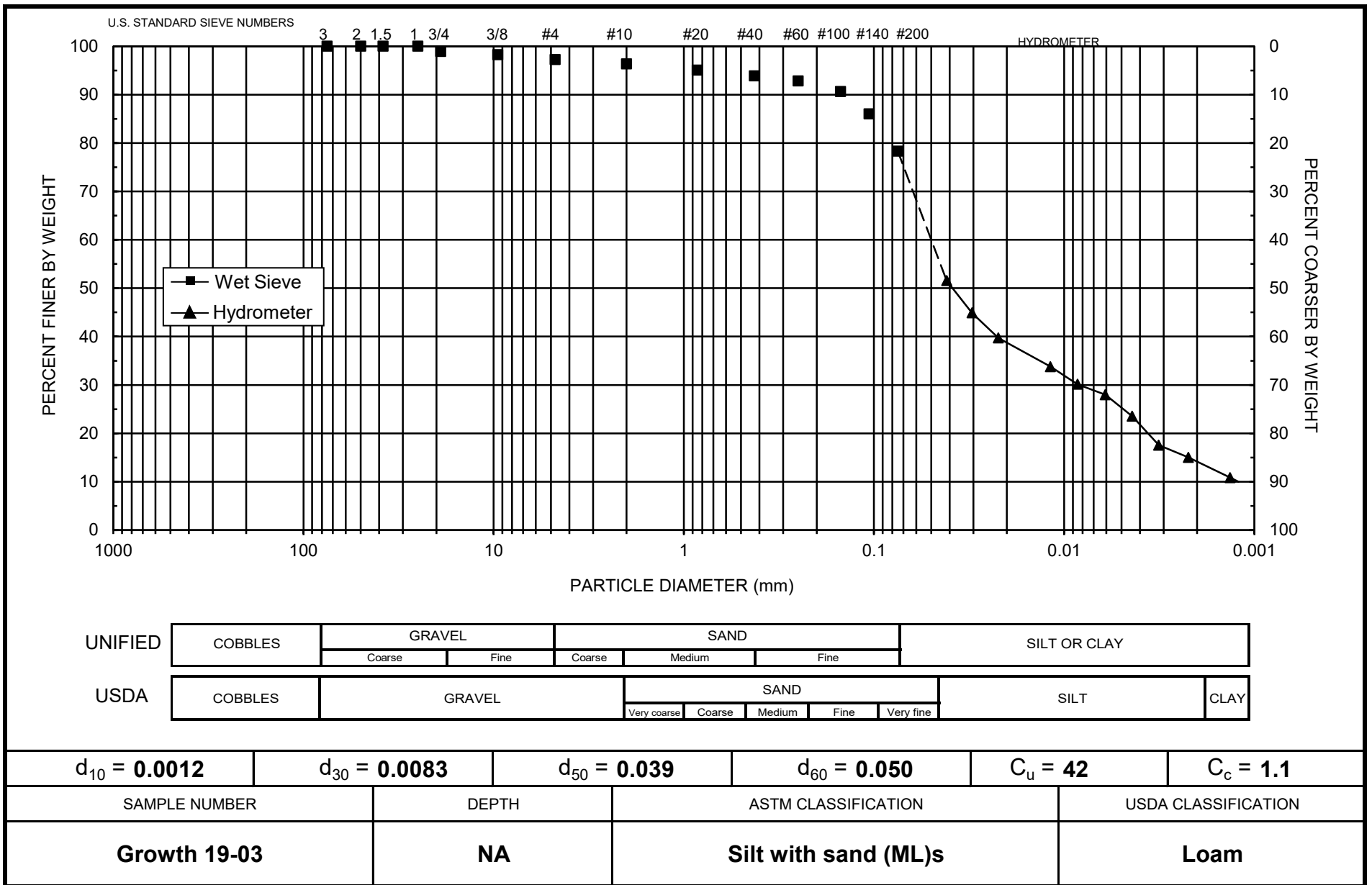
Initial Wt. (g): 65.05
Total Sample Wt. (g): 4962.44
Wt. Passing #10 (g): 4780.79

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	40.00	5.19	34.8	9	0.0415	54	51.6
	2	21.7	35.50	5.19	30.3	10	0.0305	47	44.9
	4	21.7	32.00	5.19	26.8	11	0.0222	41	39.7
	15	21.7	28.00	5.19	22.8	11	0.0118	35	33.8
	30	21.8	25.50	5.15	20.4	12	0.0085	31	30.1
	60	21.9	24.00	5.11	18.9	12	0.0061	29	28.0
	120	21.9	21.00	5.11	15.9	12	0.0044	24	23.5
	240	21.8	17.00	5.15	11.9	13	0.0032	18	17.5
	503	21.9	15.25	5.11	10.1	13	0.0022	16	15.0
18-Sep-19	1430	21.7	12.50	5.19	7.3	14	0.0013	11	10.8

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Thurgood
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Note: Reported values for d_{10} , C_u , C_c , and ASTM classification are estimates, since extrapolation was required to obtain the d_{10} diameter

Daniel B. Stephens & Associates, Inc.





Particle Size Analysis Wet Sieve Data (#10 Split)

Job Name: Piteau Associates
 Job Number: DB19.1317.00
 Sample Number: Growth 19-04
 Material Type: Growth Media
 Depth: NA
 Test Date: 20-Sep-19

Initial Dry Weight of Sample (g): 1104.24
 Weight Passing #10 (g): 1103.45
 Weight Retained #10 (g): 0.78
 Weight of Hydrometer Sample (g): 57.95
 Calculated Weight of Sieve Sample (g): 57.99

Shape: Angular
 Hardness: Hard and durable

Test Fraction	Sieve Number	Diameter (mm)	Wt. Retained	Cum Wt. Retained	Wt. Passing	% Passing
+10	3"	75	0.00	0.00	1104.24	100.00
	2"	50	0.00	0.00	1104.24	100.00
	1.5"	38.1	0.00	0.00	1104.24	100.00
	1"	25	0.00	0.00	1104.24	100.00
	3/4"	19.0	0.00	0.00	1104.24	100.00
	3/8"	9.5	0.00	0.00	1104.24	100.00
	4	4.75	0.00	0.00	1104.24	100.00
	10	2.00	0.78	0.78	1103.45	99.93
-10	(Based on calculated sieve wt.)					
	20	0.85	0.38	0.42	57.57	99.27
	40	0.425	0.79	1.21	56.78	97.91
	60	0.250	0.73	1.94	56.05	96.65
	100	0.150	1.70	3.64	54.35	93.72
	140	0.106	3.76	7.40	50.59	87.24
	200	0.075	6.01	13.41	44.58	76.87
	dry pan		0.65	14.06	43.93	
	wet pan			43.93	0.00	

d₁₀ (mm): 0.0027 d₅₀ (mm): 0.047
 d₁₆ (mm): 0.0057 d₆₀ (mm): 0.056
 d₃₀ (mm): 0.019 d₈₄ (mm): 0.095

Median Particle Diameter--d₅₀ (mm): 0.047
 Uniformity Coefficient, Cu--[d₆₀/d₁₀] (mm): 21
 Coefficient of Curvature, Cc--[(d₃₀)²/(d₁₀*d₆₀)] (mm): 2.4
 Mean Particle Diameter--[(d₁₆+d₅₀+d₈₄)/3] (mm): 0.049

Classification of fines (visual method): ML

ASTM Soil Classification: Silt with sand (ML)s
 USDA Soil Classification: Loam

Laboratory analysis by: J. Newcomer
 Data entered by: L. Thurgood
 Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Particle Size Analysis Hydrometer Data

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-04
Material Type: Growth Media
Depth: NA

Test Date: 17-Sep-19
Start Time: 9:18

Type of Water Used: DISTILLED
Reaction with H_2O_2 : NA
Dispersant*: $(NaPO_3)_6$
Assumed particle density: 2.65

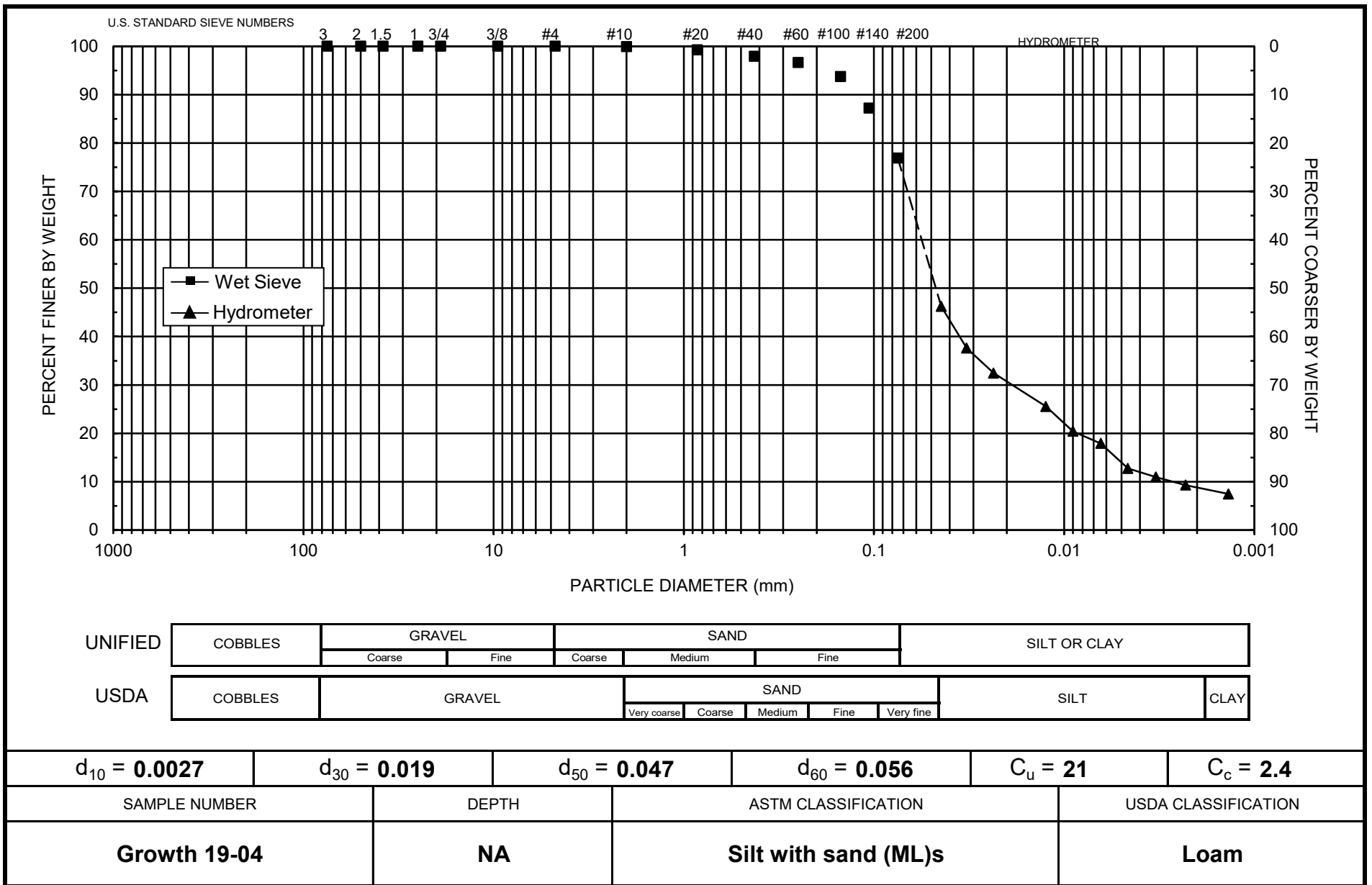
Initial Wt. (g): 57.95
Total Sample Wt. (g): 1104.24
Wt. Passing #10 (g): 1103.45

Date	Time (min)	Temp (°C)	R (g/L)	R _L (g/L)	R _{corr} (g/L)	H _m (cm)	D (mm)	P (%)	% Finer
17-Sep-19	1	21.7	32.00	5.19	26.8	11	0.0443	46	46.2
	2	21.7	27.00	5.19	21.8	11	0.0325	38	37.6
	4	21.7	24.00	5.19	18.8	12	0.0235	32	32.4
	15	21.7	20.00	5.19	14.8	13	0.0125	26	25.5
	30	21.8	17.00	5.15	11.9	13	0.0090	20	20.4
	60	21.9	15.50	5.11	10.4	13	0.0064	18	17.9
	120	21.9	12.50	5.11	7.4	14	0.0046	13	12.7
	240	21.8	11.50	5.15	6.4	14	0.0033	11	10.9
	498	21.9	10.50	5.11	5.4	14	0.0023	9	9.3
18-Sep-19	1425	21.7	9.50	5.19	4.3	14	0.0014	7	7.4

Comments:

* Dispersion device: mechanically operated stirring device

Laboratory analysis by: L. Daniell
Data entered by: L. Thurgood
Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Atterberg Limits/ Identification of Fines



Summary of Atterberg Tests

Sample Number	Liquid Limit	Plastic Limit	Plasticity Index	Classification
49-SWECO+1.0-D25B-138	49	25	24	CL
9-SWECO+1.0-E22B-348	52	26	26	CH
4-LFILTCAKE-E05B-315	---	---	---	ML
4381-Blend	43	37	6	ML
WD19-01	---	---	---	ML
WD19-02	---	---	---	ML
WD19-03	53	30	23	MH
Growth 19-01	---	---	---	ML
Growth 19-02	---	---	---	ML
Growth 19-03	---	---	---	ML
Growth 19-04	---	---	---	ML

--- = Soil requires visual-manual classification due to non-plasticity



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 49-SWECO+1.0-D25B-138
Material Type: Gangue
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:	34	26	17
Pan number:	LL1	LL2	LL3
Weight of pan plus moist soil (g):	124.54	128.86	130.72
Weight of pan plus dry soil (g)	120.73	124.19	124.41
Weight of pan (g):	112.54	114.65	111.98
Gravimetric moisture content (% g/g):	46.52	48.95	50.76
Liquid Limit:	49		

Plastic Limit

	Trial 1	Trial 2
Pan number:	PL1	PL2
Weight of pan plus moist soil (g):	121.25	124.10
Weight of pan plus dry soil (g)	119.95	122.75
Weight of pan (g):	114.76	117.41
Gravimetric moisture content (% g/g):	25.05	25.28
Plastic Limit:	25	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: 49
Plastic Limit: 25
Plasticity Index: 24
Classification: CL

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: D. O'Dowd
Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 9-SWECO+1.0-E22B-348
Material Type: Gangue
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:	31	26	19
Pan number:	LL1	LL2	LL3
Weight of pan plus moist soil (g):	127.60	129.27	132.33
Weight of pan plus dry soil (g):	123.29	124.30	127.76
Weight of pan (g):	114.77	114.78	119.34
Gravimetric moisture content (% g/g):	50.59	52.21	54.28
Liquid Limit:	52		

Plastic Limit

	Trial 1	Trial 2
Pan number:	PL1	PL2
Weight of pan plus moist soil (g):	118.91	118.93
Weight of pan plus dry soil (g):	117.77	117.75
Weight of pan (g):	113.46	113.28
Gravimetric moisture content (% g/g):	26.45	26.40
Plastic Limit:	26	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: 52
Plastic Limit: 26
Plasticity Index: 26
Classification: CH

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: D. O'Dowd
Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4-LFILTCAKE-E05B-315
Material Type: Tailings
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



**Data for Description and Identification of Fines
(Visual-Manual Procedure)**

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: 4-LFILTCAKE-E05B-315

Material Type: Tailings

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Light Yellowish Brown (2.5Y 6/4)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatency: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Daniel B. Stephens & Associates, Inc.

Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: 4381-Blend
Material Type: Tailings
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:	35	26	15
Pan number:	LL1	LL2	LL3
Weight of pan plus moist soil (g):	125.46	125.52	126.07
Weight of pan plus dry soil (g)	122.44	121.54	122.57
Weight of pan (g):	115.17	112.24	114.65
Gravimetric moisture content (% g/g):	41.54	42.80	44.19
Liquid Limit:	43		

Plastic Limit

	Trial 1	Trial 2
Pan number:	PL1	PL2
Weight of pan plus moist soil (g):	121.47	120.86
Weight of pan plus dry soil (g)	119.87	119.32
Weight of pan (g):	115.54	115.16
Gravimetric moisture content (% g/g):	36.95	37.02
Plastic Limit:	37	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: 43
Plastic Limit: 37
Plasticity Index: 6
Classification: ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: D. O'Dowd
Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-01
Material Type: Waste Rock
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



**Data for Description and Identification of Fines
(Visual-Manual Procedure)**

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: WD19-01

Material Type: Waste Rock

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Dark Yellowish Brown (10YR 3/6)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatency: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-02
Material Type: Waste Rock
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



**Data for Description and Identification of Fines
(Visual-Manual Procedure)**

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: WD19-02

Material Type: Waste Rock

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Brown (10YR 4/3)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatency: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: WD19-03
Material Type: Waste Rock
Depth: NA
Test Date: 23-Oct-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:	35	27	20
Pan number:	LL1	LL2	LL3
Weight of pan plus moist soil (g):	124.56	126.64	127.07
Weight of pan plus dry soil (g):	120.58	122.13	121.73
Weight of pan (g):	112.68	113.46	111.84
Gravimetric moisture content (% g/g):	50.38	52.02	53.99
Liquid Limit:	53		

Plastic Limit

	Trial 1	Trial 2
Pan number:	PL1	PL2
Weight of pan plus moist soil (g):	121.21	121.78
Weight of pan plus dry soil (g):	120.01	120.47
Weight of pan (g):	116.05	116.10
Gravimetric moisture content (% g/g):	30.30	29.98
Plastic Limit:	30	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: 53
Plastic Limit: 30
Plasticity Index: 23
Classification: MH

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-01
Material Type: Growth Media
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Data for Description and Identification of Fines (Visual-Manual Procedure)

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-01

Material Type: Growth Media

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Dark Brown (10YR 3/3)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatency: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-02
Material Type: Growth Media
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



**Data for Description and Identification of Fines
(Visual-Manual Procedure)**

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-02

Material Type: Growth Media

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Very Dark Grayish Brown (10YR 3/2)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatancy: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-03
Material Type: Growth Media
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



Data for Description and Identification of Fines (Visual-Manual Procedure)

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-03

Material Type: Growth Media

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Very Dark Grayish Brown (10YR 3/2)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatancy: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines



Atterberg Limits

Job Name: Piteau Associates
Job Number: DB19.1317.00
Sample Number: Growth 19-04
Material Type: Growth Media
Depth: NA
Test Date: 20-Sep-19

Liquid Limit

	Trial 1	Trial 2	Trial 3
Number of drops:			
Pan number:			
Weight of pan plus moist soil (g):			
Weight of pan plus dry soil (g)			
Weight of pan (g):			
Gravimetric moisture content (% g/g):	---	---	---
Liquid Limit:	---		

Plastic Limit

	Trial 1	Trial 2
Pan number:		
Weight of pan plus moist soil (g):		
Weight of pan plus dry soil (g)		
Weight of pan (g):		
Gravimetric moisture content (% g/g):	---	---
Plastic Limit:	---	

Results

Percent of Sample Retained on #40 Sieve: See Sieve

Liquid Limit: ---
Plastic Limit: ---
Plasticity Index: ---
Classification (Visual Method): ML

Comments:

- = Soil requires visual-manual classification due to non-plasticity
- * = 1-point method requested by client

Laboratory analysis by: D. O'Dowd
Data entered by: A. Albay-Yenney
Checked by: J. Hines



**Data for Description and Identification of Fines
(Visual-Manual Procedure)**

Job Name: Piteau Associates

Job Number: DB19.1317.00

Sample Number: Growth 19-04

Material Type: Growth Media

Depth: NA

Test Date: 20-Sep-19

Visual-manual classification of material passing the #40 sieve in lieu of
Atterberg analysis due to non-plasticity:

Descriptive Information:

Color of Moist Sample: Dark Brown (10YR 3/3)

Odor: None

Moisture Condition: Moist

HCl Reaction: None

Preliminary Identification:

Dry Strength: Low

Dilatency: Rapid

Toughness: Low

Plasticity: Non-plastic

Identification of Inorganic Fine Grained Soils:

Silt (ML)

Laboratory analysis by: D. O'Dowd

Data entered by: A. Albay-Yenney

Checked by: J. Hines

Laboratory Tests and Methods



Tests and Methods

Dry Bulk Density:	ASTM D7263
Moisture Content:	ASTM D7263, ASTM D2216
Calculated Porosity:	ASTM D7263
Saturated Hydraulic Conductivity: Falling or Constant Head: (Rigid Wall)	ASTM D5856
Hanging Column Method:	ASTM D6836 (modified apparatus)
Pressure Plate Method:	ASTM D6836
Water Potential (Dewpoint Potentiometer) Method:	ASTM D6836
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USDA Classification:	ASTM D7928, ASTM D6913, USDA Soil Textural Triangle
Atterberg Limits:	ASTM D4318
Visual-Manual Description:	ASTM D2488

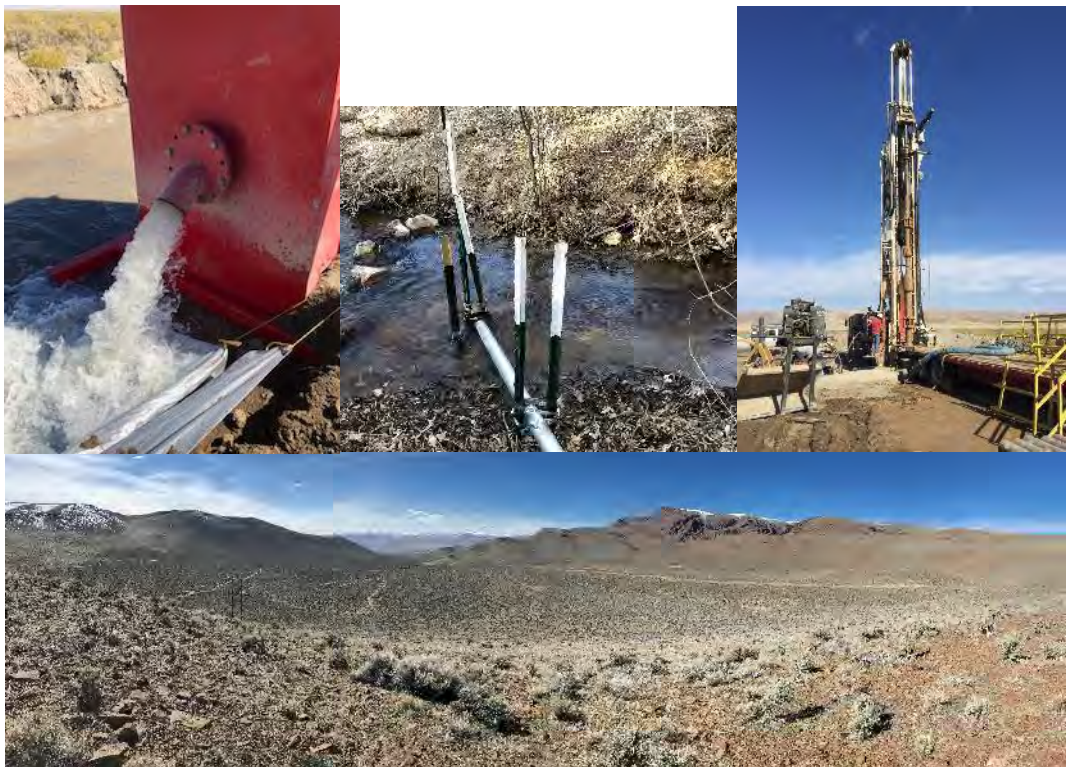
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PITEAU 2019 HYDROLOGY BASELINE REPORT



THACKER PASS PROJECT

BASELINE HYDROLOGIC DATA COLLECTION REPORT



Prepared for

LITHIUM NEVADA CORPORATION

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PROJECT 3989-R19-01

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1. INTRODUCTION

The following hydrologic baseline data collection report was written in support of the National Environmental Policy Act (NEPA) analysis for the proposed Thacker Pass Project (Figure 1.1).

This document presents hydrologic baseline data and analyses characterizing the groundwater and surface water systems adjacent to the Thacker Pass Project. Hydrologic baseline data was collected according to the “Lithium Nevada Corporation Baseline and Model Workplan” (Piteau, 2018a) approved by the BLM in August 2018. Baseline data was designed to meet the Data Adequacy Standards for the BLM and the guidelines for implementation of the Nevada BLM’s “Rock Characterization and Water Resources Analysis Guidance for Mining Activities” (IM Nos. NV-2010-014 and NV-2013-046) (BLM 2010 and 2013), “Water Resources Data and Analysis Policy for Mining Activities” (IM No. NV 2008-032) (BLM 2008a), and “Groundwater Modeling Guidance for Mining Activities” (IM No. NV-2008-035) (BLM, 2008b).

