CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION

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CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTIC STATION

EXECUTIVE SUMMARY

This final report presents results of work conducted under the Work Plan *5M Area New Well Installation and Capture Conversion* (Hydrometrics, Inc., October 2012). The Work Plan outlined monitoring well installation and capture well conversion activities at the PPL Montana, LLC (PPL) Colstrip Steam Electric Station (Colstrip-SES) Plant Site. A total of nine new wells were installed in the 5M Area. Seven wells (113M, 114S, 115M, 116M, 117A, 118A, and 122A) exhibited process water impacts; thus, they were converted to groundwater capture wells, started, and evaluated. Two wells (120A and 121A) are un-impacted by process water and will remain as monitoring wells. Hydrogeological evaluation of the 5M Area after startup of the new capture wells indicates distinct changes in groundwater flow paths indicative of increased groundwater capture. In the first nine weeks of operation, the new capture system collected an estimated 2.4 million gallons of impacted groundwater at a rate of approximately 23.4 gpm. Operational changes made to most of the new capture wells during the initial period of evaluation increased pump run times; thus, it is expected that both the cumulative groundwater collection volume and individual capture rates estimated in this report are lower than those that can be expected during future operation of the new wells. It is recommended that PPL continue to operate, maintain, and monitor the well network in the 5M Area. Monitoring data will be used to identify changes in process water impacts on local groundwater and/or gaps in the existing well network, if any exist. If necessary, PPL can install additional groundwater capture systems or convert monitoring wells to collection wells to mitigate impacts in the 5M Area.

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTIC STATION

1.0 INTRODUCTION

1.1 BACKGROUND

This final report presents results of work conducted under the Work Plan *5M Area New Well Installation and Capture Conversion* (Hydrometrics, Inc., October 2012). The Work Plan outlined proposed monitoring well installation and capture well conversion activities at the PPL Montana, LLC (PPL) Colstrip Steam Electric Station (Colstrip-SES) Plant Site. Specifically, the new well installations were proposed west of the Units 1 & 2 A Pond (A Pond).

PPL monitors groundwater on and around the perimeter - both upgradient and downgradient - of the Colstrip-SES Plant Site to detect inconsistencies in water quality that may be attributable to seepage from process ponds that are operated on site. The presence of pond seepage in groundwater is typically indicated by a rise in Specific Conductance (SC), Total Dissolved Solids (TDS), sulfate, boron, and chloride. Another indicator of process water impacts is a decrease in the ratio of dissolved calcium to magnesium concentrations. More recently, bromide has become an indicator, as PPL began adding $MgBr_2$ to their wet scrubber process in 2009.

As monitoring data become indicative of potential impacts, PPL installs groundwater capture systems or converts monitoring wells to collection wells to mitigate the influence of the seepage on local groundwater. The existing capture well network west of A Pond includes wells 5M, 5S, SRP-5 through 8, 58M, 59M, 98M, and 56D. Groundwater capture at these wells is from spoils, alluvium, McKay Coal, and shallow bedrock (56D). Further west, wells 106A, 107A, 108A, capture groundwater from shallow alluvium. The 5M Area, including the existing capture and monitoring well network, is mapped in Figure 1-1.

Six new groundwater collection wells were installed in accordance with the Work Plan (Hydrometrics, Inc., October 2012) and three new monitoring wells were added pursuant to a request from the Montana Department of Environmental Quality (MDEQ) west of A Pond in late 2012. Three of the new capture wells were installed in spoils or shallow alluvium (114S, 117A, and 118A); while the other three were installed in McKay Coal (113M, 115M, and 116M). Well 114S encountered spoil in the upper 10 feet of the borehole which were in gradational contact with the underlying alluvium. Water levels in this well were in the alluvium but an "S" designation was used due to the relationship with the isolated spoil. The three additional monitoring wells requested by MDEQ (120A, 121A, and 122A) were installed in alluvium to further evaluate potential groundwater impacts. Groundwater samples were collected at each of the new capture and monitoring wells. Upon evaluation of groundwater quality data, it was decided that well 122A would also be converted to a collection well. Locations of the new capture and monitoring wells are presented in Figure 1-1. This report discusses well installation methodology and observations, groundwater quality results, capture system construction, startup, and evaluation.