The objectives of the baseline data collection are as follows:

- Collect hydrologic data to accurately characterize baseline conditions for groundwater and surface water systems.
- Summarize hydrologic data (i.e. water levels, stream baseflows, spring discharge, and water quality).
- Develop the conceptual framework for groundwater and geochemical impact models.

Continuous hydrologic data collection commenced in 2011 and has gradually expanded in scope through present day. The chronology of data collection occurred across 5 main field campaigns between 2011 and 2018 which evolved around an expanding project layout. Description of the field campaigns’ scope is summarized as follows:

- **2011 groundwater investigation – Lumos:** A groundwater investigation was conducted by Lumos and Associates between February 2011 to March 2011 (Lumos, 2011a). Four (4) wells were drilled and tested (WSH-3, WSH-4, WSH-5, and WSH-6) in the vicinity of earlier pit designs. Only WSH-3 remains operational (Figure 1.2), all other wells were abandoned shortly after drilling.
- **2011 groundwater investigation – Schlumberger Water Services (SWS):** Additional groundwater investigations were designed and executed between August 2011 to October 2011. This campaign drilled 7 wells (WSH-7, WSH-8, WSH-11, WSH-13, WSH-14, WSH-17, PH-1 (Figure 1.2)), 5 of which have been continuously monitored for groundwater levels (SWS, 2013).
- **2011 to 2013 seep and spring surveys – SRK:** Seep and spring surveying was conducted for 36 potential locations. New springs were continuously added to the data set, extending the survey period to 7 quarters, although not all springs were monitored for the entire period.

Springs which were monitored for a period of at least 4 quarters were deemed complete (Lumos, 2011b) (SRK, 2011a, 2011b, 2012a, 2012b, 2012c, 2012d, 2013).

- **2017 water supply investigation – Piteau:** A groundwater resource investigation for mine water supply was conducted in Quinn River valley consisting of: magnetotelluric surface surveys, test hole drilling (PZ17-01), and hydraulic testing. Favorable hydrogeologic conditions led to the drilling of production well QRPW18-01 in 2018.
- **2018 hydrologic investigation – Piteau:** A comprehensive hydrologic investigation was developed to collect additional baseline data for an expanded project footprint represented by the current Thacker Pass Project area of interest (AOI). Key elements from this investigation were:
 - o Establishing 3 surface water gage stations at Crowley, Upper Thacker Creek, and Lower Thacker Creek.
 - o Installation of 9 new vibrating wire piezometer (VWP) locations, with multiple transducers deployed in each piezometer. In total 27 transducers are installed among the 9 new VWPs.
 - o Drilling and construction of 4 new monitoring wells.
 - o Seep and spring evaluation identifying 56 potential sites. Quarterly surveys were performed for 34 of these springs in 2018 and 2019. The other springs were sufficiently characterized previously.

This report presents the data collected during all field programs and revises the hydrologic conceptual model for the Thacker Pass Project AOI.

1.1 Project Description

The Thacker Pass Project is a proposed lithium mine and processing facility located approximately 20 miles west-northwest of Oroville, in Humboldt County, Nevada (Figure 1.1). Lithium ore is hosted in moat sediments, consisting of various claystones, in the southern portion of the McDermitt Caldera. The proposed project area of mining interest (AOI) and facility map is shown in Figure 1.2.

The Thacker Pass Project mine proposes an open-pit operation that requires minimal blasting given the soft nature of material. Claystone ore will be excavated, mechanically crushed, separated, made into a slurry, and placed in a leaching circuit using sulfuric acid as a lixiviant to liberate lithium from the claystone. Pregnant leach solution will be purified and processed to ultimately produce battery grade lithium carbonate (Li_2CO_3), lithium hydroxide (LiOH), and other lithium products. Tailings will be filter pressed and dry stacked on a lined, zero discharge, facility. A small waste rock facility (WRF) will be located southwest of the pit. Pit closure alternatives of a backfilled and open pit are under consideration and will be assessed in the groundwater quantity and quality impacts report.

Mining is anticipated to occur in two phases. Phase 1 will last for approximately 4 years at a production rate of approximately 33,000 tonnes per annum (tpa) of lithium carbonate equivalent. The construction of Phase 2 processing facilities is contingent upon economic and market conditions. While the operation will continue at Phase 1 level absent a decision to construct Phase 2, this report will assume the construction of Phase 2 to assess impacts. Phase 2 will increase the mining rate to 66,000 Li_2CO_3 tpa and last for approximately 37 years. Thus, the total projected mine life is 41 years. Construction and operations of the mine facilities include:

- Open pit mining below the water table;
- Slurry pipeline from mine to plant;
- Sulfuric acid plant;
- Lithium processing plant;
- Filter stack clay tailings facility;
- Waste rock facility (WRF);
- Coarse-gangue storage facility;
- Production wellfield located in Quinn River Valley and raw water pipeline to plant.

The open pit consists of three sub-pits (North, West, and South as shown in Figure 1.2) and is planned to be approximately 300 ft to 400 ft deep. Pit floor elevations of the North, West and South sub-pits are 4,757 ft, 4,774 ft, and 4,593 ft respectively (Figure 1.3). Cross-sections of the proposed open pit are shown in Figures 1.4 and 1.5. Measured groundwater elevations at the project area range from 4,810 ft to 5,270 ft, therefore the pit will intersect the water table. Some dewatering is anticipated to stabilize slopes and facilitate dry mining conditions. After approximately year 6, the open pit will be continuously backfilled with waste rock material during mining to minimize the footprint of above-ground storage facilities, support open-pit recontouring for closure, reduce dewatering requirements, and eliminate the eventual formation of a permanent pit lake upon closure (Figure 1.4 and Figure 1.5).

Process and potable water for the project will be sourced from an alluvial groundwater wellfield in Quinn River Valley and transported to the project site via pipeline. The projected water demand is 2,600 afy (1,615 gpm) for Phase 1 and 5,200 afy (3,230 gpm) for Phase 2.

Mine facilities with potential to impact surface and groundwater resources include:

- Open pit mine requiring dewatering or sump pumping;
- Closure conditions associated with either backfill or pit lake formation within the open pit;
- Water supply pumping for the duration of mine life via a wellfield located in Quinn River Valley;
- Waste rock facility construction. (zero discharge facility);
- Filter stack tailings storage facility construction (zero discharge facility).

2. BACKGROUND INFORMATION

The Thacker Pass Project area is situated in the north central region of the Basin and Range physiographic province in an area known as Thacker Pass, separating the Double H Mountains to the south from the Montana Mountains to the north (Figure 2.1). The project area is within the southern tier of the McDermitt Caldera Complex, which is the source for lithium-rich clays constituting the ore body.

2.1 Hydrographic Setting

The Thacker Pass Project straddles the topographic divide separating the Kings River Valley hydrographic basin (Rio King Subarea) and the Quinn River Valley hydrographic basin (Orovada Subarea) (Figure 2.1). The Kings River Valley hydrographic basin is divided into the Rio King Subarea to the north and the Sod House Subarea to the south. The Quinn River Valley hydrographic basin is divided into several subareas beginning with the Oregon Subarea furthest north, the McDermitt Subarea, the Orovada Subarea, and the Silver State Subarea furthest south. Topography surrounding the mine is typical of the Basin and Range province, consisting of narrow, short mountain ranges with moderate to high relief. The ranges are separated by broad valleys composed of basin fill and lacustrine deposits.

2.2 Climate

An onsite meteorological station (Thacker Pass Station) was installed in August 2011 and has continuously collected data to the present day (Figure 2.2). Project climatic conditions are arid, high desert with mild-cool winters and hot-dry summers. Average winter temperature is near freezing (32.5° F), with daily temperatures ranging from highs of ~50°F to lows of ~10°F. Summer temperatures range from highs of ~95°F to lows of ~50°F. Air moisture is generally arid, with relative humidity ranging from ~25% during summers to ~65% in winter.

2.2.1 Precipitation

The mean annual precipitation (MAP) recorded at the Thacker Pass Station is approximately 12.22 inches per year (Table 2.1), with monthly measured precipitation rates shown in Figure 2.3. The average monthly precipitation ranges between 0.32 inches (July) and 1.63 inches (December). Most precipitation occurs during the period November through May. These trends compare well to the nearby Orovada and Kings River Valley Stations whose average annual precipitation was 9.18 inches/yr and 9.12 inches/yr respectively (WRCC, 2019). For both Orovada and Kings River Valley Stations the lowest monthly precipitation occurs in August (0.09 and 0.13 inches), whereas the

highest precipitation month is March at the Orovada Station (1.38 inches) and December at the Kings River Valley Station (1.66 inch). Higher annual precipitation rates at Thacker Pass are reasonable given the station's elevation and mountainous location. Average monthly precipitation rates are shown in Table 2.2.

Table 2.1 Annual Meteorological Station Data (2011-2018)

Year	Precipitation (in)	Calculated PET (in)
2011 ¹	2.22	-
2012	11.49	65.0
2013	8.56	61.6
2014	15.71	60.6
2015	13.83	58.1
2016	13.33	57.9
2017	12.28	55.5
2018	10.33	58.3
Average	12.22	59.6

¹ Meteorological station installed August 2011, partial year

Table 2.2 Average monthly precipitation and PET (2011-2018)

Month	Thacker Pass Station Precipitation (in)	Calculated PET (in)
January	1.35	1.5
February	0.83	2.2
March	1.32	3.7
April	1.21	4.9
May	1.59	6.1
June	0.56	8.6
July	0.32	9.9
August	0.39	8.7
September	0.88	6.4
October	1.02	3.9
November	0.91	2.4
December	1.84	1.4
Total	12.22	59.6

2.2.2 Evaporation

Site specific potential evaporation rates (PET) were developed from hourly meteorological data continuously collected from the LNC station. PET was calculated using Penman-Monteith equation validated by the American Society of Civil Engineers standards (ASCE-EWRI, 2004). Average annual PET rates are 59.6 in/yr, with the highest periods of evaporation occurring during July (9.9 inches).

Winter months are calculated to have 1.4 inches to 2.2 inches of evaporation, which is an important difference from pan evaporation data, which freezes and underestimates evaporation during the winter. Calculated monthly average evaporation rates are shown graphically in Figure 2.4.

In comparison, the nearest pan data station is Rye Patch Reservoir, located approximately 58 miles to the south at an elevation of 4,135 ft. Annual average pan evaporation rates are 60 inches per year, which reduces to ~54.3 inches per year at Thacker Pass Project at an average elevation of 5,100 ft using the method of Shevenell (Shevenell, 1996).

2.3 Surface Water

2.3.1 Springs

A review of the Thacker Pass Project AOI and of potential seeps and springs from previous surveys, aerial photography, and topographic maps identified 56 seeps and springs within an expanded spring survey boundary (Figure 2.5). Thirty-six (36) seeps and springs were identified from prior seep and spring surveying including 22 seeps and springs which have been sufficiently characterized with at least four consecutive quarters of data collection and do not require continued monitoring as described in the workplan (Piteau, 2018a). The remaining 14 previously monitored seeps and springs have been chosen for continued monitoring because they represent important water supplies or the prior baseline surveys were less than four quarters. There are also 20 new potential seeps/springs identified for monitoring (16 locations identified in 2018 and 4 locations identified in 2019). Thus, a total of 34 locations were begun on a quarterly basis starting in Q1 2018 as part of the baseline data collection program. One location, SP-056, is actually a confluence location in upper Rock Creek designed to monitor flow at potential fish habitat (NDOW, 2018). Seep and spring survey data is further discussed in Section 3.2. Additional site descriptions and water chemistry samples can be reviewed in the spring and seep survey reports (Lumos, 2011b) and (SRK, 2011a, 2011b, 2012a, 2012b, 2012c, 2012d, 2013) and (Piteau, 2018b, 2018c, 2018d, 2019a, 2019b). Seep and spring locations are shown in Figure 2.5.

2.3.2 Streams

Perennial and ephemeral surface water locations are located near Thacker Pass Project include Thacker Creek, Pole Creek, Rock Creek, and Crowley Creek (Figure 2.5). Background information for each is described as follows:

- **Thacker Creek:** Historic streamflow monitoring performed over a span of 5 quarters in 1963 to 1964 identified an average flow rate of 0.39 cubic feet per second (CFS) or ~175 gpm (Malmberg, 1966). Supplemental streamflow monitoring conducted by LNC in 2018 confirmed these rates with measured flows ranging from 186 gpm to 234 gpm near the inlet

to Thacker Pond. Thacker Creek is a gaining stream, beginning from SP-011 (50 gpm to 80 gpm measured in 2018) to its discharge point at Thacker Pond. Thacker Creek receives contributions from several rheocrene springs in the area, as well as groundwater flow in the stream channel. For this reason, Thacker Creek can be conceptualized as a large rheocrene spring, or groundwater discharge system. A wetlands area in the headwaters of Thacker Creek (SP-010) is a large heleocone seepage area, discharging to phreatophytes, but generating little flow to the creek. Stream flow declines during summer months when water consumption by phreatophytes increases.

- **Pole Creek:** Pole creek is an ephemeral stream which originates in the Montana Range and infiltrates (loses) water as it flows across alluvium. The lower reaches of the creek are seasonally dry.
- There is no observed year-round baseflow in Pole Creek across the Thacker Pass Project AOI. The first groundwater expression is located as non-flowing seep at SP-036, but re-infiltrates into the stream channel prior to reaching alluvial fan sediments. During spring runoff, SP-039 discharges at high flow rates, which can temporarily sustain channel flow all the way to Crowley Creek. The reach between SP-039 to Crowley Creek is a losing stream, as observed from flow measurements in April 2018 (SP-039 = 188 gpm, at SP-043 = 84 gpm). Because there is only seasonal baseflow derived from groundwater in Pole Creek across the Thacker Pass Project AOI, only groundwater related impacts could occur.
- **Rock Creek:** Rock creek also originates in the Montana range and is also an ephemeral stream channel. The stream channel at the headwaters (SP-056) is seasonally dry. Ephemeral flows are observed in the creek bed from the confluence with Crowley Creek extending well into the Montana Range.
- **Crowley Creek:** Crowley Creek originates north of Indian Springs (SP-035) and goes through a series of gaining and losing reaches. Flow in Crowley Creek varies seasonally, reaching as far as Sentinel Rock (observed January to April 2018) and drying up prior to the confluence with Rock Creek (July and August 2018). Ultimately Crowley Creek infiltrates water across alluvium between Rock Creek and Quinn River Valley.

On a basin-scale, the main surface water feature is the Quinn River, which originates north of McDermitt and flows south. McDermitt Creek and the East Fork of Quinn River are major tributaries feeding the Quinn River (Figure 1.1) with an average annual flow rate of 30.51 cfs and 25.9 cfs respectively (USGS, 2018). Quinn River is a losing stream infiltrating to the alluvial groundwater system. Average stream flow at the McDermitt gage was 35.3 cfs, representing ~35% loss between the combined flows of McDermitt Creek and East Quinn River tributaries (distance of ~13 miles). A portion of this loss occurs as McDermitt and East Fork flow across basin alluvium prior to the confluence, while irrigation diversions account for some losses between these reaches. Quinn River flow is gone or highly reduced near Sod House (~26 miles south of the McDermitt gage station). Historically, during very wet winters, groundwater levels in the basin rise enough to support Quinn River flow through the basin, essentially flooding low portions of the valley (Visher,

1957). However, this has not been observed during the study period, likely owing to lowered basin-wide groundwater levels associated with irrigation pumping since the 1960s.

2.4 Well Inventory and Water Rights

Kings River Valley and Quinn River Valley are both designated basins that have fully allocated water rights, with perennial yields of 17,000 afy and 60,000 afy respectively. LNC has acquired water rights totaling 3,695.5 afy in Quinn River Valley through a combination of land purchases and options.

A survey of well logs from the state database identified 64 wells in Kings River Valley and 44 wells in Quinn River Valley drilled within a 5-mile radius of the Thacker Pass Project AOI (Figure 2.6). The majority are irrigation wells located in the alluvial basins with several stock and domestic wells also drilled in the alluvium. All wells within the AOI are owned by LNC, except for the qtr-qtr location for well log 380 is placed just inside the AOI boundary. This well is may be associated with several abandoned wells adjacent to SP-058.

There are 246 points of diversion located within a five-mile radius of the Thacker Pass Project AOI (Figure 2.7 and Appendix A). The diversion rate of allocated water rights ranges from 0.01 to 160 cubic feet per second (cfs) with annual duties ranging from 0 to 6,827 afy. The largest water right allocations are derived from surface water, primarily the Quinn River with diversion rates as high as 20.3 cfs. The highest spring-derived water rights are located in the northwest sector of the 5-mile radius in the western slope of the Montana Range in Kings River Valley. Predominant usage is irrigation, constituting 99% of appropriated water and 78% of the water right permits. Stock watering is used to a much lesser extent (0.3% of appropriated water and 19% of permits).

2.5 Geology

The Thacker Pass Project is located in north-central Nevada at the northern end of the Basin and Range tectonic province. This province stretches from southern Oregon to Mexico and is characterized by a series of extension-related normal faults trending roughly north-south resulting in a repetitive series of mountain ranges separated by valleys. Thacker Pass Project is located in one of the mountain ranges of this province; bounded to the north by the Montana Mountains; to the south by the Double H Mountains; to the west by the Kings River Valley; and to the east by the Quinn River Valley (Figure 2.8).

2.5.1 Thacker Pass Geology

Local geology of the Thacker Pass Project is controlled by the McDermitt Volcanic Field, a volcanic complex containing four large calderas (or “super volcanoes”) that formed in the middle Miocene.

Volcanic activity in the McDermitt Volcanic Field was contemporaneous with voluminous effusion of the earliest stages of the ~16.6 to 15 Ma Columbia River flood basalt lavas of Oregon, Nevada, Idaho, and Washington associated with impingement of the Yellowstone plume head (Coble and Mahood, 2012; Benson et al., 2017). Plume head expansion underneath the lithosphere resulted in crustal melting and surficial volcanism along four distinct radial swarms (Benson et al., 2017a). The McDermitt Volcanic Field is located within the southeastern-propagating swarm of volcanism from Steens Mountain into north-central Nevada. The Thacker Pass Project is located within the largest and southeasternmost caldera of the McDermitt Volcanic Field, the McDermitt Caldera.

The ~30 x 45 km keyhole-shaped McDermitt Caldera formed on eruption of the trachytic to rhyolitic Tuff of Long Ridge at ~16.33 Ma. Rytuba and McKee (1984) and Conrad (1984) initially interpreted the McDermitt Caldera as a composite collapse structure formed on piecewise eruption of four different ignimbrites from a single magma chamber. Recently, Henry et al. (2017) refined the stratigraphy to a singular ignimbrite called the McDermitt Tuff (herein called the Tuff of Long Ridge to avoid confusion). Regional reconnaissance work by Benson et al. (2017a) indicates that there was one large laterally-extensive and crystal-poor (<3 % feldspar) caldera-forming eruption (Tuff of Long Ridge), though other smaller-volume tuffs are exposed close to the vent and their eruptions and concomitant collapses may have contributed to the peculiar shape of the caldera. An estimated ~500 km³ of ignimbrite ponded within the caldera during the eruption, with ~500 km³ spreading out across the horizon up to 60 km from the caldera (Benson et al., 2017).

Prior to collapse of the McDermitt Caldera at 16.33 Ma, volcanism in the northern portion of the McDermitt Volcanic Field and locally small volumes of lavas erupted near the present-day Oregon-Nevada border (Figure 2.8). These lavas and the flood basalts are exposed along walls of the McDermitt Caldera and are ~16.5 Ma to ~16.3 Ma years old (Benson et al., 2017a; Henry et al., 2017). One of these lavas is a metaluminous biotite-bearing rhyolite lava just west of the caldera that is the host for uranium mineralization of the Moonlight Mine (Figure 2.8).

Following eruption of the Tuff of Long Ridge, a newly-identified crystal-rich (~15% feldspar and quartz) Tuff of Thacker Creek erupted along the western ring fracture zone of the McDermitt Caldera (Figure 2.9). The vents for this relatively small eruption are exposed along Thacker Creek, where two approximately 65-foot-wide tuff dikes crosscut the intracaldera facies of the Tuff of Long Ridge. From this vent area, the Tuff of Thacker Creek mostly flowed north atop intracaldera Tuff of Long Ridge, though a small volume flowed south into the caldera basin. The magmatic resurgence associated with this eruption resulted in a series of small (~165 ft maximum offset) normal faults radiating out from the vent area.

Following these eruptions, a large lake formed in the caldera basin. Associated caldera lake sediments that host the Thacker Pass deposit were deposited on top of the horsts and grabens

formed during the faulting associated with the Tuff of Thacker Creek (Figure 2.9). The lake captured sediments that were eroded from the surrounding drainage areas. Though no ash layers have been dated within the associated lacustrine sediments, it is estimated that sedimentation was active for ~100,000 years given that nearby Miocene caldera lakes lasted approximately this long (Coble and Mahood, 2012; Benson et al., 2017b). A cross-section of the caldera deposits at Thacker Pass is shown in Figure 2.10.

Contemporaneous with caldera lake sedimentation, minor-volume icelanditic, rhyolitic, and basaltic lavas erupted from small vents throughout the McDermitt caldera (Henry et al., 2017). Thin basaltic lava flows and rhyolitic ash beds are intercalated with caldera lake sediments in drill cores and show evidence for interaction with wet sediments, suggesting that caldera lake sedimentation occurred for the duration of post-caldera volcanism.

Lacustrine claystone sediments which host lithium ore are found intimately interbedded with thin, repetitive water laid ash sequences (Figure 2.11). Ash layers are well sorted, medium to coarse sized lapilli grains deposited across wide extents, particularly in the Southwest Basin where thick sequences of basal Ash beds were encountered across multiple exploration boreholes. Diagenesis at depth has silicified claystone beds in finely laminated, mudstone sequences (Figure 2.12). The ratio of ash to claystone in these lacustrine units is a continuum, with thick sequences of ash beds (~30 ft in LNC-126) found more abundantly in basal lacustrine deposits in the Southwest Basin Area, and greater components of claystone found in the open pit footprint. The rhyolitic Tuff of Long Ridge is found underlying lacustrine sediments and is present in latite textures of felsic phenocrysts to a fine-grained groundmass (Figure 2.13). In some instances, the Tuff of Long Ridge was deposited as viscous lava, forming flows and pseudo bedding planes. These deposits are referred to as Rheomorphic Tuffs (Figure 2.14).

In the southwest basin exploration area, a basal unit of rhyolitic ash are apparent in the core logs. Figure 2.15 shows the location of a series of geologic fence diagrams (Figures 2.16 through 2.22), which correlate the depth and extent of the basal ash layers. Ash beds are predominantly found south of the uplifted block of Long Ridge Tuff, known as Silica Hill, and the southern rim fault in the Southwest Basin. Thicker sequences are found south of state road 293 along section H-H' and I-I'. Ash deposits appear to thin and pinch out towards the east. Well logs indicate that the ash sequences are 50 ft to 200 ft thick.

Areal geophysical magnetic and resistivity surveys provide insight to stratigraphy and structure in the Thacker Pass Project area. An interpretation of survey data qualitatively combines magnetic and resistivity to identify the following geologic units:

- Tuff of Long Ridge: High magnetic / high resistivity.

- Claystone / Ash: Low magnetic / low resistivity.
- Indurated claystone: Low magnetic / moderate resistivity
- Basalt: High magnetic / moderate resistivity
- Basalt and andesite flows: moderate magnetic / low resistivity

Geophysical surveys clearly identify the western edge of the caldera (Tuff of Long Ridge) and the fault blocked uplifted tuff materials comprising Silica Hill (Figures 2.23 and 2.24). Lakebed sediments are identified as low magnetic and low resistivity (owing to higher porosity of sediments) in the central project area where the open pit will be mined (Figure 2.24). A lobe of caldera lake sediments is observed in the SW basin, which may be structurally bound to the west and east. A large high magnetic / moderate resistivity anomaly is interpreted to be basalt flows deposited above lake sediments, corresponding with thick sequences of basalt encountered while drilling WSH-3. An anomalous zone of low magnetic / moderate resistivity material is interpreted as silicified or well indurated claystones which reside south of Pole Creek. This unit is anticipated to possess greater abundance of claystone to ash and possess denser materials. The northern most zone is interpreted as basalt and andesite flows, corresponding to the basalt and volcanic ridges bordering Rock and Crowley creeks.

2.5.2 Quinn River Geology

Quinn River basin is comprised of a several thousand feet of alluvial sequence of basin fill alluvium composed principally of sand and gravel. The basin is bounded by the Santa Rosa mountains on the east and the Montana / Double H mountains in the west.

The Santa Rosa Mountains are comprised of Triassic to Jurassic age phyllite, argillite, and fine-grained quartzite (Huxel, 1966). Cretaceous granodiorite intrusion forms the prominent sawtooth peak and much of the central Santa Rosa range (Figure 2.8). The Montana mountains are comprised of Tertiary rhyolitic lavas and basalt flows, including the Tuff of Long Ridge, associated with vulcanism from the McDermitt Caldera. The Double H mountains are comprised of dacite and rhyolite flows, with more recent basalt flows deposited on top.

Basin-fill materials largely reflect the provenance of adjacent mountain ranges. Alluvial materials in the eastern margin of the valley are comprised of sub-angular to sub-rounded granite and quartzite gravels, influenced by the Santa Rosa Range. Gravels and cobbles of volcanic tuff comprise the western valley margin, with an increasing fraction of black basalt sands.

Younger alluvial sediments from reworked Quinn River basin fill sediments are deposited along the axis of the valley, removing finer-grained components in the sediment load and leaving channel deposits of well-sorted, rounded gravel / cobble beds across a ~12,000 ft swath in the valley center.

These beds pinch out laterally towards the basin margins, increasingly encountering greater fractions of medium to coarse-grained sand.

Older alluvium sediments are found along basin margins comprised of older alluvial fans and Lake Lahontan lacustrine deposits. Lacustrine deposits are placed on top older alluvial sediments typically above 4,380 ft amsl, in a 200-foot sequence mainly comprised of unconsolidated silt and clays. Deeper alluvial fans and basin fill materials are comprised of unconsolidated sand, silt, and clay in sequences of paleo floodplains, alluvial fans, and debris flows.

2.5.3 Kings River Geology

Kings River basin is comprised of a several thousand feet of alluvial sequence of basin fill alluvium composed principally of sand and gravel. The basin is bounded by the Montana / Double H mountains to the east and the Bilk Creek mountains on the west.

The Bilk Creek Mountains are also comprised of Tertiary dacite/rhyolite flows and basalt. Geomorphologic Lake Lahontan shorelines, beaches, and terraces are etched into the mountain range, particularly near the Coyote Hills (Malmberg, 1966).

Younger alluvial sediments generally comprise the upper 200 ft of Kings River valley in the valley floor. These units are composed of gravel, sand, silt, and clay in several geomorphological environments including paleochannels, talas deposits, alluvial fans, and beach/gravel bar deposits.

Older alluvium sediments are found along basin margins to a depth of 600 ft. These deposits are largely composed of gravel, sand, silt and clay in unconsolidated alluvium / colluvium. Older alluvium deposits have been faulted and uplifted along basin margins, producing outcrops at the range front.

2.5.4 Geologic Structures

Faults in the Thacker Pass Project are characterized over several episodes and structural trends. Key faults affecting geologic control are discussed as follows:

1. **Range front faults:** Major faults near the Thacker Pass Project are associated with Basin and Range extension and form the alluvial basin boundaries of Kings River and Quinn River Valleys. These faults began to form around 12 Ma, when the North American lithosphere began its extension in this area (Colgan et al., 2006; Lerch et al., 2008). Several thousand feet of offset have occurred, as noted by the steep topographic change in the western fringe of the Montana Mountains in Kings River Valley (Figure 2.8).
2. **Ring faults:** Ring faults form along the boundary of the western and southern extents of the McDermitt Caldera (Figure 2.9). The combination of ring faults and minor intra-caldera normal

faults associated with the Tuff of Thacker Creek formed a graben in the Thacker Pass Project area, preserving the Li-enriched lake sediments which have otherwise eroded from the Montana Mountain range. Ring faults control the western, southern, and eastern extents of Thacker Pass geology.

3. **E-W fault:** The principle E-W normal fault resides at the northern extent of the Thacker Pass Project, juxtaposing claystone sediments against the Tuff of Long Ridge by down dropping the southern footwall (Figure 2.9). The fault runs nearly east to west through Thacker Pass, and may also be associated with the secondary explosion of Thacker Creek Tuff. The E-W fault is an important feature which with the southern extent of ring faults, bounds the Thacker Pass Project geologically.
4. **Radial vent faults:** Younger faulting associated with the venting of Thacker Creek Tuff extend from the main vents above the headwaters of Thacker Creek into the surrounding claystone and volcanic tuff units (Figure 2.9). Vent faults form the topographically high ridges, such as Silica Hill, comprised of the Tuff of Long Ridge which separate northern lake sediments in the pit vicinity from southern lake and ash sediments. Vent faults also form several N-S trending structures in Thacker itself and the ridgeline west. Offset along vent faults is ~165 ft.
5. **Minor NE – SW faults:** Several minor NE-SW trending faults offset claystone and ash beds (Figure 2.9). The magnitude of offset in these faults is minor, on the order of tens of feet. However, their presence is hydrogeologically important in compartmentalizing groundwater flow by truncating thin but transmissive ash beds inter-deposited in claystone.

3. BASELINE HYDROGEOLOGIC DATA COLLECTION AND CHARACTERIZATION

This section provides comprehensive summary of all hydrologic field data collected to establish baseline conditions and characterize the surface and groundwater systems at the Thacker Pass Project. Data collection is discussed in four sections:

1. Surface water monitoring data
2. Seep and spring survey data
3. Groundwater monitoring
4. Hydrogeologic testing

3.1 Surface Water Monitoring

In April 2018, three (3) surface water monitoring gage locations were established in Crowley Creek, Upper Thacker Creek, and Lower Thacker Creek (Figure 3.1). Because the proposed mine plan does not affect the watershed of any nearby perennial or ephemeral streams, no impacts to the surface water runoff / interflow component of streamflow are anticipated. Therefore, the only potential impact to the streams is from the groundwater component of baseflow, if the cones of depression associated with dewatering and mining propagate to stream channels. The objectives of surface water monitoring were to:

- Characterize the component of groundwater baseflow to streams,
- Determine the seasonal demand of evapotranspiration,
- Characterize the hydrologic regime of spring runoff and storm events.

Surface water monitoring stations and data are discussed in the following sections. Station completion reports are provided in Appendix B.

3.1.1 Crowley Creek

A Crowley Creek gage station was established on April 6, 2018 in a straight, rock-lined segment that provided good hydraulic control (Figure 3.2). The station is located south of the confluence of Rock Creek and Crowley Creek, in a natural constriction of the stream channel. A decommissioned USGS gage station is located ~150 feet further south, where manual flow measurements for this study were collected.

A PT2X pressure transducer housed in a perforated aluminum pipe was anchored to several T-posts in the stream channel. The PT2X pressure transducer was connected to a Rom Comm Satellite transceiver (RID 804, Model 9601) and a 12-volt power supply to transmit via satellite to a remote database on an hourly interval. A barbed wire perimeter fence was established to discourage cattle and wild animals from disturbing the station. Manual flow measurements were collected when the stream was flowing to develop the rating curve. Several elevation benchmarks were established and surveyed periodically to check for sensor drift. A summary of manual measurements used to develop the rating curve are shown in Table 3.1. Streamflow data continues to be collected, however this report analyzes data collected between April 6, 2018 through May 3, 2019.

Discharge varies seasonally in Crowley Creek, peaking in March to April and tapering off during summer months. Dry, no flow conditions were observed from July through November 2018 corresponding to peak ET consumption. Flow resumed in late November, likely due to reduced evapotranspiration demand from upstream vegetation (Figure 3.3). The stream bed froze during early December 2018, producing several anomalous high-pressure readings from ice confinement which was corrected in the dataset. Average baseflow conditions are estimated to be 492 gpm from groundwater, all of which is consumed by ET during summer months.

Above average precipitation and snowfall, saturated ground conditions, and active storm patterns were conducive for generating high surface water flows in the creek during March 2019 and April 2019 which damaged the monitoring station. The first large flooding event occurred on February 27, 2019 (corresponding to 0.52 in of precipitation), where stream levels rose to a stage of ~0.8 m, overflowing the banks. A large amount of debris flow was associated with this event, getting caught in the fencing and T-bars of the monitoring station. Subsequent flood events occurred on March 7th, March 26th, April 8th, and April 17th, all of which generated peak flows in excess of 8,000 gpm. Corresponding 24-hr precipitation values were 0.08 in, 0.16 in, 0.12 in, and 0.08 in (LNC, 2019). Flow rates asymptotically declined between precipitation events (Figure 3.3), but the active weather pattern and runoff during April 2019 contributed to an average flow rate of ~13,235 gpm. Flow rates have declined at the end of April 2019 reaching ~5,000 gpm on May 3, 2019. Three manual flow measurements were taken during this period, confirming the elevated flow regime and re-building the rating curve after the monitoring gage station was repaired.

The Crowley station was repaired on April 11, 2019. Bench testing of the existing pressure transducer indicated that the sensor was underestimating pressure by a constant 11 cm offset. The malfunction is most likely related to freeze damage to the sensor's ceramic pressure plate, therefore this correction was implemented into the pressure data after December 2018. A replacement PT2X pressure transducer was installed May 3, 2019. The rating curve for Crowley Station is shown in Figure 3.4.

The observed spring flood events provides insight to the channel morphology of several streams in the area, where channels are wide, flat, and well scoured as a result of episodic flood events. However, the time weighted flow regimes are low or non-existent.

Table 3.1 Summary of Crowley Creek manual flow measurements

Date	Sensor reading (m)	Q (gpm)	Comments
4/6/2018 16:00	0.155	587.6	24 velocity stations
4/7/2018 10:30	0.161	778.1	22 velocity stations, high flow mark in storm event
5/9/2018 10:50	0.133	338.2	20 velocity stations
8/7/2018	Dry	Dry	Dry condition present from July 2018 – November 2018
12/10/2018	Frozen	Frozen	
3/19/2018 10:35	0.240	3,808	High flow, previous flooding event on Feb 27, 2019 had disturbed gage station.
4/11/2019 14:40	0.242	9,558	High flow, high velocity (~ 1 m/s)
4/25/2019 13:30	0.239	7,895	

3.1.2 Upper Thacker Creek

The Upper Thacker Creek gage station was established on April 6, 2018 in a very narrow, rock and sediment lined channel that provided good hydraulic control (Figure 3.5). The station is located south of the headwaters of Thacker Creek (SP-10 and SP-11) on the south side of State Route 293. A large heleoecrene spring / riparian area is the first indication of groundwater flow, which pools just north of State Route 293 and flows through a culvert, forming Thacker Creek proper. The construction of State Route 293 may have enhanced the formation of the riparian area by ponding surface water flow.

A PT2Xpressure transducer housed in a perforated aluminum pipe was anchored to several T-posts in the stream channel. The PT2X pressure transducer was connected to a Rom Comm Satellite transceiver (RID 804, Model 9601) and a 12-volt power supply to transmit via satellite to a remote database on an hourly interval. A barbed wire perimeter fence was established to discourage cattle and wild animals from disturbing the station. An earthen dam and pipe outflow were constructed to accurately measure volumetric flow measurements from the creek. The pipe consisted of a section of 8-inch Polyvinyl Chloride (PVC) pipe which was hand-buried in an earthen dam. The earthen dam was built up using sand bags of clay and silt material locally collected and sealed using 80 mil plastic sheet and bentonite. Manual flow measurements were then collected from the outflow structure using a 30-gallon or 5-gallon bucket. A summary of manual

measurements used to develop the rating curve is shown in Table 3.2. Streamflow data continues to be collected, however this report analyzes data collected between April 6, 2018 through May 3, 2019.

Flow rates varied seasonally in Upper Thacker Creek, peaking in spring months (~220 gpm) and tapering off during summer months (<5 gpm). Upper Thacker always flowed, indicative of groundwater supplied baseflow. Baseflow estimates are ~66.3 gpm (Figure 3.6). Summer declines in flow are attributed to increased evapotranspiration demand in riparian meadows upgradient of the station and along the channel banks. ET consumption for the meadows are estimated to be ~53.7 gpm from spring flow data. A separate increase in flow was observed during the end of the 35-day pumping test, as the wetting front from pumping well discharge infiltrated upgradient of the monitoring station in dry channel beds and eventually discharged to the creek. The elapse time between the onset of pumping and flow accretions in the creek was 26-days. A flood event in April 2019 had peak flow of ~840 gpm, corresponding with saturated ground conditions and precipitation. Similar events were recorded at the Crowley and Lower Thacker stations.

The rating curve for Upper Thacker is shown in Figure 3.7.

Table 3.2 Summary of Upper Thacker Creek manual flow measurements

Date	Sensor reading (m)	Q (gpm)	Comments
4/6/2018 11:00	0.163	102.4	
4/7/2018 8:30	0.177	171	Captured peak flow during storm event
4/7/2018 11:15	0.162	108	
5/9/2018 12:50	0.13	50	
8/7/2018 12:28	0.039	5.6	
11/9/2018 12:12	0.1917	119.7	Shift in rating curve, affected by cattle
12/11/2018 10:49	0.149	52.58	
1/22/2019 15:41	0.1786	126.4	
3/19/2018 10:35	0.130	45.0	

3.1.3 Lower Thacker Creek

The Lower Thacker Creek gage station was established on April 4, 2018 in a narrow, rock-lined channel that provided good hydraulic control (Figure 3.8). The station is located upgradient (east) of Thacker Pond, which is a man-made impoundment of water from Thacker Creek. Thacker Pond is an ecological resource, providing habitat for fish and waterfowl, as well as a resource for stock water and recreation (fishing).

A PT2X pressure transducer housed in a perforated aluminum pipe was anchored to several T-posts in the stream channel. The PT2X pressure transducer was connected a 12-volt power supply. A barbed wire perimeter fence was established to discourage cattle and wild animals from disturbing the station. Manual measurements were taken from a narrow stream section approximately 30 ft downstream of the channel control. A summary of manual measurements used to develop the rating curve are shown in Table 3.3. Data collected between April 4, 2018 through May 3, 2019 is summarized in this report.

Flow at Lower Thacker Creek is perennial, with smaller seasonal variation than at the Upper Thacker monitoring station. Spring time flows are ~270 gpm to 330 gpm during March and April. Baseflow rates are estimated to be 234 gpm (Figure 3.8). Summertime ET consumption is estimated to be 93.8 gpm for the upgradient reach above Lower Thacker Creek, including the 53.7 gpm associated with Upper Thacker Station. Thus, an additional 40 gpm of ET consumption is estimated to occur between the Upper and Lower Thacker monitoring stations during summer months.

The stream section between the Upper and Lower Thacker monitoring stations is a gaining reach, increasing by 120 gpm to 190 gpm throughout the year (Figure 3.10). This reach is fed by multiple smaller springs (SP-012, SP-029, SP-030, SP-031, SP-034, SP-041, SP-057), but also is supported by groundwater inflow to the channel as the spring contributions alone are insufficient. In this sense, Thacker Creek and surrounding springs are conceptually apart of a single large spring complex, supporting baseflow in Thacker Creek. The rating curve for Lower Thacker Station is presented in Figure 3.11.

Table 3.3 Summary of Lower Thacker Creek manual flow measurements

Date	Sensor reading (m)	Q (gpm)	Comments
4/4/2018 17:00	0.104	206.4	
4/6/2018 13:00	0.123	285.8	
4/7/2018 9:30	0.127	334	Captured peak flow during storm event
5/9/2018 14:55	0.109	187	
8/7/2018 13:45	0.087	82	
12/11/2018 11:30	0.104	218	
3/19/2018 16:45	0.0963	244	Shift in rating curve

3.2 Seep and Spring Survey

Seep and spring surveying spans two data collection programs. The first surveys collected data at 36 potential spring locations from 2011 to 2013 and was performed by Lumos (Lumos, 2011b) and

SRK (SRK, 2011a, 2011b, 2012a, 2012b, 2012c, 2012d, 2013). A second suite of seep and spring surveys was resumed in 2018 by Piteau across a larger footprint (Piteau, 2018a; Piteau, 2018b; Piteau, 2018c; Piteau, 2019a; Piteau, 2019b). The second survey resumed data collection at 14 locations because they represent important water supplies, and at 20 new potential seep/spring locations. Spring surveying followed Level I protocols guidelines (Stevens, 2016) for over a period of four consecutive quarters. The survey area spanned across 73,769 acres and an elevation range of ~2,100 ft (4,480 ft amsl to 6,600 ft amsl). Spring locations are shown in Figure 3.12. A summary of seep and spring information is provided in Table 3.4.

Table 3.4 Summary of seep and spring information

Spring Name	Northing (m)	Easting (m)	Elevation (ft, amsl)	Type	Description	Status	Average Flow (gpm)	Flow Status
BLM-01	417071	4622042	4952	n/a		Previously Monitored	0	None
BLM-02	406399	4619896	5040	Rheocrene		Previously Monitored	NS	Perennial
BLM-03	406384	4620052	5031	Rheocrene		Previously Monitored	NS	Ephemeral
BLM-04	406257	4617472	4403	Rheocrene		Previously Monitored	NS	Ephemeral
BLM-05	415829	4615395	4639	Runoff	Runoff, not natural spring	Previously Monitored	0	None
BLM-06	415652	4614210	4852	Stock pond	Stock pond, not natural spring	Previously Monitored	0	None
SP-001	411630	4618330	5129	n/a	Trough area, not natural spring	Previously Monitored	0	Ephemeral
SP-002	415003	4616575	4629	n/a		Previously Monitored	<1	Ephemeral
SP-003	411202	4621433	5941	n/a		Previously Monitored	0	None
SP-004	406917	4622902	6492	Hillslope	Some Flow	Continue Monitoring	1.2	Perennial
SP-006	407225	4623634	6627	Hillslope		Previously Monitored	<1	Perennial
SP-007	407852	4623387	6670	Rheocrene	Big Bend Spring; No Flow Observed	Continue Monitoring	0	None
SP-008	408367	4622208	6389	Rheocrene		Previously Monitored	0	Developed
SP-010	408054	4617328	4562	Heleocrene	Thacker Creek drainage	Continue Monitoring	0	Perennial
SP-011	408095	4617301	4553	Rheocrene	Thacker Creek drainage	Continue Monitoring	40	Perennial
SP-012	407355	4617097	4563	Hillslope	Composed of 3 small seeps/springs	Continue Monitoring	6.1	Perennial
SP-015	410586	4614404	5302	Hillslope		Previously Monitored	0	None
SP-017	412392	4613379	5268	Hillslope		Previously Monitored	0	None
SP-018	415848	4615360	4643	n/a	Trough area, not natural spring	Previously Monitored	0	None
SP-022	415511	4613579	5141	Rheocrene		Previously Monitored	1-5	Ephemeral
SP-023	421048	4622701	4641	Rheocrene		Previously Monitored	<1	Ephemeral
SP-025	418128	4618778	4644	Hillslope		Previously Monitored	0	None

Spring Name	Northing (m)	Easting (m)	Elevation (ft, amsl)	Type	Description	Status	Average Flow (gpm)	Flow Status
SP-028	416954	4619331	4798	Rheocrene		Previously Monitored	5.1	Perennial
SP-029	407490	4617228	4579	Rheocrene		Previously Monitored	0	Perennial
SP-030	407397	4617231	4554	Hillslope	Apart of SP-012?	Previously Monitored	<1	Perennial
SP-031	407281	4617220	4523	Hillslope		Previously Monitored	<1	Perennial
SP-032	407809	4617218	4499	Hillslope		Previously Monitored	<1	Perennial
SP-033	408488	4616888	4651	Rheocrene	Thacker Pass drainage	Continue Monitoring	0.95	Perennial
SP-034	408020	4617119	4551	Rheocrene	Thacker Creek drainage	Continue Monitoring	1.1	Ephemeral
SP-035	421023	4622651	4769	Heleocrene	Indian Springs	Continue Monitoring	0	Perennial
SP-036	414679	4621170	5011	Rheocrene	Pole Creek	Continue Monitoring	1.1	Ephemeral
SP-037	412456	4612715	5601	Hillside	Double H north face	Continue Monitoring	0	Ephemeral
SP-038	412548	4612835	5532	Heleocrene	Double H north face	Continue Monitoring	0.4	Ephemeral
SP-039	418033	4618907	4579	Rheocrene	Same spring Complex as SP-40	Continue Monitoring	21	Ephemeral
SP-040	418072	4618900	4657	Rheocrene	Same spring complex as SP-39	Continue Monitoring	0.48	Ephemeral
SP-041	407731	4617264	4577	Hillslope	Thacker Pass drainage	Continue Monitoring	1.5	Perennial
SP-042	421265	4622673	4750	Heleocrene	Indian Springs complex	2018 New Site	0	Perennial
SP-043	419711	4617998	4540	Hillslope	Pole Creek drainage	2018 New Site	2.3	Ephemeral
SP-044	410567	4613976	5293	Rheocrene	Double H north face	2018 New Site	0.25	Ephemeral
SP-045	410412	4613675	5413	Hillslope	re-routed; no riparian area	2018 New Site	0.43	Ephemeral
SP-046	419129	4625812	5091	Heleocrene	no flow; small pond	2018 New Site	0.43	Ephemeral
SP-047	405802	4621972	4892	Hillside	good flow channelized flow	2018 New Site	16.2	Perennial
SP-048	405664	4623896	4822	Rheocrene	good flow channelized flow	2018 New Site	24	Perennial
SP-049	404787	4624310	4668	Hillside	good flow channelized flow	2018 New Site	10.1	Perennial
SP-050	410976	4626057	n/a	n/a	-	2018 New Site	3.5	Perennial
SP-051	408094	4626907	6645	Hillside	Lyle's Spring	2018 New Site	4.1	Perennial
SP-052	407307	4627994	6601	Rheocrene	Rock Creek Spring	2018 New Site	8.7	Ephemeral
SP-053	407381	4627971	n/a	n/a	Rock Creek Spring	2018 New Site	n/a	None
SP-054	407128	4628670	6770	Hillside	Rock Creek Spring	2018 New Site	1.9	Ephemeral
SP-055	408356	4628858	6598	Hillside	Rock Creek Spring	2018 New Site	3	Ephemeral
SP-056	408550	4628257	6510	Hillside	Confluence up Rock Creek, perennial wetland	2018 New Site	3.1	Ephemeral
SP-057 ¹	410967	4626035	5948	Hillside	Thacker Pass drainage	2018 New Site	1.3	Perennial

Spring Name	Northing (m)	Easting (m)	Elevation (ft, amsl)	Type	Description	Status	Average Flow (gpm)	Flow Status
SP-058	414899	4619264	4911	Helocrene	Developed depression	2019 New Site	n/a	Ephemeral
SP-059	413499	4618705	4999	Helocrene	Developed depression with nearby wells	2019 New Site	n/a	Ephemeral
SP-060	414499	4620060	5079	Rheocrene	Headwaters of ephemeral drainage	2019 New Site	24.8	Ephemeral
SP-061	414697	4619219	4916	Helocrene	Small Hillside depression	2019 New Site	7.0	Ephemeral

Detailed descriptions of spring flows, chemistry, and riparian area are available in the individual Seep and Spring Survey reports submitted to the BLM. Spring flow hydrographs are provided in Appendix C.

The 2018 seep and spring survey, in concert with previous surveys and data collection, has led to the following set of conclusions for the entire survey dataset of 54 seeps and springs extending back to June 2011.

- Twelve (12) identified seep and spring locations are not truly expressions of groundwater and should not be classified as springs (Table 3.4 & Figure 3.12). The locations that should not be classified as springs are identified as BLM-01, BLM-05, BLM-06, SP-003, SP-007, SP-015, SP-017, SP-018, SP-025, SP-053, SP-058, and SP-059. These locations are generally developed stock ponds, pipelines from upgradient springs, or runoff catchments. In some cases, there has never been evidence of a groundwater expression (BLM-01, BLM-05, BLM-06, SP-003, SP-025).
- Twenty (20) springs are classified as ephemeral (Figure 3.13). Discharge peaks during Q2 and the site becomes dry during Q3 or Q4. The majority of the springs in Pole and Rock Creeks are ephemeral, such that the creeks do not flow perennially. In particular, the headwater of Rock Creek is seasonally dry as observed at SP-056, which was a surface water monitoring location. Although groundwater related impacts are not anticipated to occur, but will be analyzed, hypothetically reducing spring discharges is unlikely to affect aquatic habitat due to the streams' and springs' ephemeral nature. Spring flow hydrographs are shown in Appendix C.
- Twenty-one (21) springs are classified as perennial (Figure 3.13). These springs with the greatest potential for groundwater related impacts are found along the Thacker Creek spring system (Figure 3.13). A separate groundwater quantity and quality impacts report (currently being prepared by Piteau Associates) will quantify the potential impacts to flow at these locations. Range front springs in Kings River Valley are anticipated to be too far away to be impacted by activities at Thacker Pass.
- Water chemistry is generally Ca-HCO₃ type or Na-HCO₃ type (Figure 3.14). Higher elevations springs in the headwaters of Rock Creek, and the spring near Thacker Creek tend to be more calcium-rich, while springs near Pole Creek and the Double H mountains

are slightly more sodium-rich. Some analysis spring locations are SP-001, which was a stock watering trough location, and BLM-02.