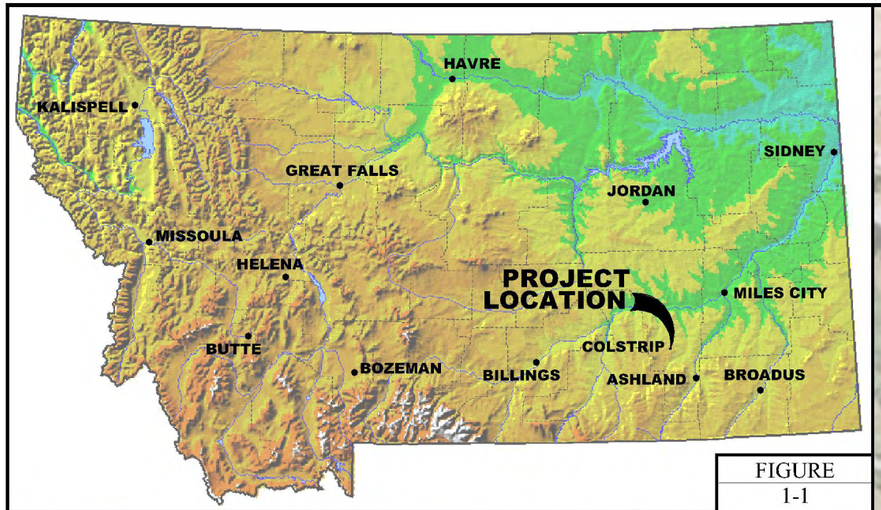


FIGURE 1-1

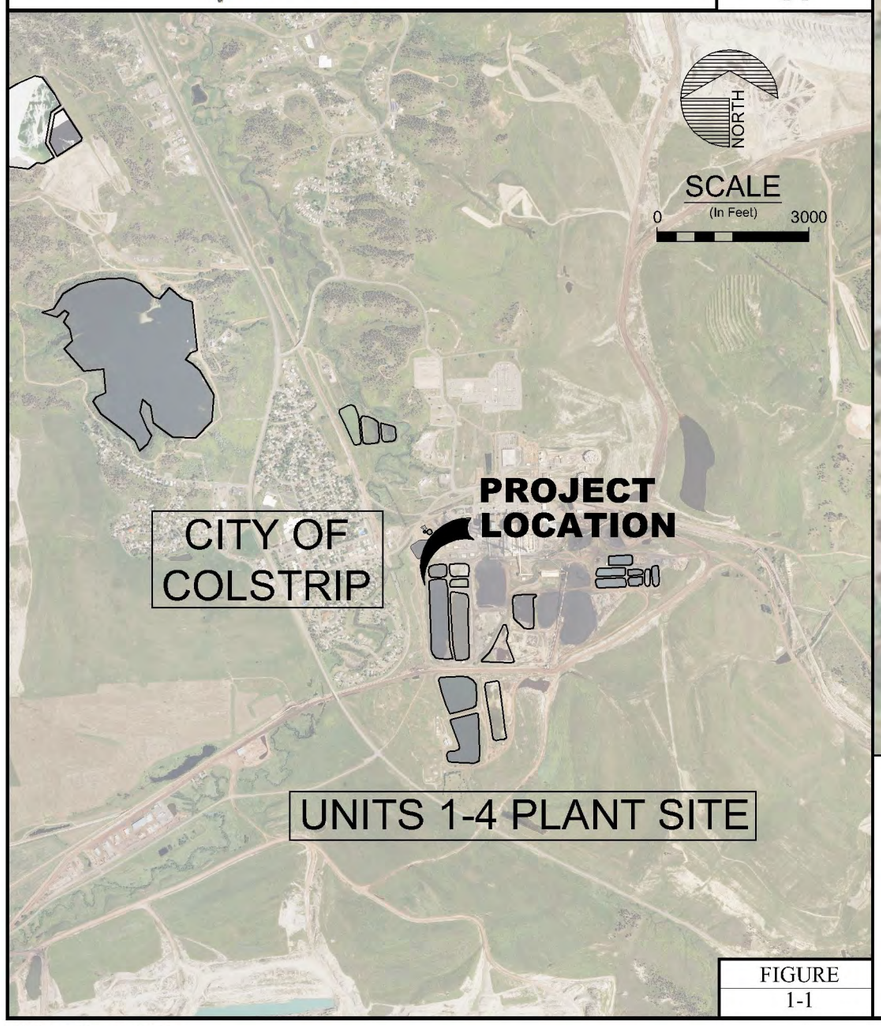
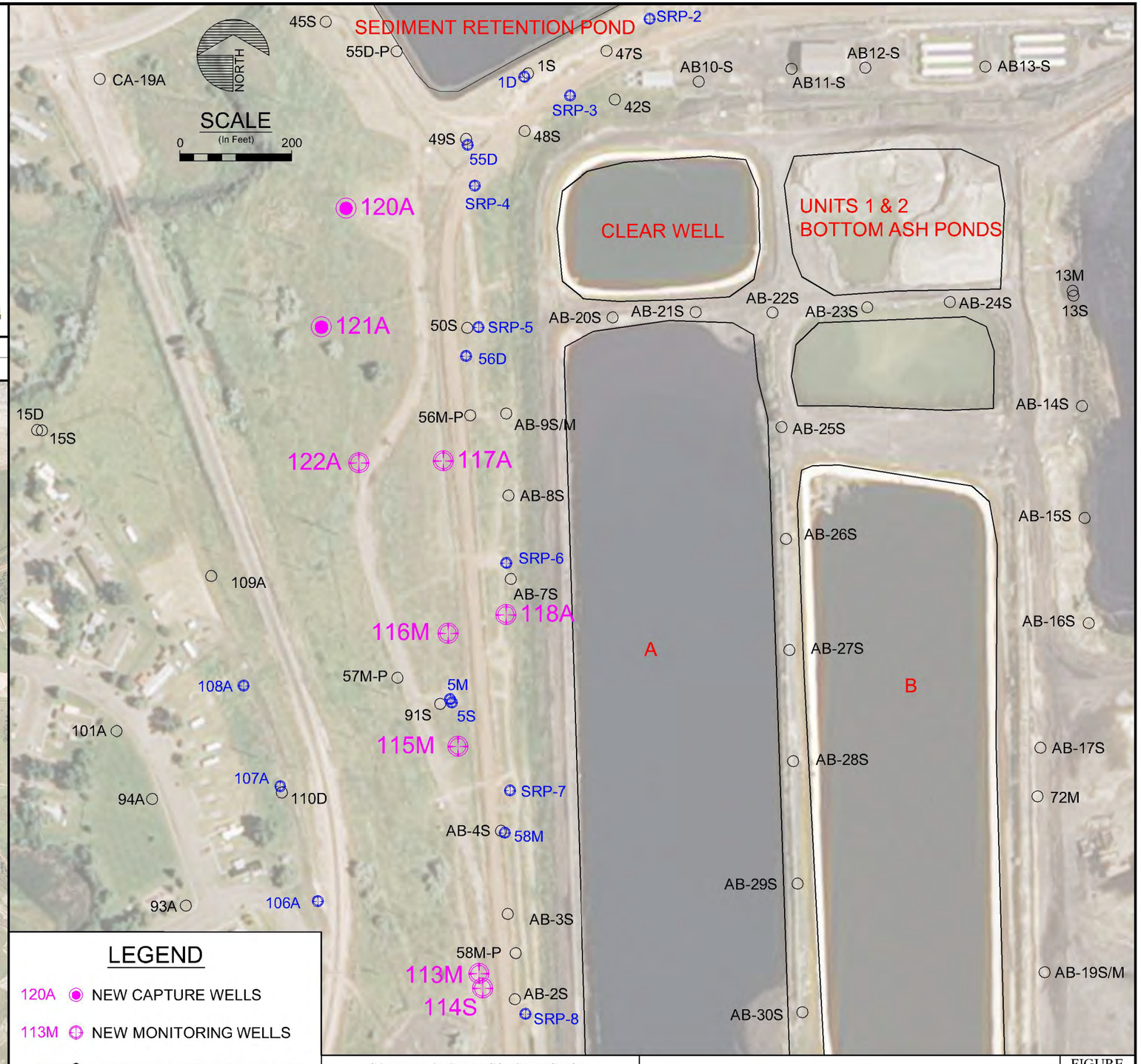


FIGURE 1-1



LEGEND

- 120A — NEW CAPTURE WELLS
- 113M — NEW MONITORING WELLS
- 56M-P — EXISTING MONITORING WELL
- SRP-6 — EXISTING CAPTURE WELL

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION

5M PROJECT AREA AND NEW WELL LOCATIONS

FIGURE **1-1**

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2.0 WELL INSTALLATION

Nine new wells were installed in spoils/alluvium (114S), alluvium (117A, 118A, 120A, 121A, and 122A), or McKay Coal (113M, 115M, and 116M) at the locations shown on Figure 1-1. Prior to drilling, buried utilities were cleared to approximately 10 feet below ground surface (ft-bgs) using an air knife and vacuum truck. The wells were drilled using air-rotary methods and were completed according to PPL's typical approach as follows:

- Steel casing was installed through unconsolidated sediments and fill to maintain the integrity of the borehole during drilling and well completion;
- Boreholes were advanced to the target interval;
- Schedule 40 PVC – 4.5-inch, with 25-slot perforations, was installed across the water-bearing horizon;
- Schedule 40 PVC – 4.5-inch well casing was connected to the perforated interval and extend to approximately two feet above ground surface;
- A 4.5-inch PVC cap was installed at the bottom of the well casing;
- Silica sand (10/20 mesh) was installed across and at least two feet above the perforated interval;
- Steel casing was pulled out of the borehole to expose the perforated interval;
- Bentonite (3/8-inch) chips were placed in the annulus above the sand pack to ground surface;
- An expandable plug was placed at the top of the 4.5-inch PVC casing; and
- Protective surface casing was installed with a locking steel lid.

Cuttings from each boring were logged for lithology, including rock type, texture, color, relative moisture, and origin (alluvium, colluvium, bedrock, etc.) by an environmental engineer. Logs of borehole lithology and well construction were submitted to the Montana Bureau of Mines and Geology and are presented in Appendix A.

Following completion, the wells were developed using either air-lift or bailing methods until water, cuttings, fines, and debris were sufficiently removed from the well casing to allow

pumping with a submersible pump. Well yield estimates were made during development and field SC of each well was measured at the end of development.

Key observations made at each well are as follows:

- 113M – This well is located at the south end of the 5M Area; it was drilled to target groundwater in the McKay coal. Saturated sand and clay was encountered at this location from 15 to 24 ft-bgs. Three feet of siltstone bedrock separated the saturated alluvium from the McKay coal, which was present from 37 to 46 ft-bgs at 113M. The upper saturated interval was sealed off with bentonite; and the well was completed in the coal. The well yield estimate and field SC measurement made upon development were two gpm and 6,700 μmhos/cm, respectively. Groundwater levels were above the upper contact of the coal.
- 114S – Well 114S was paired with 113M but targeted groundwater in the upper unconsolidated mine spoils/alluvium. This well was advanced to and completed at a total depth of 25 ft-bgs. Estimated yield at this well was approximately one gpm. Field SC rose during development from 5,700 μmhos/cm to 6,330 μmhos/cm.
- 115M – This well was installed in McKay coal approximately 100 feet southeast of well 5M. The coal is present from 28 to 36.5 ft-bgs at this location. Groundwater yield from the coal was estimated at 5 gpm. Field SC at 115M was 9,300 μmhos/cm after development.
- 116M – This well was installed in McKay coal approximately 100 feet north of well 5M. The coal is present from 25 to 35 ft-bgs at this location. Groundwater yield estimates and field SC measurements at 116M were 5 gpm and 7,200 μmhos/cm, respectively.
- 117A – Well 117A was completed in shallow alluvium, consisting primarily of sand and gravel, from 14 to 22 ft-bgs. The well was advanced an additional three feet to 25 ft-bgs to allow for more complete dewatering of the saturated sediments during groundwater capture. Field SC at 117A was 11,800 μmhos/cm after development.
- 118A – This well targeted first groundwater. Groundwater is present at this location in alluvium that grades from sand to sand and gravel from 16 to 19 ft-bgs and in weathered bedrock from 19 to 22 ft-bgs. The borehole at 118A was advanced

through dry bedrock to a total depth of 25 ft-bgs and the well was completed at total depth to allow for more complete dewatering of the upper saturated sediments. Field SC at well 118A was 12,550 μmhos/cm after completion and development.

- 120A and 121A – These wells were installed at the northwest end of the 5M Area. Each was advanced beyond the expected depth of the McKay Coal; but no coal was encountered in either of these boreholes. Groundwater was encountered in alluvium at both wells. Estimated yields of wells 120A and 121A were 15 gpm and 10gpm, respectively. Corresponding field SC measurements were 4,500 μmhos/cm and 5,000 μmhos/cm.
- 122A – Well 122A was advanced to 50 ft-bgs, which included drilling into approximately 13 feet of bedrock, to check for the presence of the McKay Coal. No coal was encountered at depth; thus it is likely that the coal was eroded away by alluvium at this location. Water-bearing alluvium at well 122A consists of sand and gravel (of mostly clinker origin) up to 4" in diameter. It was noted during drilling that yield from the open borehole increased when shale was encountered from 47 to 50 ft-bgs. SC from the open borehole at total depth was 4,500 μmhos/cm. Bedrock beneath the alluvium was sealed off with bentonite from 39 to 50 ft-bgs prior to well completion. Once completed and developed with rig air, field SC in the well was 6,700 μmhos/cm. The increase in SC after completion suggests that the bentonite seal is effective and that water quality in the alluvium is worse than that in the underlying bedrock.

3.0. GROUNDWATER QUALITY SAMPLING

Groundwater quality samples were collected from each of the new wells using methods consistent with Hydrometrics, Inc. Standard Operating Procedures (SOP) and methods commonly used by PPL for operational monitoring. At least three well casing volumes were removed from each well, using a submersible sampling pump. Field parameters (SC, pH, temperature) were measured and recorded at the time of sample collection. Samples were submitted to Energy Laboratories in Billings, Montana for analysis of the parameters listed in Table 3-1.

As outlined in the Work Plan (Hydrometrics, Inc., October 2012), process water impacts were anticipated at new well locations 113M, 114S, 115M, 116M, 117A, and 118A; thus, these wells were drilled expressly as groundwater capture points. Wells 120A, 121A, and 122A were added later as monitoring wells to evaluate groundwater quality west and northwest of the existing 5M well network. Laboratory analytical results of groundwater at all of the new capture well locations and one of the additional monitoring wells (122A) are indicative of process water impacts.

The three new wells completed in McKay Coal (113M, 115M, and 116M) have groundwater quality similar to that observed at existing capture well 5M. Boron concentrations of McKay wells range from less than one mg/L at 116M to 7.2 mg/L at well 113M; while, calcium to magnesium ratios are near or even above one. The ratios of dissolved calcium to magnesium at the new McKay wells and existing well 5M are not typical of groundwater that is impacted by process water. However, SC and concentrations of TDS, sulfate and chloride are at levels that are indicative of process water impacts. Total Dissolved Solids (TDS) concentrations at the new McKay wells ranged from 6,190 mg/L to 8,760 mg/L; and sulfate concentrations ranged from 4,400 mg/L to 5,910 mg/L.

In general, new wells completed in shallow sediments immediately west of the plant site process ponds (i.e. 114S, 117A, 118A, and 122A) exhibited worse groundwater quality than those completed in McKay coal. TDS concentrations at the new shallow wells ranged from

6,520 mg/L at 114S to 14,600 mg/L at well 117A. Calcium to magnesium ratios at the aforementioned shallow wells were less than one, ranging from 0.64 at 114S to 0.19 at both 117A and 118A.

Initial groundwater quality results from the remaining two wells (120A and 121A) were not considered indicative of process water impacts, although Ca:Mg were less than 1, and chloride levels were elevated. These wells will remain as monitoring wells and will be sampled at PPL's typical semi-annual frequency.

Table 3-1. Groundwater Quality Results at New Wells -- 5M Area

Analyte[1]	5M 10/16/2012	113M 11/27/2012	114S 11/27/2012	115M 11/27/2012	116M 11/27/2012	117A 11/27/2012	118A 11/27/2012	120A 11/27/2012	121A 11/27/2012	122A 11/27/2012
Static Water Level (ft-bmp)	--	18.48	19.29	16.48	14.72	16.27	16.26	13.57	13.22	16.71
pH (s.u.)	6.7	6.6	7.2	6.6	6.5	7.3	7.4	7.2	7.1	7
pH (s.u., Field)	6.41	6.53	6.92	6.36	6.27	6.68	6.37	7.24	7.09	6.91
SC (uMHOS/cm at 25 ^{o}C)	7130	5990	6130	7970	6710	12500	11700	4290	4020	9480
SC (uMHOS/cm at 25 ^{o}C) (Field)	7800	6550	6780	8170	7380	13500	12780	4670	4380	10720
TDS (measured at 180 ^{o}C)	8110	6190	6520	8760	6890	14600	13200	3760	3390	11500
Calcium (Ca), dissolved	864	578	442	673	769	413	382	301	316	490
Magnesium (Mg), dissolved	758	569	690	821	592	2160	1960	430	371	1510
Ca:Mg	1.14	1.02	0.64	0.82	1.30	0.19	0.19	0.70	0.85	0.32
Sodium (Na), dissolved	419	289	293	476	303	710	689	243	237	550
Potassium (K), dissolved	12	10	6	12	8	19	22	14	12	14
Bromide (Br)	4	1	ND	4	3	5	8	ND	ND	3
Bicarbonate (HCO_3)	330	295	568	308	301	593	421	673	614	744
Carbonate (CO_3)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulfate (SO_4)	5440	4400	4130	5910	5040	10900	10200	2210	2090	7680
Chloride (Cl)	167	151	95	175	177	242	231	193	145	171
Total Alkalinity as $CaCO_3$	271	242	466	253	247	486	345	552	503	610
Boron (B), dissolved	2.9	7.2	10.8	1.18	0.76	54	53.1	1.1	0.97	33.6
Selenium (Se), dissolved	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury (Hg), dissolved	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate + Nitrite, as N	--	0.03	3.26	ND	ND	ND	ND	ND	ND	0.04

[1]All results in mg/L unless otherwise specified

[2]ft-bmp = feet below measuring point (top of pvc casing)

ND = Non-detect

4.0. CAPTURE SYSTEM CONSTRUCTION AND STARTUP

4.1 CAPTURE SYSTEM CONSTRUCTION

In general, each of the seven new wells were converted according to PPL's commonly used and accepted procedure. The procedure is outlined, with notable exceptions, as follows.

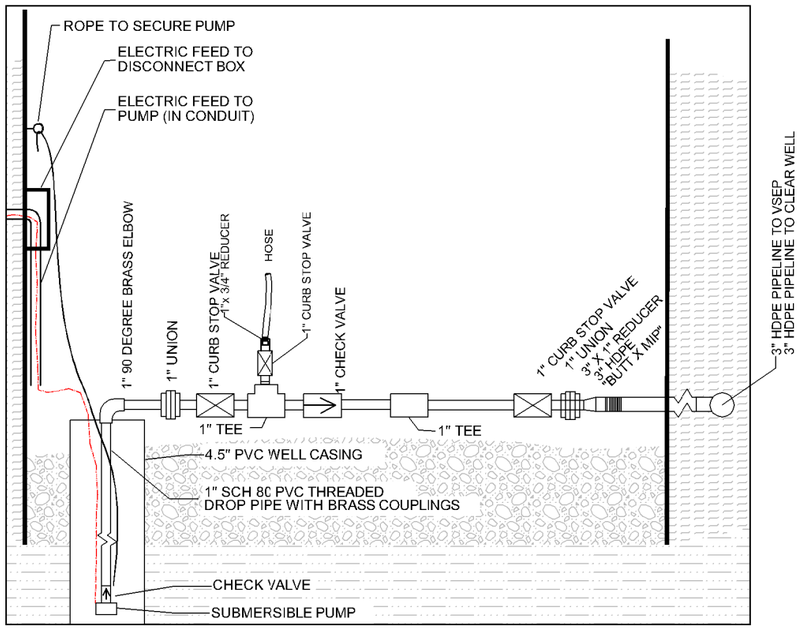
- A backhoe was used to open an excavation to an approximate depth of five to six ft-bgs and of sufficient width to place a six-foot diameter Corrugated Metal Pipe (CMP) over each of the subject wellheads.
- Excavated materials were backfilled around the CMP and mounded at the surface to promote drainage from each capture well.
- Washed gravel was placed in the bottom of the CMP at an approximate thickness of one-foot.
- Existing PVC well casing was cut off so that it extended just above the washed gravel in the bottom of each CMP vault.
- A hinged metal lid was installed at the top of each CMP.
- An aluminum ladder was secured to the inside of the CMP for access/egress into and out of each culvert.
- A ½ hp, 240V, single-phase submersible pump was installed in each of the wells selected for conversion.
- Submersible pumps were hung in wells by one-inch schedule 80 PVC threaded drop pipe with brass couplings.
- Drop pipe extends from the well to a one-inch brass pipeline on the floor of each vault.
- Necessary pipe fittings (i.e. one-inch unions, tees, valves, and sample port) were plumbed into the one-inch line in each vault.
- Redundant check valves were installed both immediately above the pump and inside the vault to prevent backflow to the well.
- Electrical controls, an hour meter, and automated pump protection (i.e. pumptec or pumpsaver) were installed in an electrical enclosure adjacent to each wellhead.