- Some anomalous locations possess high concentrations in (SP-002, SP-010, SP-034) and sodium – chloride rich water chemistries (SP-045, SP-001, SP-044). Sodium-chloride rich locations correspond with developed springs which may affect spring chemistry in transit from its natural expression.
- Water chemistry analyses indicate that the majority of springs exceed Nevada Reference Values (NRVs) for arsenic (Table 3.5). Of the 116 samples collected, 76 (66%) have exceeded the 0.01 mg/L NRV for arsenic. This is representative of background groundwater conditions and believed to be derived from host rock which is primarily volcanic tuff, claystone, or basalt and conducive to leaching arsenic. Arsenic concentrations are consistently elevated in the Thacker Creek system with an average concentration of ~0.04 mg/L and exceedances at every spring, indicating an elevated arsenic background condition.
- Aluminum, iron, and manganese also exceed NRVs at several spring locations. These exceedances occur for 22%, 22%, and 19% of total samples respectively.

Table 3.5 Summary of seep and spring Profile I exceedances

Location	No. Samples	Aluminum		Arsenic		Chloride		Iron		Manganese		Sulfate		TDS		Total Nitrogen	
		No.	% of	No.	% of	No.	% of	No.	% of	No.	% of	No.	% of	No.	% of	No.	% of
BLM-02	3	0	-	3	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-001	1	1	100%	0	-	0	-	1	100%	0	-	0	-	0	-	0	-
SP-002	1	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	0	-
SP-004	4	0	-	3	75%	0	-	0	-	0	-	0	-	0	-	0	-
SP-007	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-
SP-010	7	1	14%	3	43%	0	-	3	43%	3	43%	0	-	1	14%	2	29%
SP-011	5	0	-	4	80%	0	-	1	20%	4	80%	0	-	0	-	0	-
SP-012	8	0	-	8	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-017	1	1	100%	0	-	0	-	1	100%	0	-	0	-	0	-	0	-
SP-023	2	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
SP-025	1	1	100%	0	-	0	-	1	100%	0	-	0	-	0	-	0	-
SP-028	3	0	-	3	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-030	1	0	-	1	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-031	3	0	-	3	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-032	4	0	-	4	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-033	4	0	-	4	100%	0	-	1	25%	3	75%	0	-	0	-	0	-
SP-034	3	0	-	3	100%	0	-	1	33%	1	33%	0	-	1	33%	1	33%
SP-035	6	1	17%	2	33%	0	-	0	-	1	17%	0	-	0	-	0	-
SP-036	3	3	100%	0	-	0	-	2	67%	0	-	0	-	0	-	0	-
SP-037	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-
SP-038	3	1	33%	0	-	0	-	1	33%	0	-	0	-	0	-	0	-
SP-039	2	2	100%	0	-	0	-	1	50%	0	-	0	-	0	-	0	-
SP-040	3	3	100%	1	33%	0	-	2	67%	0	-	0	-	0	-	0	-
SP-041	6	1	17%	6	100%	0	-	1	17%	0	-	0	-	0	-	0	-
SP-042	3	0	-	3	100%	0	-	0	-	1	33%	0	-	0	-	2	67%
SP-043	1	1	100%	1	100%	0	-	1	100%	0	-	0	-	0	-	0	-
SP-044	1	0	-	1	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-045	4	0	-	3	75%	0	-	0	-	0	-	0	-	2	50%	0	-
SP-046	1	1	100%	0	-	0	-	1	100%	0	-	0	-	0	-	0	-
SP-047	4	0	-	4	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-048	4	0	-	4	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-049	4	0	-	4	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-050	3	3	100%	0	-	0	-	3	100%	0	-	0	-	0	-	0	-
SP-051	4	0	-	4	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-052	2	1	50%	1	50%	0	-	1	50%	1	50%	0	-	0	-	0	-
SP-054	3	0	-	0	-	0	-	1	33%	2	67%	0	-	0	-	0	-
SP-055	2	1	50%	0	-	0	-	1	50%	0	-	0	-	0	-	0	-
SP-056	2	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
SP-057	2	0	-	2	100%	0	-	0	-	0	-	0	-	0	-	0	-
SP-060	1	1	100%	0	-	0	-	1	100%	0	-	0	-	0	-	0	-
SP-061	1	1	100%	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Total	116	25	22%	76	66%	1	1%	26	22%	17	15%	1	1%	5	4%	5	4%

NS – not sampled

3.3 Groundwater Monitoring

Groundwater piezometric levels have been monitored through a series of 10 grouted-in piezometers, 9 active monitoring wells, and 3 production wells located across the Thacker Pass Project (Figure 3.15). A description of the groundwater monitoring network is provided in the following sections.

3.3.1 Piezometers (VWPs)

Ten (10) grouted-in piezometers have been installed across the Thacker Pass Project. One (1) VWP was installed during the 2017 production well investigation (PZ17-01), and the remaining 9 were drilled during the 2018 groundwater investigation program (PZ18-01 through PZ18-09). Each VWP is comprised of 2 to 4 individual 4500s series Geokon vibrating wire transducers deployed in the borehole at target depth intervals. A summary of VWP installations is provided in Table 3.6. VWP locations were strategically located to monitor water levels at key mine or hydrologic features. Water level hydrographs for piezometers are shown in Figure 3.16a to Figure 3.16j, with a combined hydrograph shown in Figure 3.16a. Completion diagrams for grouted-in piezometers are shown in Appendix D. A discussion of piezometers is as follows:

PZ18-01: Two sensors were deployed in PZ18-01, both in volcanic tuff. PZ18-01 was located to monitor the water level response in the uplifted horst block of volcanic tuff in Silica Hill to characterize communication between the proposed pit area and the southwest portion of the Thacker Pass Project. Water levels have equilibrated between 4813 ft amsl to 4821 ft amsl and remained steady (Figure 3.16b). This piezometer showed no response to the TW18-02 35-day pumping test.

PZ18-02: PZ18-02 was completed with 3 sensors in the bottom of alluvium and in lacustrine claystone/ash sediments. The piezometer is located near the E-W fault structure, in the hanging wall, and encountered a very thick section (~300 ft) of alluvium. This location was selected to serve as a sentinel monitoring point at the northeastern edge of the Thacker Pass Project near Pole Creek and SP-026. Water levels have gradually equilibrated since installation to ~4,780 ft elevation and remained steady (Figure 3.16c).

PZ18-03: Three (3) sensors were deployed in Claystone/Ash beds in PZ18-03. PZ18-03 is located on the eastern edge of the Thacker Pass Project to characterize water levels between the Thacker Pass Project and Pole Creek catchment. This location is east of the proposed process and tailings facilities. Water levels have equilibrated at ~ 4,681.5 ft elevation (Figure 3.16d). Data collection was temporarily affected by water in the data logger.

PZ18-04: A total of 4 sensors were placed in borehole (3 in claystone/ash and clay sediments, 1 in volcanic tuff). PZ18-04 was selected to characterize the northern portion of the Thacker Pass Project, upgradient from future pits and facilities. Water levels have equilibrated to between 4815 ft amsl to 4829 ft amsl, forming a small upward gradient (0.05 ft/ft) (Figure 3.16e).

PZ18-05: Three (3) sensors were installed, however the deepest sensor placed in rheomorphic tuff malfunctioned shortly after the installation. Water levels equilibrated to the ~4625 ft elevation, and showed very little, if any, response to the 35-day pumping test when correcting for pre-existing trends (Figure 3.16f). PZ18-05 is a sentinel piezometer adjacent to Thacker Creek. No claystone was present in the borehole, rather there was thick sections of rheomorphic rhyolite tuff, suggesting a geologic contact resides between PZ18-05 and PZ18-07. The contact is believed to be a combination of deposition and structural, with offset occurring along the N-S trending vent fault coincident with the drainage between PZ18-05 and PZ18-07.

PZ18-06: This piezometer was drilled atop a basalt flow and encountered thick sections of claystone/ash interbedded with some basalt. PZ18-06 is the only sensor in the southwest basin of the Thacker Pass Project and was located to characterize this southern extent and as a monitoring point during the 35-day pumping test. Two (2) sensors were deployed in the borehole. Water levels equilibrated to the 4761 ft and 4759 ft elevations (Figure 3.16g). Response to the 35-day pumping test was overprinted by equilibration of water levels, thus little to no drawdown was observed at PZ18-06.

PZ18-07: This piezometer was located as a monitoring location for the 35-day pumping test. Four (4) sensors were placed in claystone/ash beds and in basalt. The location for this well, and the production well for the long-term test, was selected to test the hydraulic connection between Thacker Creek and Silica Hill where PZ18-01 resides. Water levels have equilibrated to between 4676 ft to 4679 ft elevation after recovering from the 35-day test (Figure 3.16h). Water levels in PZ18-07 are ~ 40 ft lower than the production well TW18-02 (4711.9 ft, amsl), suggesting some compartmentalization between locations.

PZ18-08: PZ18-08 was placed in the footprint of the future open pit to characterize water levels and serve as a monitoring point during the 35-day pumping test. Three (3) sensors were placed in the borehole, the deepest sensor in volcanic tuff and the upper sensors in claystone/ash, however the upper sensor is dry. Water levels equilibrated at 4820 ft elevation and showed no response to the 35-day pumping test (Figure 3.16i).

PZ18-09: Three (3) sensors were placed in claystone/ash units. PZ18-09 is located directly south of the uplifted horst block and was selected to monitor response to the 35-day pumping test. Water levels equilibrated to 4,656 ft to 4,662 ft elevations after the 35-day pumping test (Figure 3.16j).

Two (2) to three (3) feet of drawdown was observed during the 35-day pumping test with a partial recovery.

Table 3.6 Piezometer Summary

Hole ID	X (UTM)	Y (UTM)	Z (ft, amsl)	Sensor ID	Install depth (ft)	Sensor Elevation (ft, amsl)	Installation date	Last Water Level (ft, amsl)	Rock Unit
PZ17-01	425337	4616164	4204	PZ17-01-3805	399	3805	12/9/2017	4167.2	Basin fill alluvium
PZ18-01	409621	4618239	5256	PZ18-01-4666	590	4666	8/11/2018	4813.3	Volcanic Tuff
				PZ18-01-4791	465	4791	8/11/2018	4821.3	Volcanic Tuff
PZ18-02	415221	4619633	4938	PZ18-02-4449	489	4449	10/4/2018	4779.6	Claystone and Ash
				PZ18-02-4519	419	4519	10/4/2018	4778.3	Basalt
				PZ18-02-4599	339	4599	10/4/2018	4781.0	Alluvium
PZ18-03	416600	4618473	4765	PZ18-03-4247	518	4247	9/9/2018	4680.4	Basalt
				PZ18-03-4347	418	4347	9/9/2018	4681.6	Claystone and Ash
				PZ18-03-4495	270	4495	9/9/2018	4682.7	Claystone and Ash
PZ18-04	413759	4618786	4979	PZ18-04-4488	491	4488	10/9/2018	4825.0	Volcanic Tuff
				PZ18-04-4548	431	4548	10/9/2018	4828.8	Claystone
				PZ18-04-4718	261	4718	10/9/2018	4814.9	Claystone and Ash
				PZ18-04-4778	201	4778	10/9/2018	4815.3	Ash
PZ18-05	408377	4617491	4656	PZ18-05-4291	365	4291	9/22/2018	n/a	Rheomorphic Tuff
				PZ18-05-4411	245	4411	9/22/2018	4625.9	McDermitt Tuff
				PZ18-05-4591	65	4591	9/22/2018	4624.8	Brecciated Volcanic Tuff
PZ18-06	409892.7	4616844	5037	PZ18-06-4552	485	4552	9/26/2018	4759.0	Claystone and Ash
				PZ18-06-4722	314	4723	9/26/2018	4761.1	Claystone and Ash
PZ18-07	409029	4617757	4817	PZ18-07-4317	500	4317	9/18/2018	4675.7	Volcanic Tuff
				PZ18-07-4457	360	4457	9/18/2018	4676.4	Rheomorphic Tuff
				PZ18-07-4532	285	4532	9/18/2018	4677.1	Claystone and Ash
				PZ18-07-4627	190	4627	9/18/2018	4679.5	Claystone and Ash
PZ18-08	409599	4618657	5177	PZ18-08-4683	494	4683	7/17/2018	4820.2	Volcanic Tuff
				PZ18-08-4777	400	4777	7/17/2018	4820.6	Claystone and Ash
				PZ18-08-4877	300	4877	7/17/2018	Dry	Brecciated Claystone and Ash
PZ18-09	409634	4617694	4924	PZ18-09-4469	455	4469	8/15/2018	4756.9	Claystone and Ash
				PZ18-09-4594	330	4594	8/15/2018	4760.9	Claystone and Ash
				PZ18-09-4674	250	4674	8/15/2018	4762.6	Claystone and Ash

3.3.2 Monitoring Wells

Nine (9) active monitoring wells are in operation across the Thacker Pass Project, 5 of which were drilled during 2011 and 4 new wells were drilled during 2018. Five (5) additional wells had been drilled in 2011 and were abandoned shortly after completion. The 2011 monitoring well locations were designed to characterize the groundwater system for a smaller mine and facility footprint.

All monitoring wells were instrumented with Geokon VWP's (suspended in open casing at various depths) and a 407 stainless steel Solinst bladder pump. Geokon Model 4500S-2MPa or 3Mpa sensors were used in the installation with LC-2 data loggers for recording water levels. Data loggers were set to collect daily readings for baseline data collection but were adjusted to 10-minute or 1-minute intervals during pumping tests. Bladder pumps were set in the screen interval and operated with a 250 psi Solinst control box to collect water samples. Data was downloaded on a quarterly basis and stored in a database.

A monitoring well summary is provided in Table 3.7, with average groundwater chemistry summarized in Table 3.8. Water level hydrographs for monitoring wells are shown in Figure 3.17a to Figure 3.17i. A complete hydrograph of all monitoring wells is provided in Figure 3.17a. Geologic and drilling logs are provided in Appendix E. Completion diagrams are shown in Appendix F. Tabulated water chemistry for all wells is provided in Appendix G. A discussion of monitoring wells is as follows:

2011 Lumos monitoring wells

WSH-3: WSH-3 was drilled from February 1, 2011 to February 20, 2011 to a total depth of 500 ft. The well encountered a 288 ft thick section of basalt (112 ft - 400 ft). The first measurable aquifer was encountered below basalt beds at 420 ft bgs with the static water level (SWL) rising to 31 ft bgs. The boring pump was tested and then construction was completed with 2 -inch OD schedule 80 PVC casing. A short pumping test was performed for 2 hours before collecting a water sample. The well drew down 5.2 ft at a pumping rate of 15 gpm yielding a specific capacity of about 3 gpm per foot of drawdown (gpm/ft-dd). Water levels have steadily declined ~8 ft since drilling the well to 4752 ft amsl (Figure 3.17a). A small recharge rise of ~1ft is associated with the winter of 2016 – 2017.

WSH-4: Drilling commenced on February 21, 2011 and was completed on March 1, 2011. The borehole intercepted interbedded clay and ash beds to a total depth of 250 feet. Water was first encountered at a depth of approximately 90 ft bgs rising to 75 ft bgs the following morning.

A limited pumping test was conducted at 126 ft bgs, at a pumping rate of 1.1 gpm to maintain water levels above the pump intake. A second pumping test was performed at total depth (250 ft). The second test was operated for 90 minutes at a rate of 13 gpm generating a total drawdown of 25.75 feet. This limited pumping test calculated a specific capacity of 0.50 gpm/ft-dd. The hole was abandoned in accordance with NDWR regulations.

WSH-5: The drilling commenced on March 2, 2011 and was completed on March 6, 2011 to a total depth of 300 feet. Groundwater was first encountered at approximately 80 feet bgs. The boring was abandoned according to NDWR regulations.

A pumping test was conducted after drilling to a depth of 212 ft bgs. The pump operated at 2 gpm for approximately 60 minutes with a maximum drawdown of 115 ft. The specific capacity from the zone equates to 0.02 gpm/ft-dd. A second pump-recovery test was conducted after drilling the bore hole to total depth (300 ft). The override casing was pulled back from 285 ft to 200 ft and the pump was set at a depth of 212 ft. A low pumping rate of 1.0 gpm was necessary to maintain water levels at a depth of 198 ft.

WSH-6: Drilling occurred from between March 7 and March 11, 2011 to a depth of 226 ft. First water was encountered at a depth of 90 ft bgs with the SWL rising to 75 ft bgs. After a limited pumping test, the recovered static water level fell to 110.1 ft bgs. Following the test pumping the boring was abandoned in accordance with NDWR regulations.

2011 SWS monitoring wells

WSH-7: Drilling commenced on August 28, 2011, reaching a depth of 520 ft bgs, and the well was completed on September 8, 2011. The well intercepted a large northwest trending structure identified from geophysics at approximately 120 ft. First water was encountered at 78.7 ft with a final SWL at 98.2 ft. Airlift testing at the end of each drill rod did not produce any sustainable water flow until 300 ft with measurable flows of 7.9 gpm at 300 ft bgs and 13.0 gpm at a depth of 320 ft bgs. At total depth the airlifting test lasted only 35 minutes with diminishing flow starting at 10 gpm. Monitoring well construction was unsuccessful due to unstable conditions in the hole within the footwall of the fault, and the hole was abandoned in accordance with NDWR regulations.

WSH-8: Drilling commenced September 8, 2011 at another geophysics anomaly, for a possible water source. No water was encountered to a depth of 445 ft and the hole was abandoned on September 11, 2011 in accordance with NDWR regulations.

WSH-11: Drilling commenced September 11, 2011 and continued through September 18, 2011. The borehole was composed primarily of claystone and ash materials from 60 ft bgs to 365 ft bgs, and volcanic tuff from 365 ft bgs to 515 ft bgs. Static water levels followed the drill string down hole, suggesting the presence of some disconnected water bearing beds. First water was encountered the morning after drilling to 180 ft bgs with a SWL of 119.7 ft bgs. Beginning the third day, the SWL was measured at a depth of 130.8 ft bgs after drilling to a depth of 260 ft bgs. At TD the SWL was 344.9 ft with the sound of cascading water heard from the surface. The boring was drilled to 515 ft with monitoring well construction from 515 ft with the screen interval from 78 ft to 478 ft bgs. Monitor well construction was completed September 18, 2011. Airlift testing at TD for approximately one hour produced an average flow of 18.8 gpm.

Water levels continued to decline for approximately 4 years after drilling until equilibrating at 4817 ft amsl (Figure 3.17c). Groundwater chemistry exceeded Profile I Nevada Reference Values (NRVs) for fluoride, manganese, and arsenic (NDEP-BMRR, 2014).

WSH-13: Drilling commenced on September 18, 2011 to a total depth of 500 ft bgs with monitoring well construction completed on September 23, 2011. The borehole intersected an 80 ft thick section of basalt from 125 ft bgs to 215 ft bgs, and then claystone material for the rest of the borehole. The SWL during drilling was 127.4 ft bgs. The hole caved prior to construction of the monitoring well and after cleaning out to 373 ft bgs, a decision was made to construct the monitoring well above increasingly poor hole conditions. A VWP was placed October 14, 2011 to a depth of 365 ft bgs and SWL recordings commenced. Airlift testing at total depth for approximately 1.75 hours produced an average flow of 14.8 gpm.

Water levels have equilibrated to approximately 4813 ft amsl, showing no seasonal variation (Figure 3.17d). Groundwater has consistently exceeded NRVs for fluoride, and once exceeded NRVs for arsenic and antimony during at the initial sample.

WSH-14: Drilling commenced September 25, 2011 and was completed on October 3, 2011 at a total depth of 443 ft bgs. The borehole was mainly comprised of claystone with many interbeds of ash. The water level was 135 ft bgs after reaching total depth. The well was completed with 2-inch schedule 80 PVC and screen placed from 140 ft to 440 ft bgs. Airlift testing at TD averaged 173 gpm over approximately 1.5 hours.

Water levels have equilibrated to 4813 ft amsl after a gradual decline between 2014 to 2016, a small seasonal response during the winter of 2016 – 2017 of <1ft is observed. Groundwater chemistry exceeded NRVs consistently for TDS and arsenic, with most of dissolved solids being bicarbonate. The initial sample exceeded antimony NRVs (Appendix G).

WSH-17: Pilot hole drilling commenced on August 19, 2011 to a depth of 400 ft bgs with a short airlift test at the end of each rod and a 2-hour airlift test at the end of drilling. The hole was completed on August 24, 2011. The borehole intersected alternating grey, brown, and white claystone/ash beds through total length. Water was first encountered at 120 ft bgs, rising to 103.6 ft bgs upon completion. Since the well was completed, water levels have gradually declined to ~196 ft bgs or 4860 ft amsl (Figure 3.17f). The decline in water levels is attributable to drilling across a minor fault boundary, which functions as a hydraulic barrier. Intercepting this structure likely connects shallower water bearing ash beds to deeper ash beds across the fault. This connection occurs in the same geologic unit (claystone/ash beds) which reside on either side of the fault.

Two hours of airlifting at TD averaged 74 gpm with a specific capacity of 4.8 gpm/ft-DD. On October 4, 2011, PH-2 was reamed to a depth of 400 ft bgs and completed as a 2-inch monitoring well with screen placed from 180 ft bgs to 390 ft bgs. Groundwater chemistry consistently exceeds NRVs for fluoride and arsenic (Appendix G).

2018 Piteau monitoring wells

MW18-01: Drilling occurred between August 29, 2018 to September 2, 2018 to a depth of 415 ft bgs. Drilling encountered lacustrine volcanoclastic sediments below 215 ft bgs. The first measurable water was encountered at about 385 ft bgs with the static water level rising to 359 ft bgs. The boring was test pumped and then constructed with 4-inch OD PVC schedule 80 casing. The screen interval was from 355 ft to 405 ft bgs as shown in Table 3.2. Water levels have remained steady (~4822 ft amsl). Groundwater chemistry meets all NRVs except for arsenic, which is consistently exceeded (Table 3.8, Appendix G).

MW18-02: The drilling of MW18-02 began on July 6, 2018 and was completed on July 10, 2018 at a total depth of 125 ft bgs. The general lithology was predominantly fine volcanic ash, very light in color, with interbedded layers of darker gray clay. The bottom 25 ft of the borehole (100 ft bgs to 125 ft bgs) encountered coarse grained volcanic sediment with interbedded tuff clasts. First water was encountered at about 60 ft bgs. Airlift testing produced ~3.5 gpm for 30 minutes, followed by water level recovery to a depth of 51.1 ft bgs. The well was built with 4-inch OD PVC schedule 80 casing with a screen interval set from 45 ft to 115 ft bgs.

Water levels have gradually declined from 4545 ft amsl to 4543 ft amsl (Figure 3.17h). Groundwater chemistry meets all NRVs except for arsenic (Table 3.8).

MW18-03: Drilling began July 27, 2018 and was completed on August 1, 2018 to a depth of 145 ft bgs. The borehole intercepted lithic tuff in the upper 55 ft, and then claystone/ash beds through total depth. Water was first encountered at ~117 ft bgs and rose to 83.9 ft bgs after reaching total depth. Airlifting produced ~1 gpm of sustained discharge. The well was completed with 4-inch PVC schedule 80 casing and screened from 75 ft bgs to 135 ft bgs.

Water levels have declined to ~ 4550 ft amsl (Figure 3.17i). a drawdown down response to the 35-day pumping test was observed at MW18-03, however the well did not fully recover suggesting limited recharge to groundwater and pre-existing trends of water level decline. Groundwater chemistry meets all NRVs except for arsenic (Table 3.8), and in one anomalous sample collected in December 2018 (Appendix G) which had elevated aluminum and iron.

MW18-04: Drilling began on July 13, 2018 and completed on July 26, 2018 at a final depth of 625 ft bgs. The lithology is composed primarily of siliceous rhyolite and rhyolitic ash flow tuff. Water was

first encountered in a confined horizon at 585 ft bgs, but due to piezometric pressure the water level rebounded to about 485 ft bgs. Airlifting the well at total depth produced ~8.1 gpm. The well was completed with 4-inch PVC schedule 80 casing and screened from 485 ft bgs to 615 ft bgs. Water levels have remained steady at ~ 4825.5 ft amsl (Figure 3.17j). Average groundwater chemistry meets NRVs.

Table 3.7 Well summary

Site Name	Active	Type	X (UTM NAD 83)	Y (UTM NAD 83)	Ground Elevation (ft, amsl)	Stickup Height (ft)	Completion Date	TD (ft)	Screen Start (ft)	Screen End (ft)	Well Bottom (ft, amsl)	Casing Diameter (in)	Casing Material
WSH-3	Yes	Monitoring	413777.07	4617204.06	4,799.9	2.58		500	420	470	4302.43	2	PVC
WSH-4	Abandoned	Test	411252.62	4618319.65	5,113.0	-	3/1/2011	250	-	-	4862.98	n/a	-
WSH-5	Abandoned	Test	411554.13	4617735.7	5,009.0	-	3/6/2011	300	-	-	4709.0	n/a	-
WSH-6	Abandoned	Test	411441.62	4618159.38	5,091.8	-	3/11/2011	226	-	-	4865.84	n/a	-
WSH-7	Abandoned	Test	411352	4619350	5,356.0	-	8/28/2011	520	-	-	4836.0	n/a	-
WSH-8	Abandoned	Test	411241	4619400	5,336.0	-	9/11/2011	445	-	-	4891.0	n/a	-
WSH-11	Yes	Monitoring	410589.28	4618237.87	5,163.9	2.6	9/18/2011	515	78	478	4651.49	4	PVC
WSH-13	Yes	Monitoring	411736.36	4617085.38	4,944.7	2.08	9/23/2011	500	120	373	4446.19	4	PVC
WSH-14	Yes	Monitoring	412115.42	4617631.34	4,958.7	1.96	10/3/2011	443	140	440	4516.9	4	PVC
WSH-17 (PH-2)	Yes	Monitoring	411245.12	4618171.32	5,085.6	2.25	10/4/2011	400	180	390	4686.79	4	PVC
PH-1	Yes	Pumping	411335.85	4618368.1	5,124.8	3.75	10/6/2011	410	100	400	4715.95	6	LCS
MW18-01	Yes	Monitoring	409067.2	4618893	5,180.0	5.0	9/1/2018	415	355	415	4770.0	4	PVC
MW18-02	Yes	Monitoring	416542	4616247	4,562.0	2.6	7/9/2018	125	45	115	4439.6	4	PVC
MW18-03	Yes	Monitoring	409024	4617822	4,833.0	5.2	8/1/2018	145	75	135	4693.2	4	PVC
MW18-04	Yes	Monitoring	411216	4619114	5,311.0	2.47	7/26/2018	625	485	625	4688.47	4	PVC
TW18-02	Yes	Pumping	409040	4617762	4,817.0	2.65	8/25/2018	604	101	603	4219.0	6	LCS
QRPW18-01	Yes	Pumping	425330	4616161.08	4,204.0	2.65	9/25/2018	565	78	548	3641.0	16	LCS

Table 3.8 Average water chemistry*

Parameter	Units	Profile I NRVs	MW18-01	MW18-02	MW18-03	MW18-04	PH-1	WSH-03	WSH-11	WSH-13	WSH-14	WSH-17	TW18-02	QRPW18- 01 Dis	QRPW18- 01 Total
Number of Samples			6	6	6	6	4	4	4	18	4	17	1	1	1
pH	pH	6.5-8.5	7.66	7.57	7.74	7.22	7.92	8.44	7.92	8.27	7.81	8.02	7.28	8.21	8.18
Bicarbonate (HCO ₃)	mg/L	-	112	145	150	65	190	260	225	208	207	176	140	110	120
Carbonate (CO ₃)	mg/L	-	0.1	0.1	0.1	0.1	0.1	1.8	0.1	1.9	0.1	0.1	0.1	0.1	0.1
Hydroxide (OH)	mg/L	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.1	0.1	0.1
Chloride	mg/L	400	22	97	8	14	73	68	43	27	130	33	12	24	24
Fluoride	mg/L	4	0.24	1.57	1.50	0.18	1.64	2.96	4.31	5.05	1.40	4.02	0.72	-	-
Sulfate	mg/L	500	22	78	26	15	63	6	41	44	61	37	19	-	-
Nitrate + Nitrite Nitrogen	mg/L	10	1.03	1.00	0.11	0.15	0.11	0.08	0.07	0.11	0.07	0.01	0.01	-	-
TKN	mg/L	-	0.04	0.26	0.25	0.04	0.07	0.45	0.01	0.15	0.01	0.17	0.04	-	-
Total Nitrogen	mg/L	10	1.16	1.25	0.32	0.32	0.11	0.11	0.11	0.33	0.11	0.11	0.05	-	-
TDS	mg/L	1000	201	455	228	138	407	412	332	331	502	286	220	-	-
Aluminum	mg/L	0.2	0.04	0.005	0.04	0.09	0.005	0.26	0.005	0.03	0.005	0.005	0.01	0.01	0.01
Barium	mg/L	2	0.02	0.08	0.08	0.04	0.09	0.00	0.06	0.05	0.08	0.06	0.05	0.002	0.002
Beryllium	mg/L	0.004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Bismuth	mg/L	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Boron	mg/L	-	0.01	0.26	0.06	0.01	0.24	0.38	0.22	0.87	0.25	0.35	0.01	0.17	0.17
Cadmium	mg/L	0.005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00012	0.0001	0.0001	0.0001	0.0001	0.0001
Calcium	mg/L	-	31.8	45.5	30.6	15.3	47.5	3.0	26.2	12.0	53.8	21.1	31.0	27.0	27.0
Chromium	mg/L	0.1	0.001	0.003	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt	mg/L	-	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper	mg/L	1	0.004	0.004	0.004	0.004	0.01	0.01	0.01	0.01	0.01	0.024	0.004	-	-
Gallium	mg/L	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-	-
Iron	mg/L	0.3	0.04	0.04	0.04	0.09	0.02	0.10	0.02	0.020	0.013	0.021	0.28	0.044	0.047
Lithium	mg/L	-	0.01	0.06	0.08	0.01	0.20	0.28	0.35	0.22	0.26	0.22	0.01	0.01	0.01
Magnesium	mg/L	-	11.0	16.1	8.6	4.2	25.0	1.2	21.5	8.4	31.4	11.8	6.7	5.6	5.5
Manganese	mg/L	0.1	0.007	0.006	0.034	0.016	0.010	0.018	0.051	0.026	0.001	0.052	0.083	0.001	0.001
Molybdenum	mg/L	-	0.002	0.002	0.05	0.002	0.08	0.01	0.01	0.08	0.03	0.02	0.002	0.002	0.002
Nickel	mg/L	-	0.003	0.003	0.003	0.003	0.001	0.001	0.001	0.002	0.001	0.002	0.003	0.003	0.003
Phosphorus	mg/L	-	0.05	0.05	0.05	0.05	0.05	0.45	0.05	0.05	0.05	0.05	0.05	-	-
Potassium	mg/L	-	1.5	3.8	4.0	2.5	3.3	2.2	1.2	1.3	3.3	1.1	1.6	7.0	7.0
Scandium	mg/L	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-	-
Silver	mg/L	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.001	0.001
Sodium	mg/L	-	17	82	33	19	46	152	62	111	65	71	35	41	41
Strontium	mg/L	-	0.1	0.3	0.2	0.1	0.9	0.01	0.6	0.3	0.8	0.4	0.1	0.2	0.2
Tin	mg/L	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Titanium	mg/L	-	0.01	0.01	0.01	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Vanadium	mg/L	-	0.00	0.03	0.001	0.001	0.02	0.001	0.01	0.01	0.02	0.01	0.001	0.01	0.01
Zinc	mg/L	5	0.01	0.002	0.01	0.03	0.04	0.02	0.001	0.00	0.001	0.00	0.002	0.002	0.002
Mercury	mg/L	0.002	0.00002	0.00002	0.00002	0.0001	0.0001	0.00001	0.00001	0.0001	0.00001	0.00008	0.00001	0.00001	0.00001
Antimony	mg/L	0.006	0.0003	0.0003	0.002	0.000	0.005	0.000	0.000	0.002	0.002	0.0003	0.0003	0.0003	0.0003
Arsenic	mg/L	0.01	0.011	0.024	0.043	0.003	0.034	0.001	0.027	0.003	0.018	0.028	0.016	0.001	0.001
Lead	mg/L	0.015	0.0003	0.0003	0.0003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Selenium	mg/L	0.05	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Thallium	mg/L	0.002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Uranium	mg/L	0.03	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	-	-

* Geometric average calculated

3.3.3 Production Wells

Three (3) production wells have been drilled to stress the hydrogeologic system with longer term pumping tests and to find an adequate source of mine production water. PH-1 was drilled in 2011, just north of the previously planned open pit, to serve as a dual-purpose dewatering / water supply well. TW18-02 was drilled in 2018 for the 35-day pumping test, to stress the groundwater system between Thacker Creek and the proposed open pit area. QRPW18-01 was drilled in the Quinn River valley as a water supply well. Well locations and summary information are provided in Figure 3.15 and Table 3.7 respectively. Geologic and Drilling Logs are provided in Appendix H. Construction as-builts are provided in Appendix I. A summary of drilling activities for each well is provided as follows:

PH-1: Pilot hole drilling commenced August 24, 2011 and ended August 27, 2011 after reaching a target depth of 410 ft bgs. Water was first encountered between 100 ft bgs and 120 ft bgs with static water levels (SWL) rising to 56.9 ft bgs on August 25, 2011. Upon reaching total depth, the SWL measured 69.1 ft bgs (August 28, 2011). Prior to the pumping test, the SWL had declined to 73.1 ft bgs (October 16, 2011). PH-1 showed productive airlift flow beginning at 160 ft bgs with a near steady flow increase from 25 gpm to just under 75 gpm with a calculated specific capacity of 48.0 gpm/ft-DD. Based on these results, PH-1 was chosen for the test production well.

On October 4, 2011 PH-1 was reamed using a tricone bit to a diameter of 9 5/8 inches. Well construction used six-inch diameter low carbon steel (LCS) casing with 300 ft of 0.050-inch mill slot perforated screen from 400 to 100 ft. Blank LCS casing completed the construction to two ft above ground surface. BCJ 8 X 16 mesh filter pack was placed from 50 to 400 ft. with neat cement placed from 0 to 50 ft bgs. A concrete pad was poured with a lockable 8-inch diameter well monument placed over the well casing. All wells were developed by air lifting until discharge water was relatively clear and free of suspended sediment. Test production well PH-1 was also developed by airlifting, swabbing, and pump development as discussed in Section 3.3.

TW18-02: TW18-02 was drilled using flooded reverse-circulation (RC) method between August 15, 2018 and August 26, 2018 to a total depth of 600 ft bgs. The borehole was entirely composed of variably colored claystone/ash sediment from 65 ft to 600 ft. Airlifting after well construction sustained 114 gpm. The well was completed with 6-inch diameter, 0.25-inch thick steel casing. Roscoe Moss Ful Flo louvered screen (125 slot openings) was placed from 100 ft bgs to 600 ft bgs depth with a ¼-inch silica gravel pack in the annular space. The well was developed for 3 days using a dual-swab airlift method. The primary purpose of TW18-02 was for 35-day pumping test. TW18-02 was permitted using a W-waiver issued by the Nevada State Engineer (W-waiver 728) which requires the well be abandoned after 1 year unless an extension is filed, or water rights

allocated to the well. On March 1, 2019, the Nevada State Engineer issued W-728 Waiver Approval for a one-year extension to delay plugging of well TW18-02.

QRPW18-01: QRPW18-01 was drilled using flooded (RC) drilling method between September 08 and September 25, 2018 to a total depth of 565 ft bgs at a borehole diameter of 22-inches. Drill cuttings were collected at 5-foot intervals and correlated with materials observed in the test well (PZ17-01). The well was developed for five (5) days during September 20 to September 25, 2018 producing between 650 gpm to 900 gpm. A surface seal was installed, and steel plate was tack welded to the conductor casing on September 25, 2018. The well was later tested to determine pumping capacity.

3.4 Hydrogeologic testing

Hydrogeologic testing was carried out to characterize hydrogeologic parameters (transmissivity, hydraulic conductivity, and storage) through a series tests spanning all field investigation campaigns. Hydrogeologic testing locations are shown in Figure 3.18. An overview of hydrogeologic tests performed at the Thacker Pass Project is as follows:

- **Packer tests:** Packer tests are typically executed in small diameter coreholes over a series of 5 injection steps or pressures. Geologic units are isolated for testing by inflating the packer across a testing interval. Water from the surface is injected into the isolated interval at a fixed pressure, and the flow rate is measured for a period of 5 to 10 minutes. The flux of water injected into the formation at pressure steps is proportional to the lithology's hydraulic conductivity. Packer testing can also provide in-situ rock strength parameters by measuring the pressure required to hydraulically fracture the rock. The characteristic stress response as pressures are increased and then decreased can provide insight to the nature of fracture dilation, hydro-fracking, and mobilization of fine-grained materials. Because packer testing occurs over a short time frame and interval, resulting values for rock transmissivity are considered localized points. Likewise, packer testing across major fracture sets or washout zones is problematic as the injection water can short circuit around the packer set. Thus, packer tests tend to present lower transmissivity values reflective of primary matrix transmissivity.
- **Injection / airlift recovery tests:** Injection or airlift recovery tests are also short-term recovery tests which are performed across the entire borehole or screen interval. Tests consist of injecting or airlifting water at a constant rate until equilibrium water levels are achieved, and then measuring the water level recovery to equilibrium. Injection or airlifting for the Thacker Pass Project generally occurred for a period of 90 minutes to 120 minutes, and the recovery is allowed to happen overnight. Recovery curves are analyzed using the Cooper-Jacob straight-line method. Injection/airlift recovery tests provide a more integrated characterization of borehole transmissivity because they incorporate fracture or highly permeable bedding horizons. The tests represent radial rock transmissivities at distances

of several to tens of feet from the borehole, thus still a localized test but provide an integrated response across the borehole.

- Long term pumping tests: Long term pumping tests operate a well at a specified pumping rate for several days. These tests measure the overall groundwater response to pumping across a wide field, including boundary effects, and thus they provide the greatest measure of characterization for a groundwater system. An adequate water level monitoring network is critical to interpreting long term pumping tests. Groundwater responses in long term pumping, or the lack of response, are particularly critical to identifying hydrogeologic flow boundaries such as faults, geologic contacts, mineralized zones, rivers, lakes, etc. Transmissivity and storage values convey higher confidence because of the longer testing period and wider footprint over which long term tests are conducted.

3.4.1 Packer testing

Packer tests were performed in selected core holes using a 4-inch (HQ diameter) QSP inflatable straddle packer. The straddle packer tested a 5-foot interval and could be deployed to a maximum depth of 600 ft bgs. Inflation pressures for packers was determined from Equation 1, to ensure an adequate seal formed. The packer assembly is shown in Figure 3.18.

$$G = (0.43 * P_{depth} + S_{packer} + P) * 1.1 \quad (1)$$

G = Inflation pressure (psi)

P_{depth} = Set depth of top packer (ft)

S_{packer} = Unconfined packer pressure rating (psi)

P = Injection water pressure (psi)

Packer tests were performed over a series of 5 injection pressures or steps, and the discharge rate was measured from a 1-inch flow meter at the surface. A piston pump (Bean pump) located on the drill rig and a series of ball valves were used to control the injection pressure going into the packer assembly. Injection pressure was increased incrementally for the first 3 steps, and then reduced for the final 2 steps in order to characterize the formation's permeability and the dynamic response of fractures under elevated pressure regimes. Packer testing was performed at 3 boreholes (PZ18-09, PZ18-05, and PZ18-04), which were afterwards completed as grouted-in piezometers. Individual packer test descriptions are described in the following sections and summarized in Table 3.9.

PZ18-09

Packer testing in PZ18-09 was performed on August 18, 2018 at three intervals (298 ft – 303 ft, 325 ft – 330 ft, 455 ft – 460 ft), corresponding to geologic units of fractured claystone, ash, and silicified Claystone respectively. Packer testing results and steps are shown in Figure 3.20. The

permeability of ash, including the fractured zone, was approximately an order of magnitude greater than the deeper silicified claystone. Characteristic curves in the upper section (298 ft – 303 ft) suggest slight mobilization of gouge or fine-grained sediments mobilized during testing. Testing of both deeper intervals hydrofracked the borehole during the 3rd and 4th steps, as evidenced by the sudden increase in flow rates which were sustained after injection pressures were lowered. The 3rd step at the lowest interval (455 ft – 460 ft) exceeded the inflation pressure, leading to flow leakage around the packers. This step was omitted from the permeability calculation.

PZ18-05

Packer testing in PZ18-05 was performed on September 21, 2018 at three intervals (62 ft – 67 ft, 125 ft – 130 ft, 237 ft – 242 ft), corresponding to geologic units of brecciated tuff, McDermitt Tuff (Tuff of Long Ridge), and rheomorphic tuff respectively. Packer testing results and steps are shown in Figure 3.21. All three tests yielded similar permeability values ($\sim 1 \times 10^{-2}$ ft/d), characteristic of crystalline volcanic tuff. Characteristic curves in the upper section (62 ft – 67 ft) suggest slight mobilization of gouge or fine-grained sediments mobilized during testing. Testing of both deeper intervals hydrofracked the borehole during the 3rd step, but fractures closed quickly after injection pressures were reduced.

PZ18-04

Packer testing in PZ18-04 was performed on September 21, 2018 at three intervals (195 ft – 200 ft, 218 ft – 223 ft, 248 ft – 253 ft), corresponding to geologic units of ash, claystone, and interbedded claystone and ash respectively. Packer testing results and steps are shown in Figure 3.22. All three tests yielded similar permeability values (1.1×10^{-1} ft/d to 4.5×10^{-1} ft/d). Testing in the upper section (195 ft – 200 ft) exceeded the packer's inflation pressure during the 2nd step, causing high discharge rates that overfilled the borehole at ground surface at the beginning of the 3rd step, thus the 2nd and 3rd steps are omitted from calculation. The characteristic curve of the 2nd interval (218 ft – 223 ft) shows a good linear trend in ascending and descending steps. The 3rd interval (248 ft – 253 ft) suggests slight mobilization of sediments in fractures.

Key conclusions from the packer testing are:

- Bulk hydraulic conductivity values for claystone /ash beds are approximately 1 order of magnitude higher than volcanic tuff units. Claystone/ash hydraulic conductivity values range from (1.1×10^{-1} ft/d to 4.5×10^{-1} ft/d) while volcanic tuff values range between (1.0×10^{-2} ft/d to 2.5×10^{-2} ft/d). Greater hydraulic conductivity of claystone/ash beds is related to the well sorted, medium to coarse-grained lapilli comprising ash beds which are interbedded among claystone.

- Hydraulic conductivity of deeper, silicified claystone is closer to that of volcanic tuff (1.6×10^{-2} ft/d), owing to the compaction and silicification of the matrix in ash beds.
- Hydro-fracking was achieved under injection pressures ranging from ~220 psi to 300 psi in shallow bedrock materials.

Table 3.9 Packer testing summary

Hole ID	Test Interval (ft)	Lithology	Number of Stage	Max Pressure (PSI)	K_{mean} (cm/s)	K_{mean} (ft/d)
PZ18-04	195-200	Ash	5	50	1.59E-04	4.51E-01
PZ18-04	218-223	Claystone	5	70	3.81E-05	1.08E-01
PZ18-04	248-253	Interbedded Claystone/ash	5	70	7.33E-05	2.08E-01
PZ18-05	62-67	Brecciated Tuff	5	50	8.70E-06	2.47E-02
PZ18-05	125-130	McDermitt Tuff	5	120	3.70E-06	1.05E-02
PZ18-05	237-242	Rheomorphic (Banded) Tuff	5	115	3.80E-06	1.08E-02
PZ18-09	298-303	Fracture Zone (Claystone /Ash)	5	10	1.30E-04	3.69E-01
PZ18-09	325-330	Ash	5	60	7.80E-05	2.21E-01
PZ18-09	455-460	Silicified Laminated Claystone	5	80	5.80E-06	1.64E-02

3.4.2 Injection / recovery testing

A total of 13 short term injection / recovery tests were performed at monitoring locations shortly after reaching total depth, or shortly after the well was completed. Individual straight-line Cooper Jacob test analyses are provided in Appendix J and summarized in Table 3.9. Injection tests were performed in coreholes (PZ18-01, PZ18-07, and PZ18-08) whereas airlift recovery tests were performed in monitoring well boreholes. Piteau utilized a specialty fabricated testing apparatus to directly measure water levels during airlifting to capture early recovery data. Previously reported values from Lumos are also included here as short-term tests (Lumos, 2011a). Key results from the injection / recovery testing are as follows:

- Overall lithologic trends agree with packer tests in that claystone/ash units tend to possess higher transmissivity values than tuff.
- Claystone transmissivities range from 0.017 ft/d to 2.8 ft/d, likely capturing a range of silicification (low values) and abundance of coarse-grained ash (high values).
- A bi-modal response is observed in TW18-02, suggesting the primary source of water to the wells is derived from a more transmissive bed, comprising the late time recovery data.
- Volcanic tuff transmissivities range from 0.009 ft/d to 0.068 ft/d.

A composite chart of all airlift / recovery drawdown responses is provided in Figure 3.23.

Table 3.10 Injection / recovery testing summary

Well ID	Date	Type	Lithology	Test Interval (ft, amsl)	Q (gpm)	T (ft ² /d)	b (ft)	K (ft/d)
MW18-01	9/1/2018	Airlift Recovery	Claystone/ash	4965-4900	5.74	94.2	55	1.713
MW18-02	7/8/2018	Airlift Recovery	Claystone/ash	4505-4535	9.14	27.4	71	0.39
MW18-03	7/30/2018	Airlift Recovery	Claystone/ash	4735-4675	2.5	1.22	50	0.025
MW18-04	7/20/2018	Airlift Recovery	Basalt / Andesite / Rhyolite	4835-4705	7.75	2.1	130	0.016
PZ18-01	8/11/2018	Injection	Fractured Tuff	5256-4256	8.9	2.29	116	0.020
PZ18-07	9/17/2018	Injection	Claystone/ash	4730-4210	37.5	10.3	121	0.085
PZ18-08	7/14/2018	Injection	Tuff	5177-4677	3.7	1.4	110	0.012
TW18-02	8/25/2018	Airlift Recovery	Claystone / Tuff / Ash	4717-4217	106	312	480	0.650
WSH-3 ¹		Pumping	Basalt	4379-4329	15	2409	80	30.1
WSH-4 ¹	2/28/2011	Pumping	Claystone / ash	5038-4863	13	100	36	2.8
WSH-5 ¹	3/5/2011	Pumping	Tuff	4809-4774	2.5	0.81	12	0.068
WSH-6 ¹	3/10/2011	Pumping	Claystone	4982-4866	0.5	0.35	21	0.017
WSH-13	October 2011	Pumping	Claystone	4825-4572	17	58	387	0.15

¹ Lumos, 2011b

3.4.3 PH-1 pumping test

PH-1 pumping test occurred from October 13 through October 19, 2011 and consisted of pump development, a step drawdown test, and a constant rate test. A 50 horsepower (HP) submersible pump was installed on October 14, 2011 with the intake set at 305 ft bgs to develop the production well and test the system. After installation of the pump, the system was tested and the well was further developed through pumping and then allowed to recover prior to testing. During the well development stage, 45,600 gallons were discharged at a rate between 240 and 260 gpm.

The step drawdown test was conducted on October 15, 2011 with pumping rates at 75, 100, 125, and 140 gpm as shown in Figure 3.24. The first three steps were run for 1 hour each, while the fourth step lasted only for 14 minutes at which time the pump cavitated at a drawdown of 210 feet. The step drawdown test curve shows a very steep decline in drawdown between the rates of 100 to 125 gpm indicating a boundary condition was encountered, likely caused by nearby minor faults. The step test at 140 gpm was terminated early because of the severe drawdown which caused cavitation.

Projecting the drawdown curve for a period of seven days indicates a sustainable pumping rate during a 7-day constant rate pumping test would range from 75 to 100 gpm. A rate of 85 gpm was chosen for the constant rate test to adequately stress the aquifer. Aquifer recovery was rapid after pump shut down, suggesting much of flow occurs along a deep, discrete interval in the borehole. The recovery curve indicated good recharge with nearly 98% recovery in approximately 6.5 hours as shown in Figure 3.24.

The constant rate pumping test commenced on October 16, 2011 at 09:33 with the pumping rate adjusted to 85 gpm. During the evening and early morning hours of October 16 and 17, 2011, the pumping rates were manually adjusted which caused fluctuation between 60 and 95 gpm before it stabilized at 85 gpm. During the morning of October 17, 2011, the pumping rate steadily declined to a rate of 66 gpm while the drawdown stabilized at 210 ft bgs as shown in Figure 3.25. The pumping rate could not be increased without causing pump cavitation. The pump was shut off at 18:00 hours on October 18, 2011 and the well was allowed to recover. The constant rate test was performed for 56 hours with an average pumping rate of 76.6 gpm. Review of drawdown curves and pump records indicated variable pumping rates occurred during the first night and a second pumping test was attempted at a rate of 50 gpm.

Pumping resumed on October 19, 2011 at 06:00 hours at a reduced rate of 50 gpm but pumping was terminated at 10:15 hours after a seal on the flow meter failed. At this point it was determined to end the pumping test. The pump was restarted on October 20, 2011 to collect a water sample after which the pump was removed. Water level monitoring continued during recovery in all wells until October 26, 2011. The data was downloaded and the VWP monitoring duration was changed to daily readings. PH-1 recovered to 99% of the SWL at the start of the constant rate test and 97% of the SWL prior to test pumping as shown in Figure 3.25. A water level measurement on December 14, 2011, indicates the SWL was 3.52 ft below the average SWL before the pumping test.