Well 117A is located very near a fence on the west side of A Cell. The well's proximity to the fence precluded capture by the conventional means previously described. The capture well configuration was altered to include a one-inch pitless adapter at the wellhead. Captured groundwater is routed from well 117A through the adapter in a buried one-inch HDPE pipeline to a CMP manhole located approximately 20 feet to the west. A brass pipeline with check valves, a sample port, and other appurtenances consistent with typical capture installation are present in the CMP. A typical pitless adapter capture well conversion is illustrated in Figure 4-1.

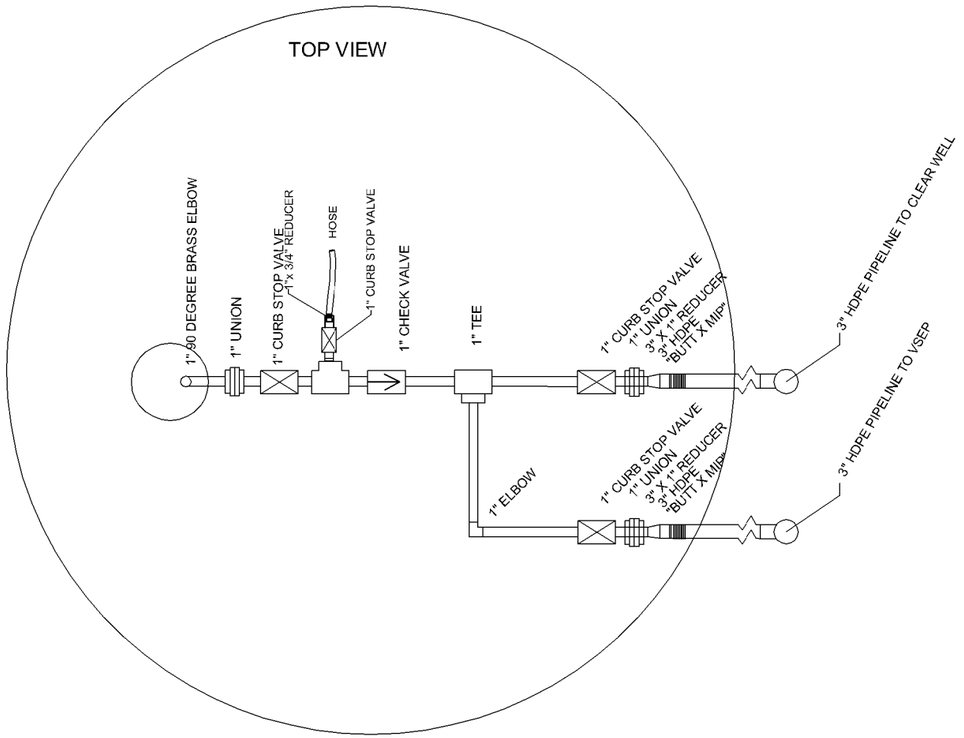
A pair of new three-inch HDPE pipelines were installed to convey captured groundwater from new wells 113M, 114S, 115M, 116M, 117A, and 122A. The new pipelines are stacked in a common trench; and each is routed to separate existing pipelines that either service the Vibratory Shear Enhancement Process (VSEP) water treatment plant or discharge to the Clearwell. Laterals from both of the new pipelines are routed to the CMPs of the capture wells listed above. A small header with isolation valves is included in each CMP to route captured groundwater to either the VSEP or Clearwell. Wells with groundwater SC greater than 8,000 μmhos/cm are routed to the Clearwell; while, wells with lower groundwater SC are routed to the VSEP. Captured water from well 118A is routed to B Pond via the existing two-inch HDPE pipeline that services capture wells SRP-6, -7, and -8. The layout and approximate location of new and existing pipelines in the 5M Area are illustrated in Figure 4-2.

A. TYPICAL VAULT CONVERSION DETAILS

SIDE VIEW

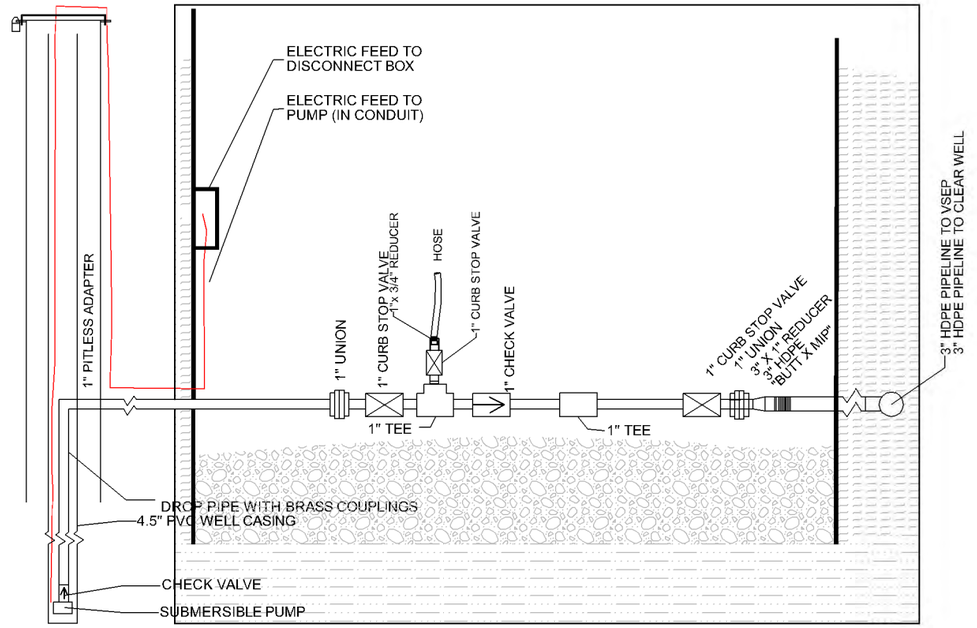


TOP VIEW

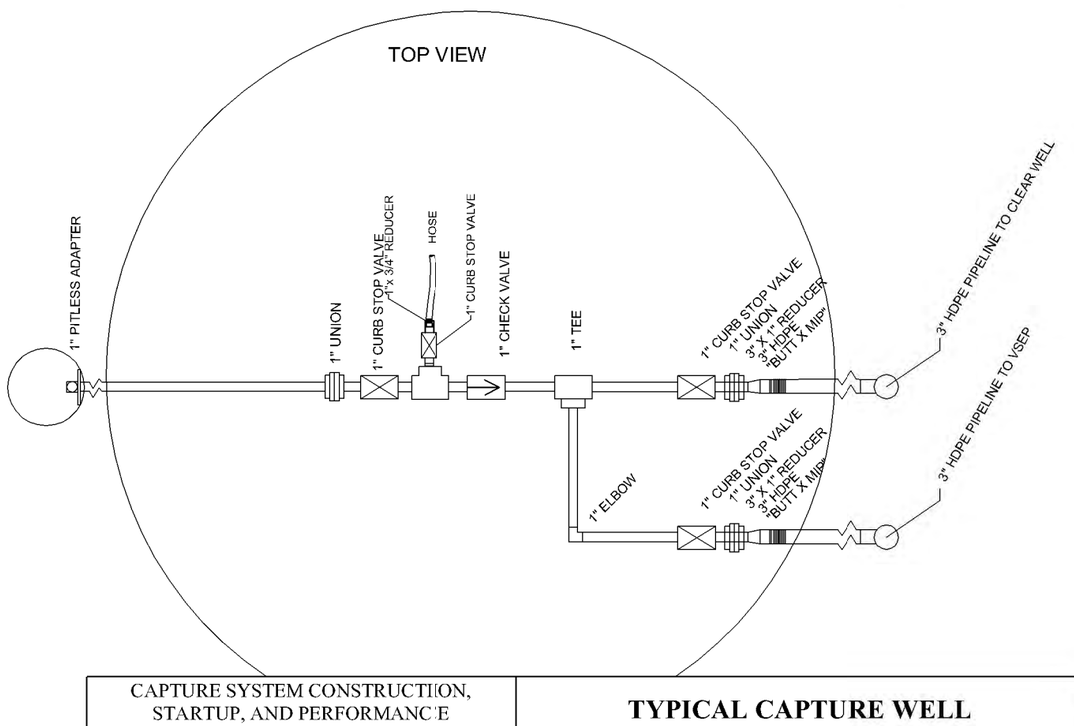


B. PITLESS ADAPTER CONVERSION DETAIL

SIDE VIEW



TOP VIEW



CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION

TYPICAL CAPTURE WELL CONSTRUCTION

FIGURE **4-1**

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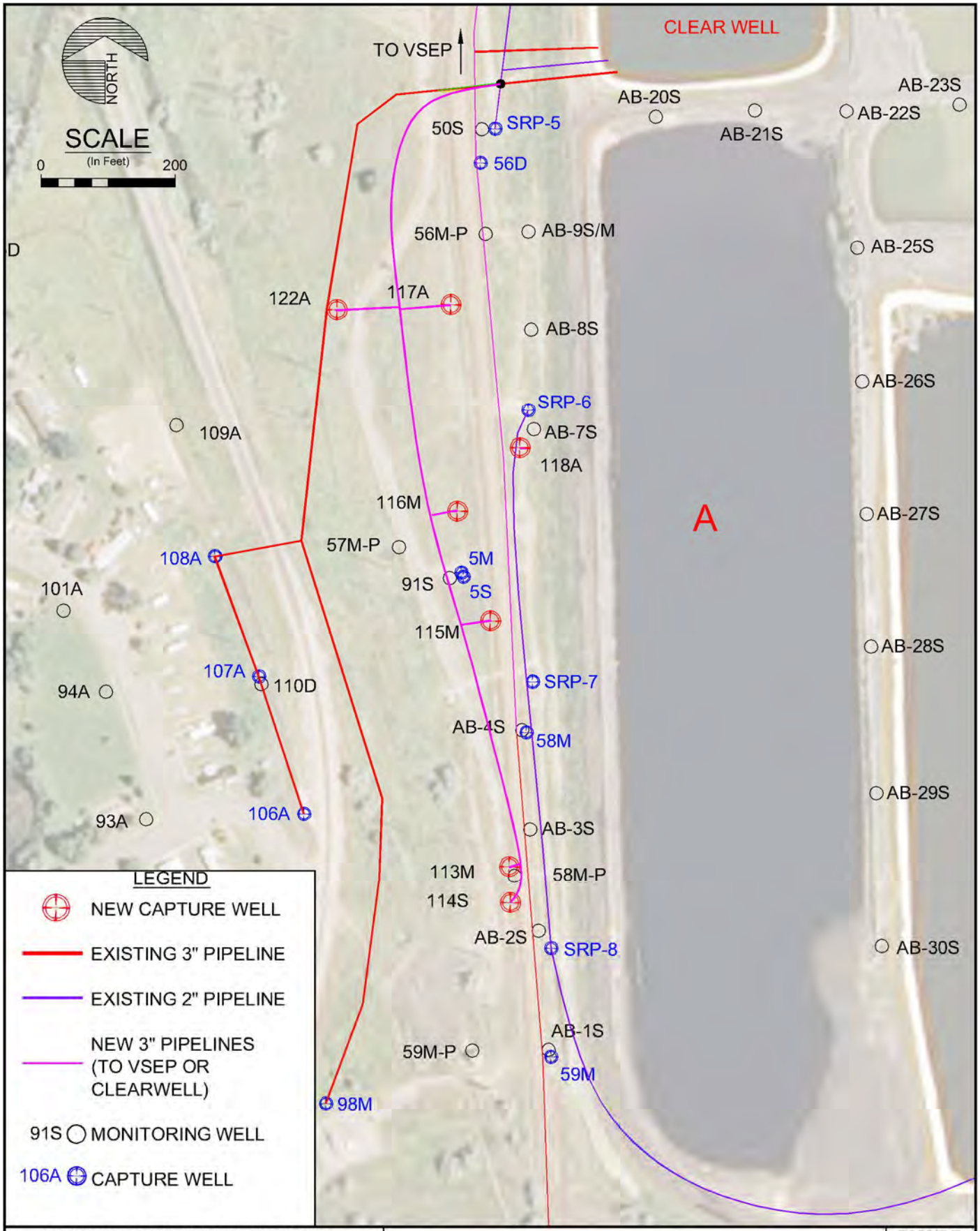

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION

PIPELINE LAYOUT IN 5M AREA

FIGURE 4-2

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4.2 CAPTURE SYSTEM STARTUP AND EVALUATION

Effectiveness of a groundwater capture system is typically gauged by its capture zone within the radius of pumping influence (i.e. the amount of drawdown observed at nearby wells impacted by process water), by the rate and/or cumulative volume of groundwater that is extracted, and ultimately by its ability to induce improvements in groundwater quality both at the capture point and at nearby monitoring sites. Ongoing groundwater/capture system monitoring at PPL includes monthly water levels at observation wells and more frequent water levels, discharge measurements, and field SC measurements at operating capture wells. These data, coupled with biannual laboratory analytical results at most wells provide the long-term record of capture system effectiveness.

Preliminary data collected immediately before and after capture system startup provides an initial indication of capture system effectiveness. Like longer term results, these data are used to select future operational parameters (i.e. pumping rate) of a given capture system, to identify site-specific or network scale deficiencies, if any, in the capture system, and/or to formulate recommendations for additional capture or monitoring wells, if necessary. Capture system start-up data typically include more frequent, or even continuous, water level monitoring at appropriate sites and more frequent measurements of pumping rates and/or field SC at new capture wells.

4.2.1 Start-up

Pumping began at wells 113M, 115M, 116M, 117A, 118A, and 122A on March 21, 2013. Pumping began at well 114S on March 28, 2013. Prior to starting the pumps, pressure transducers with water level data-loggers were installed in capture wells 113M, 116M, 117A, and 122A and in monitoring/observation wells AB-2S, AB-7S, 56M-P, 58M-P, and 91S. Depending on well access, which was limited due to construction activities in the 5M Area, the transducers were installed up to two weeks before startup of the new capture wells. Manual water level measurements were recorded to supplement transducer data and were recorded at wells not instrumented with transducers.

Startup of new capture wells in the 5M Area was not without issue: new hour meters at wells 114S, 115M, and 118A failed to record initial run times, although field checks indicated that the pumps were actively running; flow measurements and field SC measurements were not recorded immediately after startup because hoses were not available prior to startup; and unexpected downtime was experienced at some existing wells resulting in incomplete capture in the 5M Area during the evaluation period. Specifics of each of the issues mentioned above are discussed in the appropriate sections to follow.

4.2.2 Capture and Observation Well Hydrographs

Water level hydrographs were constructed for capture wells 113M, 114S, 115M, 116M, 117A, 118A, and 122A and observation wells AB2-S, AB7-S, 56M-P, 58M-P, and 91S for the period of record for each well. The observation wells were chosen based on their respective completion intervals and proximity to pumping wells. The hydrographs help identify trends at individual capture wells or wells influenced by capture system pumping. Hydrographs for capture wells are presented in Figures 4-3A&B. Observation/monitoring well hydrographs are included in Figure 4-4. A brief discussion of the response at each well is as follows.