The PH-1 pumping test lead to the following key conclusions:

- The constant rate drawdown curve vs. time on an arithmetic scale (Figure 3.25) indicates a boundary condition was reached where drawdown increases significantly. This is likely a result of dewatering compartmentalized beds juxtaposed against a series of minor faults. As the upper water bearing zones are dewatered, the drawdown rate increases to the next saturated zone which was not identified in the step testing. At the presumed cavitation zone at a drawdown of approximately 210 ft bgs, pumping appears to be sustainable at a rate of 65 gpm.
- The PH-1 pumping test removed a sufficient quantity of water during its duration to partially dewater the hydrogeologic block. The lack of response from neighboring wells suggests that this is the key mechanism in causing a partial recovery. This mechanism reinforces

the concept that local faults serve to compartmentalize and separate groundwater into blocks.

- Continued equilibration of water levels through boreholes which penetrate minor faults functioning to compartmentalize hydrologic blocks. Water levels are slowly equilibrating across blocks, as indicated in the water-level decline within the monitoring well network (WSH-11, WSH-14, and WSH-17). Equilibration has been observed to range from rapid, as in WSH-14 where water is cascading down the borehole, or a slow decline as in WSH-17 which is asymptotically reaching equilibrium four months after drilling. This mechanism is expected to account for a component of the lower recovered water level in PH-1.

Data from the drawdown and recovery tests for the two constant rate tests at 85 gpm and 50 gpm were analyzed using the Cooper-Jacob method to determine transmissivity (T) and hydraulic conductivity (K). Analytical matches for the 85 gpm test and the 50 gpm test are shown in Appendix K and summarized in Table 3.11.

Table 3.11 PH-1 constant rate pumping test results

Test Period	Type	Lithology	Q (gpm)	T (ft ² /d)	b (ft)	K (ft/d)
85 gpm	Constant Rate	Claystone/ash	76.6	211	350	0.6
85 gpm	Recovery	Claystone/ash	76.6	352	350	1.1
50 gpm	Constant Rate	Claystone/ash	53.6	367	350	1.1
50 gpm	Recovery	Claystone/ash	53.6	472	350	1.4

The data correlates well for both drawdown and recovery with an average T value of 351 ft²/day and an average K value of 1 ft/day.

3.4.4 QRPW18-01 pumping test

QRPW18-01 was hydraulically stressed by two pumping tests, a 2-hr step test and 72-hr constant rate test, to evaluate well performance and aquifer parameters. A 150 horse-power (HP) vertical lineshaft turbine pump (FlowServe 12EBM/12HH220 5-stage) was placed at a depth of 294 ft below top of casing. The discharge line was routed 500 ft offsite and allowed to freely flow and infiltrate towards Quinn River. The wellhead assembly consisted of a sampling port, sand line, and flowmeter. The initial depth to water in QRPW18-01 was 28.7 ft bgs. Three transducers were in place a minimum of 24-hours prior to testing to monitor water level response:

- A Geokon 4500s transducer a depth of 501.9 ft in the QRPW18-01 sounding tube.
- A grouted transducer in PZ17-01, located at a distance 24.3 ft from the pumping well.
- An Insitu level logger transducer was placed in the West Windmill Well at a depth of 49.8 ft. The West Windmill Well is located at a distance of 3,066 ft.

Step-testing began on October 2, 2018 at 5:00 pm and consisted of 4 steps of 1500 gpm, 2000 gpm, 2500 gpm, and 3473 gpm. Each step lasted 30 minutes, as water levels in the well quickly

equilibrated. The final step of 3,473 gpm overlocked the pump motor and was not sustainable, although it demonstrated the well is capable of higher production rates. Step test summary is provided in Table 3.12 and Figure 3.26.

Table 3.12 QRPW18-01 Step Testing Results

Step	Drawdown (ft)	Q (gpm)	Specific Capacity (gpm/ft)
Step 1	13.02	1500	115
Step 2	19.03	2000	105
Step 3	25.62	2593	101
Step 4	36.54	3473	95

The step test analysis evaluated both a linear and exponential projection of specific capacity with pumping. The exponential projection is more conservative, suggesting the aquifer can produce ~11,000 gpm with a corresponding depth to water (DTW) of 250 ft (Figure 3.26). However, production at this rate is likely unachievable owing to:

- Desaturating the highly transmissive gravel beds found from 40 ft bgs to 110 ft bgs depths, which would greatly reduce production.
- Exceeding the design grade for water velocity in the column pipe (10 ft/s), leading to accelerated wear on fittings and increased friction losses.
- Increasing the entrance velocity across the well screen to above 0.2 ft/s, which raises the potential for silt and sand grains to mobilize. However, given the degree of development and aquifer conditions, the recommended entrance velocity criteria of 0.2 ft/s is considered precautionary and conservative. The American Water Works Association criteria for design efficiency recommends an upper limit of 1.5 ft/s for entrance velocity; and that entrance velocities below this threshold do not meaningfully reduce well efficiency, although they can lead to sanding the of the well if not properly developed.

Based on the foregoing, a maximum production rate of 4,000 gpm was recommended for the well. This production rate meets design criteria for a 12-inch diameter column pipe, and the projected DTW of 70.5 ft will not desaturate the upper gravel beds. The aquifer appears capable of sustaining higher pumping rates but would require a column pipe diameter greater than 12-inches, which will begin to constrict the inner screen diameter. If higher production rates are desired, additional testing is recommended to ensure production is sustainable. However, the need for this seems impractical given the relatively low water consumption requirement for the project and limitations with casing diameter.

The 72-hour constant rate pumping test was initiated on October 3, 2018 9:00 and ended on October 6, 2018 at 9:00 at a target rate of 2500 gpm. The actual time-weighted pumping rate for the constant rate test was 2516 gpm, which was sustained through the entire 72-hour test. QRPW18-01 had fully recovered prior to initiating the constant rate test.

Drawdown was observed in all three monitoring locations, summarized in Table 3.13. Water level hydrographs are shown in Figure 3.27. Individual monitoring well drawdown hydrographs are shown in Figure 3.28. Water levels asymptotically declined at the onset of pumping and fully recovered at approximately the same rate suggesting a broad, unconfined aquifer. A small amount of drawdown (~ 4 inches or 0.26 ft) occurred at the West Windmill Well but does not occur until ~2.5 days after testing begins. The delayed yield is reflective of aquifer storage parameters. A small, episodic amount of pumping (<15 gpm) occurs at the West Windmill Well for stock watering, but the effect is excluded in the pumping test analysis.

Table 3.13 Constant rate testing results

Well	Drawdown (ft)	Radial Distance (ft)
QRPW18-01	28.86	0.83
PZ17-01	13.45	24.3
West Windmill Well	0.26	3,066

A Cooper-Jacob distance-drawdown analysis was performed to assess aquifer parameters and well efficiency of the overall aquifer system (Figure 3.29). The evaluation generated an aquifer transmissivity of 28,107 ft²/d and storage coefficient of 0.017. The theoretical drawdown at the production well's borehole was estimated to be 22.7 ft. Dividing the theoretical drawdown (22.7 ft) by the actual drawdown (28.9 ft) produces a well efficiency of 79%, which is an efficient well.

Cooper-Jacob time-drawdown and recovery analyses were prepared for each monitoring location, and shown in Appendix L. The resulting values for aquifer transmissivity are remarkably well aligned. Average transmissivity is 28,158 ft²/d, excluding the outlier value for West Windmill recovery, corresponding to a hydraulic conductivity of 52.5 ft/d. Storage coefficients are less well aligned owing to multiple simultaneous processes of elastic storage and gravity drainage. However, a value of 0.16 observed at the West Windmill Well correlates well with the range of specific yield values for a sandy gravel with a limited fine-grained component.

The analysis indicated that a recharge boundary was intersected after ~ 550 minutes of pumping. This is likely higher permeability gravel and cobble beds associated with the Quinn River bed and reworked alluvial sediments.

3.4.5 TW18-02 pumping test

TW18-02 was hydraulically stressed by two pumping tests, a 3-hr step test and a 35-day constant rate pumping test to characterize the groundwater system between Thacker Creek and the proposed open pit. A 4-inch, 10 HP submersible electric pump was placed at a depth of 556 ft below top of casing (Grundfos SP-62S 24-stage). The pump was outfitted with a variable frequency drive (VFD) and genset at the well head to adjust operating hertz during the test. Discharge water was routed to a 3,000-gallon settling tank prior to routing ~500 ft to the east where it discharged

across erosion control (pallets and tarps) prior to flowing down a natural drainage towards Thacker Creek. The wellhead assembly consisted of a sampling port, sand line, and flowmeter.

Data loggers at nearby monitoring locations (MW18-03, WSH-11, PZ18-08, PZ18-01, PZ18-09, PZ18-07, and PZ18-05) were modified to collect water levels on a 10-minute interval. The selection of piezometer and monitoring well locations were specifically designed to characterize the groundwater system between the future open pit and Thacker Creek, and particularly potential hydraulic barriers which may separate the creek system from open pits. Objectives of monitoring locations are summarized as:

- PZ18-08 and WSH-11 were located in the footprint of the open pits.
- PZ18-01 was located in the uplifted horst block of Silica Hill to monitor any response, or lack of response, to pumping.
- PZ18-07, PZ18-09, and PZ18-06 were in claystone units south of the uplifted block to serve as monitoring locations for pumping.
- PZ18-05 was located west of a geologic contact, as a proxy for Thacker Creek, to evaluate the propagation of drawdown to the west.

Step-testing commenced October 3, 2018 at 5:00 pm and consisted of 3 steps of 30 gpm, 49 gpm, and 62 gpm at which maximum pump capacity was reached. Static water level was ~107.6 ft below top of casing prior to initiating the test. Each step lasted 60 minutes and had stabilized. Summary of step test results are provided in Table 3.14 and Figure 3.30. Although the well had drawn down over 192 ft, there was still ~247 ft of water above the pump, therefore the maximum rate of ~62 gpm was chosen for the 35-day pumping test.

Table 3.14 TW18-02 Step Testing Results

Step	Drawdown (ft)	Q (gpm)	Specific Capacity (gpm/ft)
Step 1	67.4	30	0.44
Step 2	127	49	0.38
Step 3	192	62	0.32

The constant rate pumping test was initiated on October 5, 2018 at 12:05 at a target rate of 62 gpm (maximum pump capacity). The actual time-weighted pumping rate for the test was 58 gpm as pump performance declined during the test. Tabulated pumping test discharge, water level, and pump data are presented in Appendix M.

Hydrographs of monitoring wells during the 35-day pumping test are shown in Figure 3.31, and corresponding drawdown is shown in Figure 3.32 and summarized in Table 3.15. Water levels in

several piezometers such as PZ18-09, PZ18-05 and PZ18-06 were in decline prior to the pumping test, thus a log-scale correction factor was calculated using the pre-pumping trend to distinguish between pumping test and background related drawdown. Hydrographs of correction factors are provided in Appendix N.

Table 3.15 TW18-02 Constant Test Results

Monitoring location	Drawdown (ft)	Radial Distance (ft)
TW18-02	152.05	0.5
PZ18-07-4317	10.07	43
PZ18-07-4457	9.97	43
PZ18-07-4532	9.80	43
PZ18-07-4627	7.87	43
PZ18-06-4552	<0.52 ¹	1340
PZ18-06-4722	<0.85 ¹	1340
PZ18-09-4469	1.49	600
PZ18-09-4594	1.48	600
PZ18-09-4674	1.77	600
MW18-03	1.92	75
PZ18-01-4666	none	765
PZ18-01-4713	none	765
PZ18-08-4683	none	1065
PZ18-05-4411	<0.23 ¹	705
PZ18-05-4591	<0.28 ¹	705

¹ Sensor continued drawdown post pumping test. It is not possible to separate out TW18-02 related drawdown from the equilibrium drawdown. Therefore, these piezometers are considered to have no drawdown and are omitted from the analysis.

Maximum drawdowns recorded during the test, and the interpreted drawdown isopleths are shown spatially in Figure 3.33. Cooper-Jacob time-drawdown analyses are compiled for drawdown and recovery periods for each sensor in Appendix O. A discussion of responses to pumping test is as follows:

- PZ18-07:** PZ18-07 is located approximately 43 ft from TW18-02 and observed a maximum drawdown of ~10 ft during the 35-day test. Drawdown response was slightly greater at deeper sensors (~10 ft) than in shallower sensors (~7.9 ft). Water levels responded almost immediately to variations or temporary shut downs in TW18-02 (Figure 3.34). Temperatures increased progressively through the test's duration in the lower two sensors (from 16.5°C to 18.7°C), suggesting that source water to the production well was deep, lower than the bottom of PZ18-07. The combined temperature and pressure responses suggest most of the water is sourced from a deeper bed below PZ18-07, potentially corresponding to the thicker sequences of ash beds found south of Silica Hill. This is also

validated by TW18-02's operation which exhibits high well skin losses that can be attributed to the primary flow horizon coming from deep-seated beds. Thus, the resulting hydrogeologic parameters may be more reflective of this bed. Water levels had not yet fully recovered (~0.8 ft) by the end of recovery (also 35 days), indicating dewatering of the groundwater system. Cooper-Jacob time-drawdown analyses are provided in Appendix O.

- **PZ18-09:** PZ18-09 is located approximately 600 ft east of TW18-02 and completed in claystone/ash units. Drawdown responses of 1.5 ft to 1.7 ft were evenly measured across all three sensors (Figure 3.16i). PZ18-09 appeared to encounter a recharge boundary, or zone of higher permeability after approximately 20 days. Water levels had not fully recovered by the end of the test (0.3 ft to 0.5 ft) and continued to decline. Cooper-Jacob time-drawdown analyses are provided in Appendix O.
- **MW18-03:** MW18-03 is located approximately 75 ft northwest of TW18-02 and completed in a shallower set of claystone/ash units. MW18-03 total depth is 145 ft as opposed to TW18-02 which is 600 ft. A drawdown response of 1.88 ft was observed at the well, which is slightly more than drawdown response observed at PZ18-09, located at a greater distance. The reduced drawdown at MW18-03 supports the concept of a more transmissive source bed supplying flow to TW18-02 which was not intercepted by MW18-03.
- **PZ18-06:** PZ18-06 is located approximately 1340 ft southeast of TW18-02 and completed in claystone/ash units. Water levels continued to decline after the test (Figure 3.16f), thus the measured drawdown is more related to equilibration than pumping at TW18-02. Even with a correction for drawdown, it is not possible to separate the equilibrium drawdown from any potential drawdown related to the pumping test.
- **PZ18-05:** PZ18-05 is located approximately 705 ft west of TW18-02 and completed in volcanic tuff units. Water levels continued to decline after the test (Figure 3.16e). The drawdown response is overprinted by declining water levels prior to and after the test, thus any drawdown associated with TW18-02 pumping is <0.28 ft and likely zero. Additionally, a vent fault and geologic contact reside between PZ18-05 and TW18-02, which are interpreted as hydrologic barriers based on pumping test response. The lack of obvious pressure response coupled with the geologic setting infer that the piezometer was not affected by the 35-day test.
- **PZ18-01:** PZ18-01 is located 765 ft northeast of TW18-02 in the uplifted horst block of volcanic tuff material. No drawdown response was observed during the 35-day test.
- **PZ18-08:** PZ18-01 is located 1065 ft northeast of TW18-02 in the open pit footprint. No drawdown response was observed during the 35-day test.
- **WSH-11:** WSH-11 is located 5300 ft east of TW18-02 in the open pit footprint. No drawdown response was observed during the 35-day test.

Individual Cooper-Jacob time-drawdown analyses are summarized in Table 3.16. Key results from the Cooper-Jacob analysis are:

- Values for transmissivity and hydraulic conductivity were consistent ranging from 542 ft²/d to 1900 ft²/d for transmissivity and from 1.11 ft/d to 3.9 ft/d for hydraulic conductivity. These ranges are somewhat higher than those obtained from packer and injection / airlift testing.
- Recovery and drawdown slopes were well aligned, although full recovery was not achieved after the testing period.
- Storage coefficients at the nearest location, PZ18-07 are indicative of storativity, suggesting a confined connection between the piezometer and pumping well. Whereas storage values from more distal monitoring locations (PZ18-09) are in line with broad specific yield values for sedimentary units.

A Cooper-Jacob distance drawdown analysis was developed in Figure 3.34. Transmissivity was estimated to be 576 ft²/d. Hydraulic conductivity was estimated to be 1.18 ft/d, which agrees with other values calculated during the 35-day pumping test (Table 3.15). A storage value of 0.04 was calculated, which is conceptually aligned with sedimentary and mudstone rock units. The distance-drawdown analysis identifies MW18-03, PZ18-01, and PZ18-08 as locations which are disconnected from the stressed groundwater system (Figure 3.35).

Key conclusions from the TW18-02 pumping test are summarized as follows:

- The lack of piezometric responses at PZ18-01, PZ18-08 and WSH-11, confirms that Silica Ridge and vent faults compartmentalized the southwest basin from the open pit area.
- Lack of response at PZ18-05 indicates additional hydrogeologic compartmentalization between Thacker Creek and the test well (TW18-02). This is geologically confirmed by the contact between more permeable claystone/ash beds in the vicinity of TW18-02 and volcanic tuff at PZ18-05.
- Groundwater flow to the well appears to be supplied by deeper seated beds, evidenced by the sustained borehole water level in TW18-02 at approximately 272 ft below top of casing (Appendix M) and the increase in temperatures observed at PZ18-07. The mechanism for groundwater flow geologically aligns with the thicker sections of basal ash beds found in the southwest basin which may preferentially transmit groundwater.
- Transmissivity values calculated from the pumping test are higher than claystone/ash values obtained from packer or injection / airlift testing but are within reasonable values for ash – rich endmembers of the claystone / ash unit. This further supports the presence of basal ash beds in the southwest basin, and that this unit has higher transmissivity than the beds of claystone / ash near the open pit which have a greater abundance of clay.

Table 3.16 35-day Cooper-Jacob analysis results

Monitoring location	Lithology	T (ft ² /d)	B (ft)	K (ft/d)	Storage
Distance-Drawdown (maximum)	Basal ash	649	487	1.33	0.024
Distance-Drawdown (minimum)	Basal ash	576	487	1.18	0.043
TW18-02	Basal ash		487		
PZ18-07-4317	Basal ash	1327	487	2.72	1.23E-05
PZ18-07-4457	Basal ash	1419	487	2.91	7.13E-06
PZ18-07-4532	Basal ash	1419	487	2.91	7.13E-06
PZ18-07-4627	Basal ash	1439	487	2.96	1.73E-04
PZ18-09-4469	Tuff	1482	487	3.04	1.02E-02
PZ18-09-4594	Tuff	1900	487	3.90	1.07E-02
PZ18-09-4674	Basal ash	1672	487	3.43	9.41E-03
MW18-03	Claystone/ash	1103	487	2.27	1.32E+00

3.4.6 Summary

Hydrogeologic testing from all programs are summarized into 5 lithologic groups in Table 3.17. The overall estimates are a result of 32 separate analyses. The testing and characterization program led to several key conclusions pertaining to the Thacker Pass Project hydrogeologic system:

- Volcanic tuff units are the least transmissive unit tested (generally an order of magnitude less than claystone/ash), with an average hydraulic conductivity value of 0.019 ft/d. Claystone/ash and basalt are the next transmissive units (although basalt is lightly tested) with bulk hydraulic conductivity values of 0.35 ft/d AND 0.69 ft/d respectively. Basin alluvium is the most transmissive unit.
- The presence of faults compartmentalized groundwater units are substantiated by pumping tests conducted at PH-1 and TW18-02. The corridor of N-S minor faults is responsible for the elevated groundwater levels encountered while drilling WSH-5, WSH-6, WSH-17, and PH-1. The PH-1 pumping test was affected by nearby hydraulic barriers, accelerating the rate of drawdown. During the TW18-02 pumping test, NW – SE trending vent faults (and the uplifted block of volcanic tuff) hydraulically separated the pit area monitoring locations from the production well. Compartmentalization will affect the resulting geometry of drawdown during mine operations.
- Thacker Creek was hydrologically separated from the TW18-02 pumping test by geologic contacts and N-S trending vent faults. This compartmentalization will reduce or possibly prevent impacts from mine dewatering.
- The basal ash unit in the southwest basin was the primary flow unit for groundwater during the TW18-02 pumping test. The basal ash beds had approximately an order of magnitude

higher transmissivity and hydraulic conductivity values than the more abundant claystone/ash beds.

- QRPW18-01 is located in a very transmissive alluvial aquifer. Water production from QRPW18-01 will be sustainable at a rate of 4,000 gpm and is capable of satisfying the water requirements for the project.

Table 3.17 Summary of hydrogeologic testing

Geology	# of tests	Transmissivity (ft ² /d)			Hydraulic Conductivity (ft/d)			Storage Coefficient (unitless)		
		Max	Min	Mean ¹	Max	Min	Mean ¹	Max	Min	Mean ¹
Tuff	6	2.23	0.81	1.4	0.068	0.012	0.019	--	--	--
Claystone/ash	12	952	0.35	62.5	2.8	0.016	0.35	0.043	2.39E-02	2.91E-02
Basalt	2	2409	2.1	71	4.05	0.016	0.69	--	--	--
Alluvium	2	28107	26472	26935	52.5	51	51.4	1.67E-01	4.07E-04	9.00E-03
Basal ash	10	1900	1.11	320.7	3.90	0.22	1.58	4.60E-02	7.13E-06	5.17E-04

¹ Geometric mean

4. CONCEPTUAL HYDROGEOLOGIC MODEL

An extensive conceptual hydrogeologic model was developed for the Thacker Pass Project and portions of the Quinn River and Kings River hydrographic basins. Conceptual model development synthesized data collected through LNC's field investigations as well as Nevada Division of Water Resources (NDWR) Bulletins and USGS reports:

- Water Resource Bulletin No. 31 "The Effects of Pumping on the Hydrology of Kings River Valley, Humboldt County, Nevada, 1957-64. (Malmberg, 1966).
- Water Resource Bulletin No. 34 "Effects of Irrigation Development on the Water Supply of Quinn River Valley Area, Nevada and Oregon, 1950-65". (Huxel, 1966).
- Water Resource Bulletin No. 14. "Geology and Ground-Water Resources of Quinn River Valley, Humboldt County, Nevada". (Visser, 1957).
- "Groundwater in the Alluvium of Kings River Valley Humboldt County, Nevada". (Zones, 1963).

4.1 Model Domain and Boundaries

The Thacker Pass Project resides along the hydrographic basin divide between Kings River Valley and Quinn River Valley. Therefore, of necessity the conceptual model must extend into both hydrographic basins, although the basins themselves are hydrologically separate. The conceptual model domain was selected with the following criteria:

- Encompass the key hydrogeologic features adjacent to the Thacker Pass Project including Thacker Creek and the Thacker Creek spring system, Pole Creek, Rock Creek, and Crowley Creek.
- Include all mine facilities that may influence the hydrogeology (open pits, dewatering wells, Quinn River production wells).
- Conceptual model boundaries should coincide with natural hydrologic boundaries or features, such as basin divides, when practical. When this is impractical due to distances, the boundaries should be placed far enough away so they do not over-constrain the model solution.
- Constant head boundaries should be located close to known water-level observation points to accurately specify the boundary.

The conceptual hydrogeologic model domain and boundaries are shown in Figure 4.1. Conceptual model boundaries in the Kings River Valley hydrographic basin were selected as:

- Northern boundary: Gaging station at the crossing of Kings River and Rio King Ranch Road (a perennially dry channel). An estimated groundwater elevation of 4,110 ft amsl is assigned at this location based upon water levels at NDWR Site ID 030A N45 E33.
- Southern boundary: Subarea boundary between Rio King and Sod House Subareas. A groundwater elevation of 4,100 ft amsl is estimated based upon interpolated water levels measurements younger than 1980 from the NDWR well logs (030A N44 E34 17DBBB1, 030B N44 E33 24DDBA1, and 030B N43 E34 13BBCA1).
- Western boundary: Hydrographic divide between Pine Forest Valley and Kings River Valley Basins.

In the Quinn River hydrographic basin, model boundaries were selected as:

- Northern boundary: Boundary between the McDermitt and Orovada Subarea coincident with the Quinn River gage station (USGS 10353500), with historic annual average flow rate of 35.3 cubic feet per second (cfs) flow in the Quinn River. A groundwater elevation of 4214 ft amsl (~40 ft below ground surface) is assigned based on NDWR well site 033A N45 E37 24BCDC1.
- Southern boundary: A groundwater elevation of 4,125 ft amsl is assigned based on interpolated water levels from NDWR well sites (033A N42 E37 04BADD2, 033A N42 E37 04BADD1, and 033A N42 E37 08DADD1).
- Eastern boundary: Hydrographic divide between Paradise Valley and Quinn River Valley Basins.

The conceptual model domain is sufficiently large to identify potential groundwater related impacts related to mining operations by placing boundary conditions beyond the effects of project pumping with the Thacker Pass Project placed in the center. From east to west, the model spans approximately 37 miles, and from north to south it spans approximately 14 miles.

4.2 Hydrogeologic Setting

The conceptual hydrogeology is similar to most basin and range settings, beginning with precipitation derived recharge in higher elevations entering the groundwater system and flowing towards alluvial basins (Huxel, 1966 and Malmberg, 1966). Groundwater is ultimately discharged to springs and seeps, phreatophytes, groundwater flow out of basins, or anthropogenic consumption (via irrigation, stock watering, commercial, etc.). Recharge reaches the alluvial basin via two processes:

1. Percolation into bedrock at high elevations and eventually discharging at depth in alluvial basins. This is referred to as “deep bedrock recharge” and comprises the smaller component of recharge in Quinn and Kings River Valleys (Huxel, 1966 and Malmberg, 1966).

2. Infiltration from surface water runoff as it flows across alluvium material along basin margins. This is referred to as “runoff recharge” and comprises the majority of recharge to the basins. Excellent examples of runoff recharge are the ephemeral flows in Pole, Rock, and Crowley Creek all of which fully infiltrate to groundwater when flowing.

Groundwater gradients and flows are controlled by the transmissivity of rock materials and the presence of geologic structures. Groundwater flow in bedrock units is generally dominated by discrete fractures, fissures, and structural fabrics which provide conduits to transmit water and is referred to as secondary permeability that occurs at the mesoscopic scale (1s to 10s of feet) (Fetter, 2001). Secondary permeability tends to normalize to average hydraulic conductivity values at the macroscopic scale (100s of ft), but is still fundamentally controlled by fracture density, aperture width, and tortuosity. In the Thacker Pass Project area, the presence of interbedded ash layers function as an additional pathway to transmit groundwater flow which can be characterized as secondary permeability because they interconnect transmissive beds of ash in a broader fabric of claystone at the mesoscopic scale. On a macroscale claystone/ash beds exhibit somewhat homogenous properties, which break down at small scales and particularly when coupled with vertical offsets from faulting. Thus, the presence of faults are particularly important because they tend to discretely impeded groundwater flow by truncating ash beds.

Steep groundwater gradients occur across faults and in low permeability bedrock units such as volcanic tuffs and flows. These materials possess crystalline rock matrices with very little intrinsic permeability. Claystone / ash bedrock units are more transmissive, and thus somewhat lower groundwater gradients, owing to the greater abundance of ash layers. The lowest groundwater gradients are present in alluvial sediments, which have greater pore spaces and connectivity depending on grain size, degree of sorting, and compaction.

A detailed discussion of localized groundwater conditions in the conceptual model and hydrogeologic units is provided in the following sections.

4.2.1 Thacker Pass

Groundwater levels in the vicinity of Thacker Pass are shown in Figure 4.2. Water levels tend to reside between 4,625 ft amsl to 5,034 ft amsl across the Thacker Pass Project and open pit area. Highest water levels are observed at WSH-7 (~ 5,285 ft amsl) which was drilled north of the principle E-W fault which functions as a hydrologic barrier. Water levels in the western portion of the Thacker Pass Project decline to an elevation of ~4,625 ft amsl (PZ18-05), which is approximately 20 ft higher than the headwaters of Thacker Creek (4,604 ft amsl). To the east, water levels decline to 4,513 ft amsl at MW18-02 which serves as the down gradient monitoring point. Key observations and conclusions for the groundwater system at Thacker Pass are summarized as follows:

- Water level data indicates the groundwater divide is shifted ~3,500 ft east of the hydrographic divide. The groundwater divide corresponds with a corridor of elevated water levels from WSH-7 (5,285 ft amsl), PH-1 (5,034 ft amsl), and WSH-17 (4,861 ft amsl) which

are compartmentalized by minor faults (Figure 4.2). Groundwater levels in the topographic divide are approximately 40 ft lower (~4,820 ft) as measured at WSH-11 and PZ18-08.

- Stair-stepping water levels across the minor faults (WSH-11 to WSH-17 to WSH-13) is further evidence which characterizes minor faults as hydraulic barriers. Likewise, the continuous drainage of WSH-17 suggests the borehole intercepted the fault barrier and is slowly re-equilibrating to the downgradient hydrologic block.
- Steep groundwater gradients occur south of the E-W vent fault as evidenced by the contrast in water levels between WSH-7 (5,285 ft amsl) versus WSH-8 and MW18-04 (4,827 ft amsl). Contrast in permeability along the E-W fault is attributable to the intrinsic properties of the fault itself because geologic logs of WSH-7 and MW18-04 indicated both wells are completed in rhyolitic volcanic tuff.
- Water levels have remained steady through time (Figure 4.3) with the exception of WSH-17. Most monitoring locations equilibrate in a period of weeks to months, and then remain steady through time. Recharge is thus interpreted as steady and predominantly from bedrock sources located at higher and wetter elevations rather than from surface runoff. The lack of surface water channels passing through the Thacker Pass Project suggests that runoff recharge is low across the Thacker Pass Project.
- Although water levels in the Thacker Pass Project show no seasonal variation, spring flows in Pole and Rock Creeks exhibit strong seasonal trends. Discharge at SP-039 in Pole Creek seasonally peaks in April and May and is dry by mid-summer. The strong seasonal response suggests stream channels can behave as transmissive bedrock corridors, hydraulically well connected along trend to upgradient recharge zones but poorly connected laterally to adjacent bedrock. Likewise, seasonal spring flow at Thacker Creek and attributable to enhanced transmissivity along the stream channel into the Montana Range because spring flow increases with limited surface water runoff from the headwaters north of SP-010.
- Groundwater levels across the claystone/ash sediments are generally flatter ranging from 0.007 ft/ft to 0.014 ft/ft. Interbedded ash layers function as pathways to transmit groundwater flow, thus the abundance of ash affects the transmissivity of claystone/ash sediments. Drilling and testing suggest claystone/ash can be partitioned into three zones where the abundance of ash is fairly uniform.
 - o Claystone/ash in the area of the proposed open pit. Claystone is the dominant rock type but is frequently deposited with ash beds of <1 ft to 5 ft thick.
 - o Indurated claystone. This is claystone located in the north east portion of the Thacker Pass Project (Figure 2.24 and Figure 2.25) and is conceptually composed of thick sections of well indurated claystone devoid of ash layers.
 - o Basal ash is an important unit present in the Southwestern Basin of the Thacker Pass Project. Basal ash is characterized as having thick (~30 ft) sequences of ash at the bottom of lacustrine sediments.

- In volcanic tuff, groundwater levels are steeper, ~ 0.025 ft/ft suggesting lower transmissivity of materials. Volcanic tuff possess a rhyolitic to andesitic groundmass with little pore spaces in the rock matrix to transmit water. Thus, volcanic tuff is conceptually characterized as low permeability material unless tectonic stress and shearing has opened fractures to transmit water, such as those inferred in the stream channels of Pole, Rock, and Thacker Creeks.
- Open pit mining is anticipated to begin at the north-western side of the pit, above the water table. As mining progresses to the east and south, the open pit will intercept the water table. The greatest saturated thickness is anticipated to be ~ 400 ft.

4.2.2 Quinn River Valley

Groundwater flow in Quinn River Valley is from north to south, ultimately discharging to Silver State Subarea or into Kings River Valley. Water levels in the northern extent of the conceptual model are 4,214 ft, amsl (NDWR Site ID 033A N45 E37 24BCDC1) and decline to $\sim 4,110$ ft amsl (NDWR Site IDs 033A N42 E37 04BADD2, 033A N42 E37 04BADD1, and 033A N42 E37 08DADD1). Overall water level gradients are very flat (Figure 4.4). Water level gradients in the north portion of the conceptual model are slightly steeper (0.003 ft/ft), whereas the central and southern portions possess a very flat gradient <0.0003 ft/ft suggesting very transmissive materials. Steeper gradients and higher water levels are found along basin margins corresponding to older alluvial fan, lakebed, and colluvial deposits. Water levels immediately south of Orovada are slightly elevated, likely caused by runoff recharge and alluvial fan geomorphology deposited by Horse Canyon and Buffalo Canyon Creeks. A corridor of low groundwater levels is found along the eastern portion of the basin, coincident with irrigation pivots and agricultural farming.

Hydrographs for select wells in Quinn River are shown in Figure 4.5. A steady decline in water levels is observed across the basin over the last 30 years. On average water levels have declined approximately 20 ft during this interval (~ 0.66 ft/yr). Drawdown of 30 ft to 40 ft is observed at locations within the agricultural corridor (locations 3, 4, 7 on Figure 4.4) owing to the increased demand in pumping. Location along alluvial margins (i.e. Location 6 in the alluvial fan of Horse Canyon and Buffalo Canyon Creeks), are more sensitive to climatic conditions and runoff infiltration. Water level increases occurred with ~ 1 -year delay after heavy winters in 2010 (16 inches, WRCC, 2019) and 2015 (10.81 inches, WRCC, 2019).

Quinn River water levels are indicative of a broad, transmissive alluvial basin with slightly less transmissivity along margins and in the northern portion. The agricultural corridor appears to have very high transmissivity, likely due to the weathering and deposition of quartzite and granite rocks in the Santa Rosas. Likewise drilling near the Quinn River revealed transmissive materials, from reworking of sediments in river channels during wetter pluvial climates. These observations agree

with mapped transmissivities by Huxel (1966) from well testing. Quinn River is a designated basin by the Nevada State Engineer, meaning no new water rights will be appropriated.

4.2.3 Kings River Valley

Groundwater flow in Kings River Valley is from north to south, ultimately discharging to south to Sod House. Water levels are very flat across the conceptual model domain, ranging from ~4,110 ft amsl north (NDWR Site ID 030A N45 E33 24BCCC2) and ~4,100 ft amsl in the south (Figure 4.6). Kings Valley possesses a very flat gradient <0.0002 ft/ft suggesting high transmissivity materials. Agricultural pumping has produced a 12-mile long cone of depression in the western central portion of the valley, where water levels have declined as much as 70 ft (Figure 4.7) in the past 30 years. This drawdown is a result of coalescing cones of depression between production wells in the very transmissive alluvium. Steeper gradients and higher water levels are inferred along basin margins using the gradient between Kings Valley and Thacker Pass as a guideline.

The water level hydrograph for select wells in Kings River Valley is shown in Figure 4.7. Steady water level decline of 30 ft to 70 ft is observed across the basin over the last 30 years. On average water levels have declined approximately 50 ft during this interval (~ 1.66 ft/yr), although in recent years the trend is flattening.

Kings River water levels are indicative of a broad, transmissive alluvial basin which is under a stress of heavy pumping for agriculture. Kings River is a designated basin by the Nevada State Engineer with a curtailment order issued in 1980. Thus, the decline in water levels is anticipated to be curtailed as basin production reaches perennial yield ($\sim 17,000$ afy).

4.2.4 Hydrogeologic units

Geologic units were grouped and subdivided into unique hydrogeologic units (HGUs) or zones of similar properties. A two-step approach was used to delineate HGUs:

1. Group geologic units of similar hydrogeologic properties into a bulk HGU. For example, beds of brown claystone, grey claystone, and interbedded white ash would be grouped together as claystone/ash.
2. Spatially divide and differentiate HGUs according to their location in Kings River Valley, Thacker Pass, and Quinn River Valley. Natural spatial variability is incorporated by delineating HGUs across these three areas of interest, which possess unique geologic and depositional settings.

Groundwater model calibration may further define additional HGUs to fit observation data, which will be addressed at that time. A description of conceptual HGUs is provided as follows and summarized in Table 4.1.

- **Quinn River Valley (QRV)-Basement McDermitt Tuff:** The majority of the Montana mountains is comprised of undifferentiated McDermitt Tuff, also referred to as the Tuff of Long Ridge. Tuff thickness varies between 0 to over 2,000 ft, such as is found in the Montana mountains. McDermitt tuff is stratigraphically lower than claystone/ash sedimentary units and is the basement HGU in the Montanas. Stream channels in the Montana Range represent corridors of elevated transmissivity and are broken out as a unique HGU.
- **QRV-Basalt:** Andesite and basalt flows are co-deposited throughout the McDermitt caldera, and generally lie unconformably above older volcanic tuff or interbedded within claystone/ash units. Basalt is generally on the order of hundreds of feet thick but can be found in flow deposits over 1,000 ft thick (Malmberg, 1966). Hydrogeologic properties are analogous to basalt tested in the Thacker Pass Project, namely moderate permeability along secondary fractures or weathering planes.
- **QRV-Rhyolitic flows and younger extrusive rocks:** This HGU is comprised of rhyolitic flows and extrusive rocks in the McDermitt Caldera.
- **QRV-Dacite:** Dacite deposits in the Santa Rosa mountains. The conceptual model is relatively insensitive to this HGU owing to its distal location to the Thacker Pass Project.
- **QRV-Jurassic granodiorite:** Granodiorite deposits in the Santa Rosa mountains represent the oldest rocks in the conceptual model domain and form bold outcrops such as Sawtooth mountain. The conceptual model is relatively insensitive to this HGU owing to its distal location to the Thacker Pass Project, although its weathering contributes source material to high transmissivity gravels in Quinn River Valley.
- **QRV-Undifferentiated rhyolite flows, lavas, tuffs:** Undifferentiated rhyolite flows, lavas, and tuffs outside the McDermitt Caldera comprise the Double H mountain range. These tuffs preceded the McDermitt Tuff. Bulk transmissivity of rhyolite flows is inherently low, with limited capacity to transmit groundwater except through secondary fractures and fissures. Hydrogeologic properties are analogous to volcanic tuffs tested at the Thacker Pass Project.
- **QRV-Winnemucca formation:** The Winnemucca formation is comprised of siltstone, quartzite, and shale in the Santa Rosa mountains. The conceptual model is relatively insensitive to this HGU owing to its distal location to the Thacker Pass Project.
- **Older alluvium (Quinn River and Kings River Valleys):** Older alluvium sediments are exposed along the basin margins. The alluvium is highly variable and is composed of unconsolidated sand, silt, and clay. Older alluvium is composed of paleo-channels and floodplains, ancient alluvial fans, and basin fill. Towards the center of the valleys, older alluvium becomes better sorted, less angular, and has smaller grain sizes. Transmissivity measured in the older alluvium is estimated to range from 1,350 to 6,740 ft²/d (Malmberg, 1966). Older alluvium pinches out at the basin margins, reducing the unit's thickness and transmissivity. Both older and younger alluvium units have horizontal hydraulic conductivity values several times larger than vertical hydraulic conductivity.

Older alluvium lies conformably beneath Lake Lahontan sediments in both Kings River Valley and Quinn River Valley. Lake Lahontan sediments deposited during the wetter pluvial period of the Pleistocene era are approximately 200 feet thick and consist of fine-grained lacustrine deposits. These sediments span across the entire valley where they have not been eroded by incising stream channels (Malmberg et al 1966). Along the basin margins, erosion from uplift and run-on has stripped lakebed sediments, exposing older alluvium beneath.

- **Basin fill alluvium (Quinn River and Kings River Valleys):** Basin fill alluvium transitions from the basin margins towards the basin center and are formed by bulk alluvial, younger alluvial fans, and floodplain deposits. Materials are comprised of sub-angular gravels, sands, and silts, with generally < 30% fine-grain content. QRPW18-01 was tested in mostly basin fill alluvium, yielding a transmissivity value of 26,935 ft²/d and in agreement with other observed values in the basin (Huxel, 1966). Basin fill is incised by younger reworked alluvium and pinches out towards the basin margins.
- **Younger alluvium (Quinn River and Kings River Valleys):** Younger alluvium and playa sediments are found in both Kings River Valley and Quinn River Valley along the central axis of the basins. These sediments consist of unconsolidated gravel, sand, and silt which has been reworked in alluvial fan deposits and historic river channels during wetter climate epochs. Younger alluvium thickness is approximately 200 ft in channel deposits and pinches out laterally towards the basin margin. Geologic logs of QRPW18-01 correlate with this thickness, encountering well sorted gravel and cobble beds between 40 ft to 120 ft depths.
- Younger alluvium has the highest transmissivity and storage of any material in the conceptual model. Transmissivity values ranging from 70,000 ft²/d to 100,000 ft²/d have been measured (Huxel, 1966), and the recharge boundary encountered at QRPW18-01 supports the presence of higher transmissivity units in the basin. The storage coefficient (specific yield) was identified at 0.17 (Malmberg, 1966), and correlates well with calculated storage values at the West Windmill Well.
- **Thacker Pass alluvium:** Alluvium in Thacker Pass is generally thin, ranging from a few feet to less than 100 ft, and comprised of fine-grained sands, silt, and clays. Alluvial hydrogeologic properties are envisioned to be similar to that of older basin margin alluvium, which would be relatively higher than underlying volcanic tuff and slightly higher than claystone/ash beds. Alluvium is thicker near structural fault boundaries (as observed in PZ18-04) where deposition is actively ongoing. Stream drainages, such as Thacker Creek, are thought to have some structural control, thus relatively thicker sequences of alluvial materials are anticipated.
- **Thacker Pass basalt:** Basalt in the Thacker Pass Project area is conformably deposited within and above claystone/ash beds. Basalt can be a key marker bed in the ore body. Shallow basalt flows are found in the ridge near PZ18-06, and in the eastern portions of Pole and Rock Creeks. A 300-foot thick sequence of basalt was observed in WSH-3 and at other exploration holes on the eastern fringe of the project area. This data and aerial

magnetic surveys suggest that thicker basalt flows lie east of the project area beneath older alluvium sediments. Hydrologic testing indicates that basalt can be very permeable (30.1 ft/d at WSH-3).

- **Thacker Pass claystone/ash:** The claystone unit is dominantly composed of most sediments in the form of clays, lithified claystone, and ash. Thin beds of volcanic ash, ranging from less <1 ft to 5 ft in thickness are regularly interbedded within claystone deposits. Ash beds are comprised of well sorted fine to coarse-grained lapilli sands and are the primary flow conduits in the unit. It is because of the abundance of ash in beds that the claystone/ash unit is more susceptible to groundwater compartmentalization than other units. Slight offsets due to faulting (such as the network of minor faults through the ore body) juxtapose more transmissive ash beds against claystone beds, effectively disrupting groundwater flow.
- Claystone is generally well indurated with good recovery during drilling. This suggests that bedding planes and fractures can remain open as conduits for groundwater flow and serve as the primary flow mechanism. The claystone unit is approximately 300 ft to 400 ft thick in the Thacker Pass Project. This unit hosts the Li-rich hectorite clays which compose the ore body and is the unit in which open pit mining will occur.
- **Thacker Pass indurated claystone:** Indurated claystone is comprised of compacted, and possibly silicified, claystone beds with less abundant ash beds. They are located in the northeast sector of the Thacker Pass Project, delineated through surface geophysics which characterizes the area as low magnetic resonance (indicative of claystone) and moderate resistivity (a result of cementation and the absence of ash).
- **Thacker Pass basal ash:** The basal ash unit is found in the Southwest basin, south of Silica Hill and lies stratigraphically below the claystone/ash unit. Basal ash is primarily composed of rhyolitic volcanic lapilli ranging from 50 ft to 200 ft thick. Claystone is interbedded in the ash, but less abundant than in the claystone/ash unit. Thus, vertical hydraulic conductivity is limited by thin interbeds of claystone and several times lower than horizontal hydraulic conductivity.
- **Thacker Pass volcanic tuff:** Volcanic tuff (primarily the Tuff of Long Ridge or McDermitt Tuff) is located stratigraphically below the claystone/ash unit. The top of the lithic tuff is a lithified, competent silicic volcanic rock which serves as the boundary between claystone and tuff. Groundwater flow principally occurs through secondary fractures and along structural features. The overall permeability and storage are quite low, even after accounting for fractures. In some instances, pseudo folded-bedding planes are observed due to the high viscosity of the tuff at deposition, this is referred to as rheomorphic tuff. In the project area, the tuff unit dips to the west-southwest until it is overlain by the ring faults at the caldera margins. Lithic tuff represents the deepest bedrock unit encountered by exploration drilling.

- **Thacker Pass drainages:** Stream channels in the Montana Range represent corridors of enhanced transmissivity, interpreted as tectonic shear zones. These zones connect springs and streams to upgradient recharge areas but are enveloped by unfractured bedrock.

Table 4.1 Summary of hydrogeologic units

Lithology Unit	K _h Range (ft/d)	K _v Ratio	S _s Range (1/ft)	S _y Range	Source
QRV-Basement McDermitt Tuff	1x10 ⁻⁴ – 1x10 ⁻¹	1 - 10	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	2018 Testing
QRV-Regional Basalt	1x10 ⁻² – 10	1	1x10 ⁻⁷ – 1x10 ⁻⁵	0.04 – 0.01	2018 Injection / recovery tests
QRV-Rhyolitic flows and younger intrusive rocks	1x10 ⁻⁴ – 1x10 ⁻¹	1 - 10	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	2018 Testing
QRV-Dacite	1x10 ⁻⁴ – 1x10 ⁻¹	1 - 10	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	Literature estimates
QRV-Jurassic granite	1x10 ⁻⁴ – 1x10 ⁻²	1	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	Literature estimates
QRV-Undifferentiated rhyolite flows, lavas, tuffs	1x10 ⁻⁴ – 1x10 ⁻¹	1 - 10	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	2018 Testing
QRV-Winnemucca fm: Shale, siltstone, sandstone and carbonate	1x10 ⁻³ – 1x10 ⁰	1 - 100	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	Literature estimates
QRV - Older alluvium	1x10 ⁻¹ – 1x10 ¹	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁴	0.17 – 0.03	Water Resource Bulletin 34
QRV – Basin fill alluvium	2x10 ¹ – 1x10 ²	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁴	0.20 – 0.05	QRPW18-01 pumping test
QRV- Younger alluvium / gravel beds	2x10 ¹ – 2x10 ²	1 - 10	1x10 ⁻⁶ – 1x10 ⁻⁴	0.20 – 0.05	Recharge boundary observed in QRPW18-01
Thacker Pass - Alluvium	1x10 ⁻¹ – 1x10 ¹	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁴	0.17 – 0.03	Literature estimates
Thacker Pass – Claystone/ash	5x10 ⁻² – 5x10 ⁰	1 - 1000	1x10 ⁻⁷ – 1x10 ⁻⁵	0.04 – 0.01	2018 Testing
Thacker Pass – Indurated claystone	5x10 ⁻² – 5x10 ⁻¹	1 - 1000	1x10 ⁻⁷ – 1x10 ⁻⁵	0.04 – 0.01	2018 Testing
Thacker Pass Basal ash	1x10 ⁻¹ – 5x10 ⁰	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁵	0.04 – 0.01	2018 Testing
Thacker Pass – Volcanic tuff	9x10 ⁻³ – 1x10 ⁰	1 - 10	5x10 ⁻⁷ – 5x10 ⁻⁵	0.01 – 0.005	2018 Testing
Thacker Pass - Basalts	1x10 ⁻² – 10	1	1x10 ⁻⁷ – 1x10 ⁻⁵	0.04 – 0.01	2018 Testing
Thacker Pass - Drainages	1x10 ⁻¹ – 1x10 ⁰	1 - 10	1x10 ⁻⁶ – 1x10 ⁻⁵	0.01 – 0.005	2018 Testing
KRV – Undifferentiated rhyolite flows, lavas, tuffs	1x10 ⁻⁴ – 1x10 ⁻¹	1 - 10	1x10 ⁻⁷ – 1x10 ⁻⁵	0.01 – 0.005	2018 Testing
KRV - Older alluvium	1x10 ⁻¹ – 1x10 ¹	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁴	0.17 – 0.03	Water Resource Bulletin 31
KRV – Basin fill alluvium,	5x10 ⁰ – 1x10 ²	1 - 100	1x10 ⁻⁶ – 1x10 ⁻⁴	0.20 – 0.05	Water Resource Bulletin 31
KRV – Younger alluvium, playa	2x10 ¹ – 2x10 ²	1 - 10	1x10 ⁻⁶ – 1x10 ⁻⁴	0.20 – 0.05	Analogous QRPW18-01 pumping test

K_h – Horizontal hydraulic conductivity

K_v – Vertical anisotropy (K_h / K_z)

S_s – Specific storage

S_y – Specific yield

Cross-section of HGUs in the vicinity of Thacker Pass Project shown in Figures 4.8 through 4.10.

4.3 Groundwater Quality

Groundwater chemistry ranges from Ca/Na – HCO₃ to Ca/Na – SO₄ types, showing nearly equal components of calcium and sodium cations (Figure 4.11). Monitoring wells WSH-3, WSH-13, and WSH-17 have increasing components of sodium, which may be related to groundwater age and ion exchange. Major ion chemistry of seeps and springs is similar to that of monitoring wells with slightly higher Ca composition and lack any sodium-rich outlying springs (Figure 4.12). Chemistry correlation between monitoring wells and springs supports that springs, where they have perennial flow, are expressions of the groundwater system, and they are recharged by younger groundwater with shorter flow paths and residence times.