<u>Capture Wells (Figures 4-3A and 4-3B)</u>

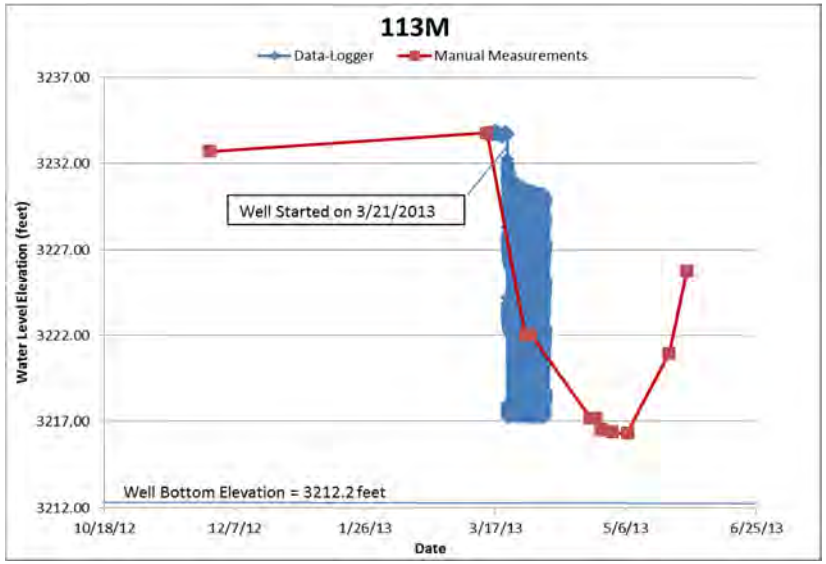
- 113M – The hydrograph at well 113M is typical of a pumping well and exhibits a drawdown curve analogous to a Theis non-equilibrium curve except that the pump cycled on-and-off during the early pumping period. Pump cycling was triggered by the well's inability to maintain the initial pumping rate. Pump protection (Pumptec) installed at the wellhead tripped repeatedly to protect the pump when cavitation occurred due to low water levels within the well. The water level in well 113M has declined by greater than 16 feet since pumping began.
- 114S – An automated data-logger was not deployed in capture well 114S; but manual water level measurements were used to create the hydrograph in Figure 4-3A. Well 114S is a low head well. The initial water column depth in well 114S was approximately 6.8 feet. The pump intake is located approximately three feet from the bottom of 114S, which results in an available water column of less than three feet.

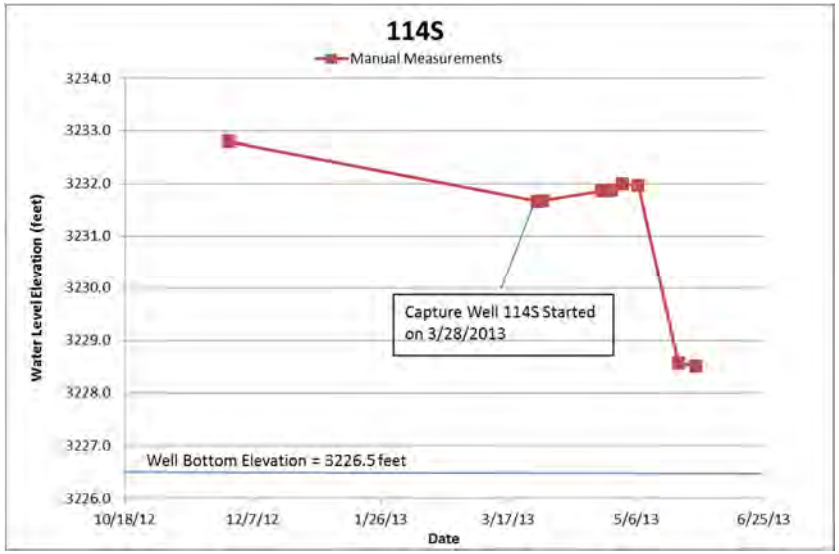
Since pumping began at both 113M and 114S, the water level in well 114S has dropped by about one foot. During the initial startup period, the pump in well 114S was not valve controlled and a pumping rate of 15.9 gpm was measured at the wellhead. Yield at 114S is estimated to be less than 2 gpm; thus, frequent pump cycling and short pumping durations would be expected. Hour meters used at the capture wells record run times to the nearest 0.1 hours; so no run time may be recorded if the pump does not run continuously for six minutes or more. No run time was recorded throughout the first six weeks of pumping at well 114S. The pumping rate was adjusted from 15.9 gpm to 1.7 gpm on May 6, 2013 to more closely match the estimated well yield, decrease pump cycling, and increase run time. Water levels in 114S dropped by about 3.5 more feet after this flow adjustment; and the hour meter began to record run time.

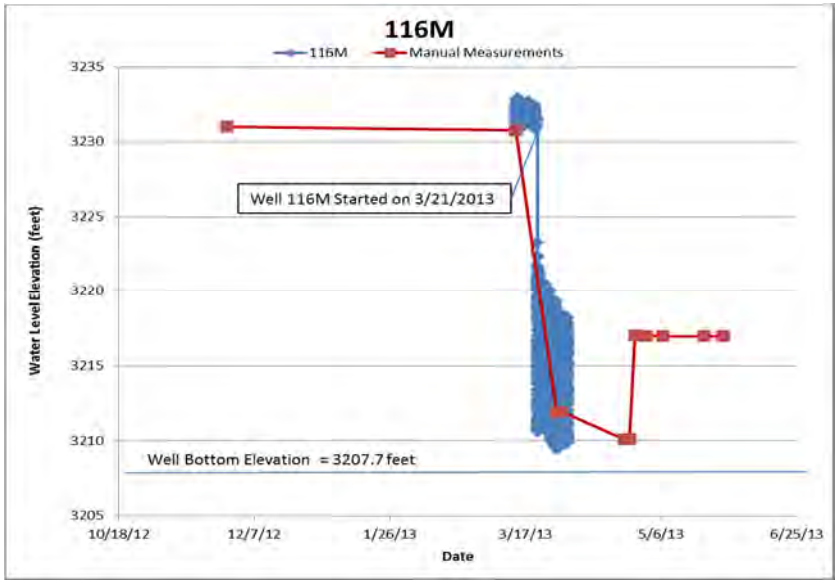
- 115M – Similar to well 114S, automated water level measurements were not logged at new capture well 115M. However, manual water level measurements made at 115M indicate that sustained drawdown of greater than 12 feet has been achieved by pumping. Estimated well yield at 115M was 5 gpm. The initial unchecked pumping rate measured at the well was greater than 16 gpm. Because the initial pumping rate exceeded well yield, it is possible that pump cycling - similar to that described above - prevented the hour meter from advancing. Prior to May 6, 2013, only 0.1 hours of run time were recorded. The recorded run time is likely from the first six minutes of pumping; then, the pump probably cycled at periods less than six minutes in duration. The pumping rate was adjusted to 4.7 gpm on May 6, 2013 to more closely match the estimated well yield, decrease pump cycling, and increase run time.
- 116M – The hydrograph at McKay capture well 116M closely mimics that of 115M, except that automatic water level measurements reveal a pattern of oscillating water levels due to pump cycling. While pumping, the water level in well 116M reaches an elevation that is up to 21 feet lower than the static water level. Water levels recorded during periods of pump inactivity are approximately 14 feet lower than the static water level.
- 117A – The initial water column thickness in well 117A was 10.14 feet. The startup hydrograph for well 117A (Figure 4-3A) indicates water level drawdown as great as

eight feet and as minimal as 1.5 feet has been observed since pumping began. Water level measurements include those made manually and by an automated pressure transducer/data-logger installed at the top of the pump. Pump cycling is evident in the hydrograph.

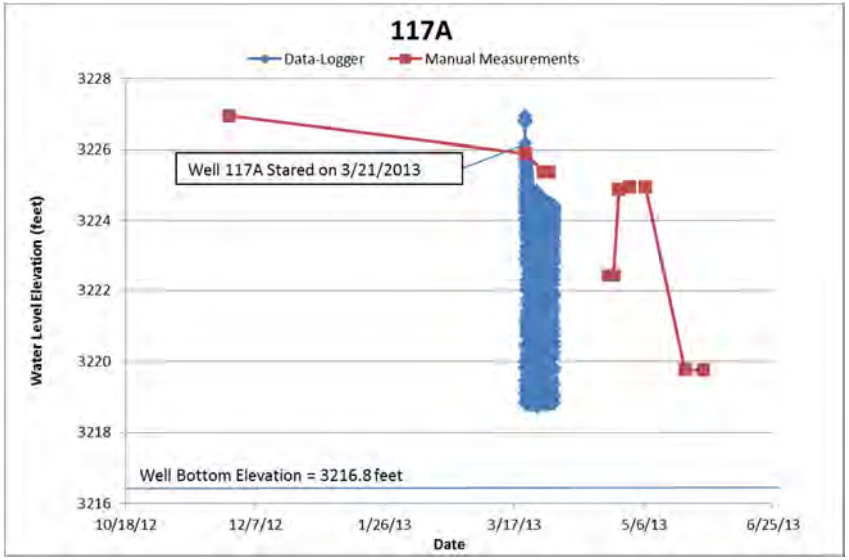
- 118A – The startup hydrograph at well 118A indicates that pumping water levels are between 3.44 and 4.06 feet lower than the initial static water level. No automated water levels were recorded at well 118A; but it is likely that frequent water level oscillations due to pump cycling took place. Well 118A was pumped initially without any flow restriction, which likely resulted in a rate that is much greater than the anticipated yield of this well (2 gpm or less). The pumping rate was valved back to 1.3 gpm on May 6, 2013.
- 122A – Well 122A is unique among the new capture wells because it ran continuously during the startup period without any pump cycling. This was possible because well 122A has the greatest yield of all of the new capture wells. Pumping rates of 12 to 15 gpm were recorded during the two months following capture well startup. Pumping water levels in the well have dropped to a sustained level of nearly 22 feet lower than the initial static water level.