A spatial evaluation of major ion chemistry is presented in Stiff diagrams for springs and wells in Plan 4.1 and Figure 4.13. The Stiff diagrams suggest homogeneity among locations in terms of the distribution of ions, except for WSH-3 which is sodium-rich. The magnitude of ions are greater in evapoconcentrated seeps (SP-010, SP-035, SP-035, and SP-034) and in monitoring wells completed in claystone/ash near the pit vicinity (WSH-17, PH-1, WSH-14, WSH-13, MW18-02). Monitoring well locations tend to have higher overall concentrations of constituents that are in similar proportions with springs and seeps.

Minor ion composition of groundwater chemistry possesses elevated background concentrations of several constituents (arsenic, fluoride, iron, manganese) which exceed NRVs. The frequency of exceedances is summarized in Table 4.2 and Table 4.3 (note only constituents with minimum 10% exceedance frequency are summarized). The abundance of arsenic, fluoride, iron, and manganese is common for groundwater hosted in volcanic rocks or their weathered derivatives. A description of the background concentrations for these elements is as follows:

- **Arsenic:** Elevated concentrations of arsenic, relative to NRVs, are naturally found across the Thacker Pass Project as a background condition. It is the most abundant exceedance to NRVs, occurring in 66% of monitoring well samples and 66% in springs (Table 4.2). Average background arsenic concentrations in groundwater are ~0.019 mg/L. The lower bound 95% confidence interval of monitoring well data has an arsenic concentration of 0.011 mg/L, which confirms that elevated arsenic concentrations are encountered across the Thacker Pass Project (Table 4.3). Elevated concentrations of arsenic are found at most springs, including the Thacker Creek complex and in range front springs in Kings River Valley (Figure 4.14). Typical arsenic concentrations in springs range from 0.03 mg/L to 0.005 mg/L, but have been measured as high as 0.087 mg/L at SP-01 in the Thacker Creek headwaters. The distribution of arsenic levels tends to be higher near Thacker Creek and the Thacker Pass Project, although elevated concentrations have been observed throughout the caldera.

- Fluoride:** Approximately 35% of groundwater monitoring well samples are found to have elevated fluoride concentrations across the Thacker Pass Project (Table 4.2). Exceedances occur more frequently in the WSH-series of monitoring wells in the footprint of the proposed pit (Figure 4.15). Concentrations between 1.2 mg/L to 3.1 mg/L are commonly observed in the Thacker Pass Project. Although the mean groundwater concentration (2.15 mg/L) and 95% confidence intervals are below NRVs, certain locations such as WSH-17 and WSH-13 have consistently elevated concentrations. None of the spring samples have exceeded NRVs for fluoride. The highest spring concentrations were observed at SP-051, located in Rock Creek headwaters, with a value of 2.2 mg/L. The spatial distribution of fluoride suggests the element may be a leached product in claystone/ash beds.
- Iron:** Iron occasionally exceeds NRVs across the Thacker Pass Project. Iron exceedances occurred more frequently in springs than in wells, inferring that near surface weathering of minerals may be affecting spring chemistry. Iron concentrations generally range from 0.3 mg/L to 0.01 mg/L and show localized consistency (Figure 4.16). For example, springs in Thacker Creek tend to exhibit iron concentrations <0.2 mg/L whereas springs in Rock Creek headwaters are ~0.3 mg/L. Locally high concentrations of iron were found in SP-050, SP-046, SP-001, and SP-002.
- Manganese:** Manganese exceeds NRVs primarily in Thacker Creek (SP-010, SP-011, SP-033, and SP-034) where concentrations range from <0.01 mg/L to 1.5 mg/L. Other locations in the Thacker Pass Project are below NRVs, with an occasional exception such as SP-002 (Figure 4.17). Groundwater chemistry sampled from monitoring wells has an average concentration of 0.028 mg/L and rarely exceeded NRVs.

Table 4.2 Summary of groundwater Profile I exceedances

Constituent	Wells (82 total samples)			Springs (116 total samples)		
	No. Exceedance Samples	Percentage (%)	Key Wells	No. Spring Exceedances	Percentage (%)	Key Springs
Aluminum	5	6%	WSH-03	25	22%	SP-036, SP-040, SP-050
Antimony	5	6%	PH-1, WSH-13, WSH-14	0	0%	
Arsenic	61	66%	Most wells	76	66%	SP-011, SP-010, SP-012, SP-041
Fluoride	26	35%	WSH-series wells	0	0%	SP-051
Iron	5	5%	PH-1, MW18-04	26	22%	SP-050, SP-011, SP-010, SP-040
Manganese	1	1%		17	15%	SP-033, SP-011, SP-010, SP-054

Table 4.3 Statistical summary of element exceedance in monitoring wells

	Units	Arithmetic Mean	Geometric Mean	Standard Deviation	Upper 95% Confidence Interval	Lower 95% Confidence Interval
Aluminum	mg/L	0.046	0.016	0.075	0.091	0.002
Antimony	mg/L	0.0011	0.0006	0.0014	0.0019	0.0003
Arsenic	mg/L	0.019	0.012	0.013	0.027	0.011
Fluoride	mg/L	2.15	1.43	1.60	3.10	1.20
Iron	mg/L	0.062	0.039	0.075	0.106	0.018
Manganese	mg/L	0.028	0.016	0.024	0.043	0.014

Exceedance to Profile I NRVs

Exceedance to Profile III NRVs

Deuterium and Oxygen-18 isotopes generally follow the meteoric water line which undergo evaporation enrichment of Oxygen-18 (Figure 4.18). Deuterium levels seasonally increase during Q2 that is coincident with spring runoff and higher flows. This component of interflow recharge temporarily masks the evaporation enrichment groundwater until flows recede, generally in Q3, and support the conceptual framework of higher transmissivity drainages where these springs occur. Isotopic spring data appears to be consistent with groundwater signatures further supporting a groundwater source to spring flow.

4.4 Recharge

Recharge in Quinn River and Kings River Valleys begins in mountain blocks with elevations above 5,000 ft amsl, and is distributed to the alluvial basin via two processes (Huxel, 1966 and Malmberg, 1966):

1. Deep Bedrock recharge representing precipitation and snowmelt percolation in bedrock mountain blocks.
2. Runoff Recharge derived from infiltration of surface water runoff as it flows across alluvium material along basin margins.

NDWR resource bulletins reports estimate total recharge for Quinn River Valley to be ~74,400 afy and specifically 25,000 afy in the Orovada Subarea (Huxel, 1966). Recharge is partitioned between Deep Bedrock recharge and Runoff recharge as 7,000 afy and 18,000 afy respectively. Most Runoff recharge occurs on the eastern side of the basin, associated with the Santa Rosa mountains and infiltration from Willow and Rebel Creeks. Recharge estimates for the Orovada Subarea are scaled to the conceptual model area using an area weighted average of ~61.5% (the area of the conceptual model in the Orovada Subarea). Thus, the components of Deep Bedrock and Runoff recharge in the conceptual model are estimated to be 4,304 afy and 11,066 afy respectively; making a total recharge value of 15,370 afy to the Quinn River portion of the conceptual model.

Recharge estimates total for Kings River Valley to be ~23,500 afy; 16,800 afy is associated with the Rio King Subarea, which is the only Subarea pertinent to the conceptual model (Malmberg,

1966). Runoff recharge comprises ~ 15,900 afy in the Rio King Subarea, with a limited 900 afy derived from Deep Bedrock source. The Rio King Subarea recharge estimates are scaled down to the conceptual model area using an area weighted average of ~45.3% (conceptual model area in King River Valley). Thus, the components of Deep Bedrock and Runoff recharge in the conceptual model are estimated to be 407 afy and 7,195 afy respectively; making a total recharge value of 7,602 afy to the Kings River portion of the conceptual model.

Conceptual model recharge components are summarized in Table 4.4

Table 4.4 Conceptual model recharge summary

Basin	Orovada Subarea	Rio King Subarea	Quinn River – Conceptual Model ¹	Kings River – Conceptual Model ²
Runoff Recharge	18,000	15,900	11,066	407
Deep Bedrock Recharge	7,000	900	4,304	7,195
Total	25,000	16,800	15,370	7,602

¹ Quinn River conceptual model scale factor is 61.5%

² Kings River conceptual model scale factor is 45.3%

4.4.1 Catchment recharge distribution

Recharge into the conceptual model is spatially scaled from NDWR resource bulletins using the 1965 Hardman map through a process of catchment delineation. Processing steps are described as follows:

1. Delineate major catchments for in Kings River and Quinn River Valleys. Catchments are sub-divided into a “bedrock” catchment and a “runoff” sub-catchment at the contact between alluvium and bedrock (Figure 4.19). A total of 18 catchments were defined (14 in Quinn River hydrographic basin and 4 in Kings River). No catchments are defined in the basin axis because it is a groundwater discharge zone.
2. Calculate the volume of recharge in each basin using the method of Maxey-Eakin for an area weighted average of recharge from the 1965 Hardman map (Maxey and Eakin, 1949; Hardman, 1965). The total values derived from the Hardman map were 532 afy in Kings River and 7,236 afy in Quinn River, both of which are less than estimates from NDWR Resource Bulletins.
3. Estimate the relative percentage of recharge contributed from each catchment to the overall basin by calculating the percentage of recharge for each catchment ($R_{\text{catchment}} / R_{\text{total basin}}$). For example, Catchment I contributes 90 afy out of 532 afy in Kings River Valley, it represents 17% of the basin’s recharge.
4. Scale the NDWR Resource Bulletin estimates for Deep Bedrock and Runoff Recharge for each basin across the catchments by multiplying the catchments relative percentage (calculated in step 3) by the total basin value.

Catchment summaries and calculations are presented in Table 4.5 and shown in Figure 4.19.

Table 4.5 Recharge distribution by catchment

Catchment Name	Sub-Catchment Name	Area (acres)	Basin	% Basin ²	Deep Bedrock Recharge (afy)	Runoff Recharge (afy)	Recharge Rate (in/yr)
1.60402E+11	1.60402E+11-Bedrock	6,899	Quinn River	0.062	267	0	0.46
1.60402E+11	1.60402E+11-Runoff	10,539	Quinn River	0.062	0	686	0.78
A	A-Bedrock	4,577	Quinn River	0	0	0	0.00
A	A-Runoff	3,096	Quinn River	0	0	0	0.00
B	B-Bedrock	15,927	Quinn River	0.025	108	0	0.08
B	B-Runoff	2,351	Quinn River	0.025	0	277	1.41
C	C-Bedrock	7,993	Quinn River	0.072	310	0	0.47
C	C-Runoff	1,410	Quinn River	0.072	0	797	6.78
D	D-Bedrock	1,410	Quinn River	0.001	4	0	0.04
D	D-Runoff	470	Quinn River	0.001	0	11	0.28
E	E-Bedrock	3,761	Quinn River	0.015	65	0	0.21
E	E-Runoff	4,231	Quinn River	0.015	0	166	0.47
F	F-Bedrock	3,526	Quinn River	0.003	13	0	0.04
F	F-Runoff	10,814	Quinn River	0.003	0	33	0.04
G	G-Bedrock	1,410	Quinn River	0.005	22	0	0.18
G	G-Runoff	1,410	Quinn River	0.005	0	55	0.47
H	H-Bedrock	4,702	Quinn River	0.038	164	0	0.42
H	H-Runoff	5,642	Quinn River	0.038	0	420	0.89
Middle Crowley Creek	Middle Crowley Creek-Bedrock	20,955	Quinn River	0.144	620	0	0.35
Middle Crowley Creek	Middle Crowley Creek-Runoff	6,406	Quinn River	0.144	0	2767	5.18
Rebel Creek	Rebel Creek-Bedrock	8,228	Quinn River	0.138	594	0	0.87
Rebel Creek	Rebel Creek-Runoff	1,410	Quinn River	0.138	0	1527	12.99
Upper Crowley Creek	Upper Crowley Creek-Bedrock	17,748	Quinn River	0.104	448	0	0.30
Upper Crowley Creek ¹	Upper Crowley Creek-Runoff ¹	-	Quinn River	0.104	0	0	0
Willow Creek	Willow Creek-Bedrock	18,454	Quinn River	0.226	973	0	0.63
Willow Creek	Willow Creek-Runoff	7,052	Quinn River	0.226	0	2501	4.26
M	M-Bedrock	10,740	Quinn River	0.17	732	0	0.82
M	M-Runoff	6,582	Quinn River	0.17	0	1881	3.43
Total Quinn River		187,745			4,317	11,121	
I	I-Bedrock	5,756	Kings River	0.19	170	0	0.35
I	I-Runoff	1,227	Kings River	0.19	0	1205	11.79
J	J-Bedrock	9,876	Kings River	0.2	382	0	0.46
J	J-Runoff	1,067	Kings River	0.2	0	1076	12.10
K	K-Bedrock	16,220	Kings River	0.5	204	0	0.15
K	K-Runoff	11,519	Kings River	0.5	0	3598	3.75
L	L-Bedrock	3,291	Kings River	0.11	45	0	0.16
L	L-Runoff	1,646	Kings River	0.11	0	792	5.77
Total		50,599			406	7,173	

¹ Upper Crowley catchment has no runoff component and is routed directly to Middle Crowley runoff sub-catchment.

² Relative basin percentage is calculated for the entire catchment, thus repeated in sub-catchments

4.5 Discharge

Groundwater discharge from Quinn River and Kings River Valleys occurs primarily through four processes:

- Evapotranspiration through phreatophytes
- Irrigation pumping
- Seeps and springs
- Groundwater outflow to adjacent basins

Prior to the 1950s, discharge occurred primarily through evapotranspiration of phreatophytes. However, with the increase in agricultural production during the 1950s and 1960s irrigation pumping is the largest component of groundwater discharge. Both basins have been given the status of “designated basins” by the Nevada State Engineer, Quinn River was designated in 1965 (NDWR, 1965) and Kings River in 1980 (NDWR, 1980a). Kings River Valley is also currently under a curtailment order from the Nevada State Engineer (NDWR, 1980b). Water level decline in the basins over the past 30 years is indicative of the changing proportions of increasing irrigation pumping and declining evapotranspiration. Individual components of groundwater discharge are discussed in the following sections.

4.5.1 Irrigation Pumping

Modern irrigation pumping in Quinn River Valley was estimated from the 2018 crop inventory compiled by NDWR (NDWR, 2018). There were 62,038 afy of water irrigated across ~ 57,200 acres, making the water usage rate to be ~1.1 ft/acre which correlates well to alfalfa consumption. Nearly all irrigation pumping occurs in the Orovida Subarea (Figure 4.20), but drawdown has propagated throughout the basin due the constraints on the basin’s hydrologic budget. Irrigation pumping in the conceptual model area is estimated to be 37,725 afy, as determined by multiplying the area of irrigated acreage in the conceptual model domain (34,780 acres) by the average annual consumption rate.

Irrigation pumping in Kings River Valley was estimated to be 17,125 afy across an area of 28,360 acres (NDWR, 2018). All irrigation occurs in the Rio King Subarea, which is evident by the cone of depression in groundwater levels. Irrigation pumping in the conceptual model area is estimated to be 6,000 afy based on 9,940 acres of irrigated land in the conceptual model domain.

4.5.2 Evapotranspiration

Evapotranspiration in Quinn River prior to the 1950s was estimated to be 63,000 afy across 161,600 acres of phreatophyte vegetation. Evapotranspiration was primarily from Greasewood and Rabbitbrush (~29,000 afy) and native meadow grass (~22,000 afy) (Huxel, 1966). Irrigation pumping has reduced natural evapotranspiration discharge by lowering the water table below the root depths of phreatophytes. Evapotranspiration in the conceptual model area was developed by estimating the footprint of existing phreatophyte features from aerial photography (~14,640 afy) and scaling evapotranspiration from the current area to the historic area. Modern evapotranspiration is calculated to be approximately 5,410 afy, as summarized in Table 4.6.

Evapotranspiration in Kings River prior to the 1950s was estimated to be 16,400 afy across 64,000 acres of phreatophyte vegetation. The majority of evapotranspiration occurred in the Rio King sub-area (9,400) from Greasewood and Saltgrasses (Malmberg, 1966). Modern evapotranspiration acreage was estimated to be 8,200 acres using the same method as Quinn River Valley and is calculated to be approximately 2,660 afy, summarized in Table 4.6 and Figure 4.20.

Table 4.6 Conceptual evapotranspiration summary

Basin	Units	Orovada Subarea	Rio King Subarea
Pre-1950s ET Estimate	afy	34,000	9,400
Pre-1950s ET Area	acres	92,000	29,000
Average ET Rate	ft/yr	0.37	0.32
Modern ET Area	acres	14,640	8,200
Modern ET Estimate	afy	5,410	2,660

4.5.3 Seeps / Springs

Seeps and spring discharge from Quinn River Valley is estimated to be 300 afy (186 gpm) (Huxel, 1966). This value incorporates the average flows measured during the seep and spring survey which is approximately 156 afy.

Spring discharge in Kings River Valley NDWR reconnaissance reports was consumed for irrigation or evapotranspiration, thus included in the evapotranspiration estimate. However, discharge from Thacker Creek (376 afy) should be considered as its load is captured in an impoundment and does not re-infiltrate to the alluvial basin. Other spring fed impoundments (SP-48 and SP-49) account for an additional 55 afy as spring discharge. Total spring discharge for the conceptual model is estimated to be 431 afy (268 gpm).

4.5.4 Groundwater outflow

Groundwater inflow occurs in the subsurface between basins, but is difficult to calculate. The difference between groundwater inflow and known discharges is estimated to be groundwater outflow.

4.6 Water Budget

The conceptual model's water budget was developed from the overall, modernized basin-wide water budget for Quinn River and Kings River Valleys. Steps taken to develop conceptual water budgets are described as:

- Develop natural pre-1950s water budget based on Water Resource Bulletins for each groundwater basin and corresponding Subarea. This is provided in Appendix P and Appendix Q.
- Calculate an assumed value of 25% of irrigation pumping quantity as return flows into the Subarea.
- Update basin-wide water budget components irrigation pumping, evapotranspiration, and groundwater outflow to modern values. The groundwater outflow component is calculated between Subareas as the difference between inflows and outflows, which is then added as an inflow component to the down-gradient Subarea. In some cases, irrigation pumping in one Subarea is so large that phreatophyte evapoconcentration must be reduced in adjacent basins (i.e. basin-wide drawdown). For example, to accommodate the 62,038 afy of irrigation pumping in the Orovada Subarea, evapoconcentration is reduced from upgradient McDermitt Subarea from 17,000 afy to 9,300 afy. These budgets are provided in Appendix P and Appendix Q.
- Scale Subarea water budgets to the conceptual model domain based on corresponding areas of irrigation pumping, phreatophyte area, and recharge.

Conceptual model water budgets for Quinn River and Kings River valley are presented in Table 4.7.

Table 4.7 Conceptual model water balance

	Quinn River Conceptual Model		Kings River Conceptual Model	
	Conceptual Model (afy) ¹	Area (acres)	Conceptual Model (afy) ¹	Area (acres)
Inflows				
Basin Recharge	15,370	248,620	7,600	86,492
<i>Runoff Recharge</i>	<i>11,070</i>		<i>7,195</i>	
<i>Deep Recharge</i>	<i>4,300</i>		<i>405</i>	
AG Return Flow	8,700 ²		1,500	
GW-Inflow	30,980 ³		0	
Total	55,050		9,100	
Outflows				
Phreatophytes	3,790	10,260	1,405	4,335
AG Pumping	34,780	34,780	6,000	9,942
Springs	150		431	
GW outflow	16,320		1,264	
Surface Water Outflow	0		0	
Total	55,050		9,100	

¹ Rounded to nearest 10 afy

² Assumed to as 25% irrigation pumping

³ Approximately 25,600 afy is attributed to the Quinn River (USGS, 2018)

5. CONCLUSIONS

Hydrologic investigations in the Thacker Pass Project and surrounding Quinn and Kings River Valleys have expanded the conceptual understanding of the groundwater system and character of groundwater flows. The following key conceptual conclusions can be distilled from hydrologic investigations.

- Thacker Creek is the only perennial stream near the Thacker Pass Project. All other creeks have ephemeral flow near the Thacker Pass Project, although the upper reaches of Crowley are likely perennial. Thacker Creek is a gaining stream system with its headwaters coinciding with SP-010 and SP-011. Groundwater contributions to the creek occur directly to the streambed itself and through a network of small springs which are tributaries to the creek. The total estimated baseflow to Thacker Creek is 234 gpm, estimated during fall and winter seasons when evapotranspiration losses are minimal.
- Groundwater levels across the Thacker Pass Project range from 4,625 ft amsl to 5,034 ft amsl and are steady, indicating the system is in equilibrium and unaffected from seasonal fluctuations in precipitation and recharge. However, spring flows in Pole and Rock Creeks fluctuate seasonally, suggesting the creeks reside in a transmissive drainage corridor, separated from the more massive bedrock units in the Thacker Pass Project.
- Groundwater levels surrounding WSH-7, PH-1, and WSH-17 form a groundwater divide, located approximately 3,500 ft east of the topographic divide and are controlled by a series of faults which compartmentalize the groundwater system.
- Stair-stepping water levels and steep horizontal gradients between PH-1, WSH-17, WSH-11, and between MW18-04 and WSH-7 indicate groundwater compartmentalization attributable to fault structures which act as hydraulic barriers. Likewise, the response to the TW18-02 35-day pumping test was compartmentalized to claystone/ash sediments in the southwest basin, further characterizing faults as hydraulic barriers. The nature of faults as hydraulic barriers is attributable to a combination of truncating ash beds (minor faults adjacent to PH-1), juxtaposition of low transmissivity beds against higher transmissivity beds (vent faults of Silica Hill), and intrinsic low permeability of the fault itself (E-W northern fault).
- Mining will intercept the water table, likely requiring some dewatering to facilitate mining, such as sump pumping from pits. The thickest seepage face is anticipated to be a maximum of 400 ft. Fault structures surrounding the open pit are anticipated to constrain drawdown associated with dewatering.
- The abundance of ash in claystone/ash bedrock is a key control on the bulk hydraulic conductivity of the unit with hydraulic conductivity values ranging from 0.05 ft/d to 5 ft/d. Claystone/ash units are conceptually divided into three hydrogeologic units according to the abundance of ash described as: i) claystone/ash unit which is adjacent to the proposed

open pit, ii) indurated claystone located northeast portion of the Thacker Pass Project, and iii) basal ash found in the Southwest Basin, south of Silica Hill.

- Volcanic tuffs have hydraulic conductivities which are approximately one order of magnitude lower than claystone/ash, ranging from 0.009 ft/d to 1 ft/d. Most basement rock materials in the Montana and Double H mountains (Tuff of Long Ridge, rhyolitic flows and tuffs) possess similar hydrogeologic properties as volcanic tuffs.
- Groundwater possesses naturally elevated concentrations of arsenic, particularly in the Thacker Creek spring system. Arsenic was measured above NRVs in 66% of well samples and 67% of spring samples. Fluoride is also naturally elevated in pockets of claystone/ash units in the open pit. Iron and manganese exceedances occasionally occur in springs. Well exceedances of iron and manganese are nearly always associated with an anomalous sample.
- QRPW18-01 in Quinn River Valley will be capable of supplying water for mine operations at a maximum capacity of ~4,000 gpm. The corresponding cone of depression is anticipated to be shallow and broad only in basin fill alluvial sediments. Operating water levels with the well are projected to drawdown of ~44 ft owing the transmissive nature of alluvial sediments. Because Quinn's River Basin is designated, the appropriate quantities of water rights will be obtained and transferred according to NDWR protocols to facilitate production from the valley, thus there will be a net zero overall impact to the basin in terms of water consumption. Basin water levels are currently in decline due to agricultural pumping in the Orovada sub-area. Incremental impacts to other stakeholders will be evaluated using a numerical groundwater model.

6. LIMITATIONS

Piteau Associates has exercised reasonable skill, care and diligence in obtaining, reviewing, analyzing and interpreting the information acquired during this study, but makes no guarantees or warranties, expressed or implied, as to the completeness of the information contained in this report. Conclusions and recommendations provided in this report are based on the information available at the time of this assessment.

In preparing the recommendations contained herein, Piteau Associates has relied on information and interpretations provided by others. Piteau Associates is not responsible for any errors or omissions in this information. This report is comprised of text, tables, figures, photos and appendices, and all components must be read and interpreted in the context of the whole report. The report has been prepared for the sole use of Lithium Nevada Corporation, and no representation of any kind is made to any other party.

Respectfully submitted,

PITEAU ASSOCIATES USA

A handwritten signature in black ink, appearing to read "Tyler Cluff".

Tyler Cluff, PG
Senior Hydrogeologist

TC/ap

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