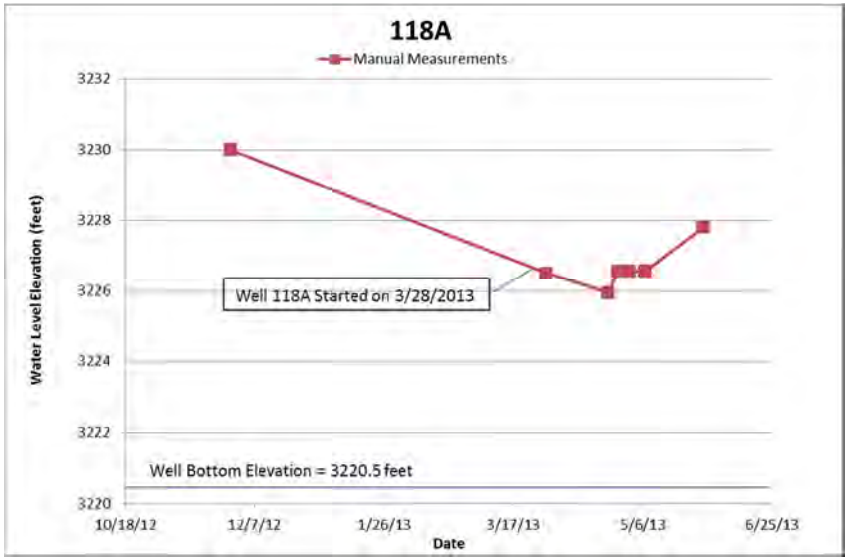


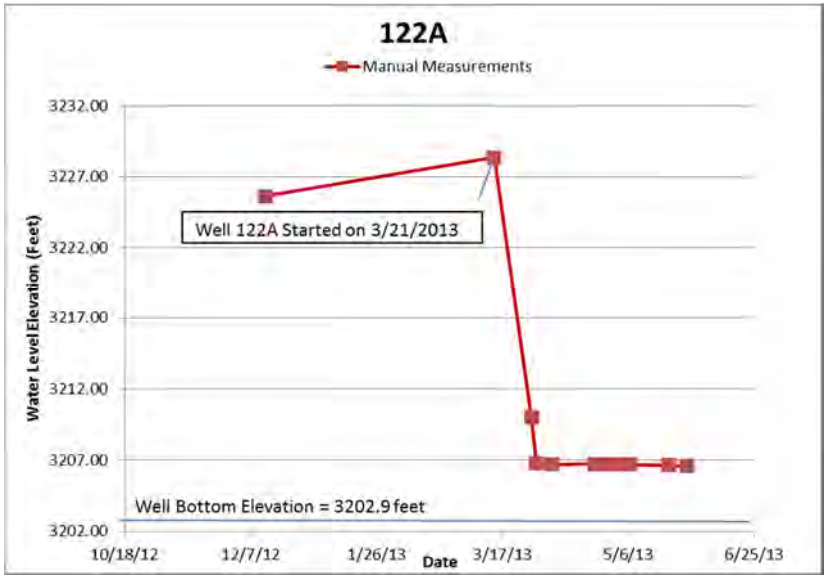




PPL MONTANA, LLC **CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION**	**CAPTURE WELL HYDROGRAPHS**	**FIGURE** **4-3A**







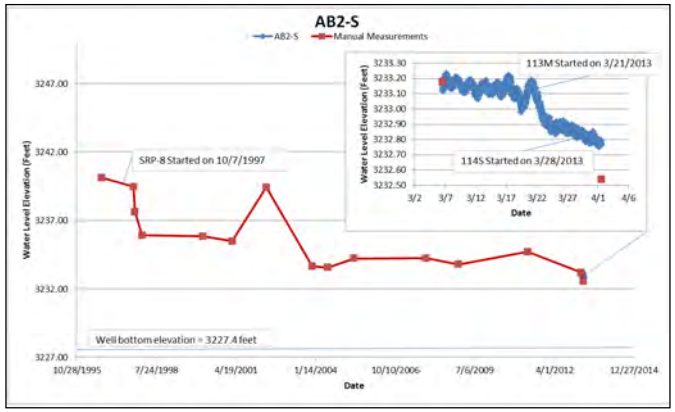
PPL MONTANA, LLC CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	CAPTURE WELL HYDROGRAPHS	FIGURE 4-3B

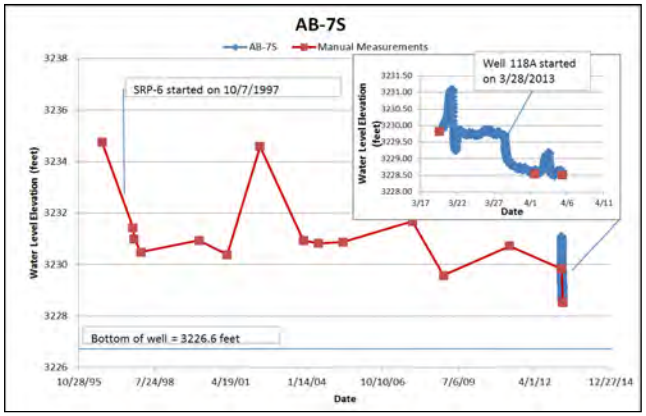
Observation Wells (Figure 4-4)

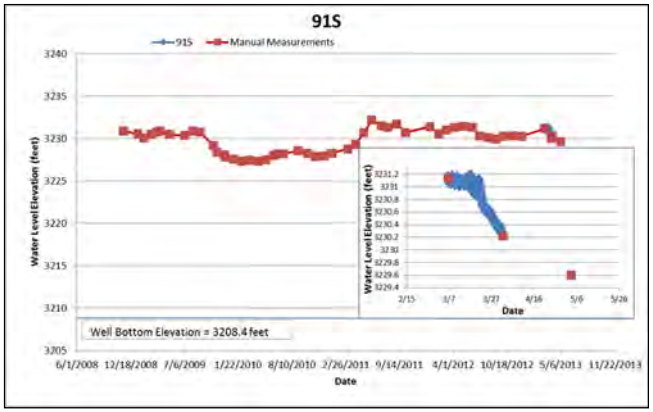
- AB2-S – Observation well AB2-S is located approximately 60 feet southeast of new shallow capture well 114S and 80 feet southeast of new McKay capture well 113M. Existing capture well SRP-8 is located 30 feet southeast of AB2-S. The hydrograph for the period of record at well AB2-S indicates a declining water level shortly after capture well SRP-8 began pumping in 1997. The decreased water level appeared sustained throughout the period of record except for a water level measured on May 9, 2002 that was indicative of recovery. The recovered water level may have been the result of downtime at nearby capture wells or increased recharge in the spring of the year. The water level in well AB2-S reached its lowest point after startup of capture wells 113M and 114S. However, cumulative drawdown from the two new wells was just over 0.6 feet; and there is still more than five feet of available water in the well.
- AB7-S – Observation well AB7-S is located 70 feet north of new capture well 118A and 30 feet south of existing capture well SRP-6. The hydrograph of the period of record at well AB7-S indicates a declining water level response to pumping at SRP-6. SRP-6 was started in October 1997. Water levels measured with a pressure transducer and automated data-logger in the two days prior to startup of well 118A indicated a rising trend of approximately one foot, possibly due to recharge from spring runoff. However, once pumping began at 118A, the water level in AB7-S dropped by nearly 2.5 feet.
- 56M-P – Monitoring well 56M-P was installed in the McKay coal in 2002. Water levels collected throughout the period of record indicate seasonal fluctuations and/or possible minor influences on water levels due to nearby capture system pumping. However, the hydrograph has remained relatively constant because there are no nearby capture wells (i.e. within 400 feet) completed in the McKay coal. New alluvial monitoring well 122A is completed at a depth below the base elevation of the nearby un-eroded McKay coal. For this reason, it was anticipated that some drawdown may be seen at well 56M-P as a result of pumping at well 122A. Similar to other wells in the 5M Area, the static water level in well 56M-P was at a seasonal

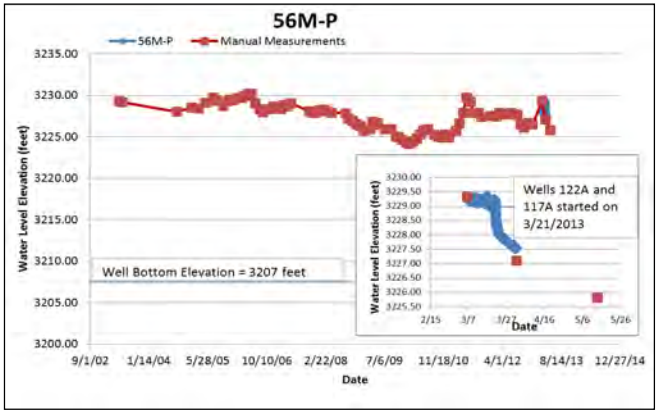
high prior to capture system startup. However, after wells 122A and 117A were started, the water level in well 56M-P declined from an elevation of 3229.2 feet on March 21, 2013 to an elevation of 3225.80 feet on May 14, 2013. Despite the decrease in water level, there is still approximately 18.8 feet of water available in the water column at well 56M-P. Additional groundwater capture may be necessary in the McKay coal near well 56M-P.

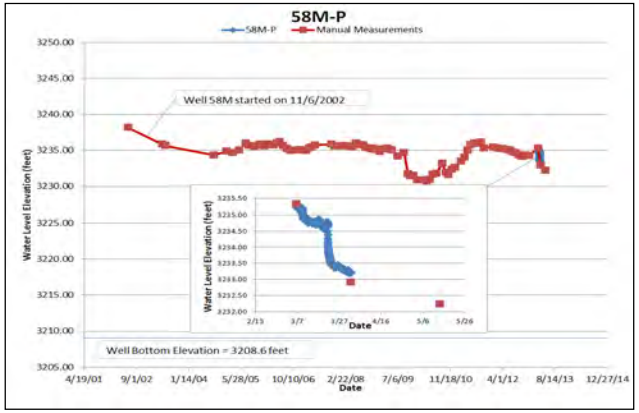
- 58M-P – Monitoring well 58M-P was installed in the McKay coal in 2002. Capture well 58M was converted and began pumping on November 6, 2002. From 2003 to late 2009, the water level in 58M-P remained fairly constant except for minor seasonal fluctuations. The water level in 58M-P dropped by greater than two feet in response to pumping in the new capture well.
- 91S – This well was installed in November 2008 as an observation well for capture well 5S. Capture well 5S was started in January 2009. Despite the proximity of 91S to pumping well 5S, minimal drawdown was observed after 5S was started. Water levels at well 91S after startup of new nearby capture wells 115M, 116M, 117A, and 118A also suggested a muted response to pumping. Further evaluation of capture in this area needs to be conducted after prolonged pumping with the new wells.











PPL MONTANA, LLC CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	OBSERVATION WELL HYDROGRAPHS	FIGURE 4-4

4.2.3 Aquifer Properties Analysis

Water level data collected during the initial capture well startup period from select pumping and monitoring wells were converted to drawdown observations and analyzed for aquifer properties using Aqtesolv Pro software. Specifically, drawdown data from well 58M-P were paired with pumping data from new capture well 113M and drawdown data from well AB7-S were paired with pumping data from both existing capture well SRP-6 and new capture well 118A. These wells were selected for analysis because they generated the best drawdown observations and because these wells provided an opportunity for analysis of both the McKay coal aquifer and the shallow saturated spoils unit. Pumping wells 117A and 122A are completed in alluvial deposits of Armells Creek. Excessive pump cycling during startup of 117A and poor transducer placement at well 122A precluded single well pumping test analytical solutions at these sites. Drawdown curves and results to the appropriate analytical solution for each set of pumping/observation data are included in Appendix B. A brief discussion of the analyses is as follows.

The (Theis, 1935) analytical solution was applied to drawdown observations from well 58M-P that were made immediately after startup of new capture well 113M. Well 58M-P is located approximately 75 feet from capture well 113M. In the first 11 days after 113M was started 1.2 feet of drawdown were observed at 58M-P; and the drawdown curve exhibited trends typical of the non-equilibrium curve (Theis, 1935). Note from previous discussion that cyclical pumping in well 113M created an oscillating water level pattern. These oscillations were muted in the observation well. Because the pump cycled on-and-off, the average pumping rate (about 1 gpm) was used in the analysis. Further discussion of capture well pumping rates and collection volumes is presented in Section 4.2.5 of this report. Well 58M, the nearest existing capture well, was not in operation during startup of 113M; so interference from this well was not modeled in the analysis. Aquifer hydraulic characteristics calculated by the analytical solution are transmissivity (T) = 84 ft^2/day; hydraulic conductivity (K) = 9.3 ft/day; and storativity (S) = 0.00055. The estimated T and K are within but at the upper end of the range of values expected for the McKay coal on the Plant Site. For example, T values estimated from previous tests ranged from 18 ft^2/day at well 5M to 107 ft^2/day at well 13M (Hydrometrics, Inc., January 1995). Typical thickness of the coal

in this area is nine feet. The S value estimated based on 113M startup analysis is within the upper range of values anticipated for a confined aquifer.

Drawdown observations made at monitoring well AB7-S after startup of capture well 118A were analyzed to estimate hydraulic properties of the shallow hydrostratigraphic unit in the 5M Area. Much heterogeneity is inherent in the shallow interval because its composition ranges from a sequence of thick coarse-grained alluvial gravels to re-deposited fine-grained mine spoils. Automated water level measurements made at well AB7-S indicated greater than one foot of drawdown resulted in the first four days after startup of well 118A. Well AB7-S is approximately 60 feet from the new pumping well. Existing capture well SRP-6 is even closer, approximately 30 feet away, and has been shown to influence water levels at AB7-S. For this reason, pumping at SRP-6 was simulated in the analysis. Specifically, a multiple pumping well solution was applied to AB7-S using Aqtesolv Pro software and the Theis (1935) method. One week (7 days) of pumping was simulated at well SRP-6; after which, quasi-equilibrium drawdown conditions of just over four feet were reached. This level of drawdown is consistent with that observed at well AB7-S after well SRP-6 was originally started in 1997 (see Figure 4-4). The average pumping rate at well 118A was applied after quasi-equilibrium conditions were reached and the cumulative drawdown curve was fit as seen in Appendix B. Resulting T, K, and S values are 92 ft^2/day, 12.3 ft/day, and 0.003, respectively. These values reflect the fact that the new pumping well (118A) is completed in a thin layer of sand and gravel alluvium that is not laterally continuous, but is hydraulically connected to finer grained sediments present at wells AB7-S and SRP-6. If the saturated interval were comprised strictly of fine-grained materials, such as the clay and silt at AB7-S, values of K and T would reasonably be expected to be much lower. In contrast, if a thicker gravel deposit were present at 118A, a greater calculated hydraulic conductivity would result.

Drawdown data collected at capture wells completed in Armells Creek alluvium (117A and 122A) are not applicable to single well pumping test analysis because of excessive pump cycling at well 117A and because of the lack of water level measurements during drawdown at well 122A. Results of extensive testing previously conducted at wells completed in

Armells creek alluvium are presented in the startup evaluation of trailer park wells (Hydrometrics, Inc., January 2010). K values ranging from 32.5 ft/day to 220 ft/day were estimated based on pumping test results at alluvial wells.

4.2.4 Potentiometric Surface Maps

A series of six potentiometric surface maps were created to evaluate the site-wide response to pumping in both the McKay coal and shallow hydrostratigraphic intervals in the localized 5M Area. Specifically, three maps were developed for each depth interval for the following time periods:

1. after completion but prior to startup of the new capture wells in December 2012;
2. one month after startup of the new capture wells in April 2013; and
3. six weeks after startup of the new capture wells in early May 2013.

Maps are presented in Figures 4-5 through 4-10. A discussion of groundwater flow patterns inferred from the maps, with emphasis on changes due to capture system pumping, is as follows.

4.2.4.1 Alluvium and Spoils (Shallow) Potentiometric Surface

The shallow potentiometric surface after completion but prior to startup of the new capture wells is included in Figure 4-5. This map was created primarily with water levels recorded in early December; however, water levels for wells 114S, 117A, and 122A were recorded on November 27, 2012. The shallow potentiometric surface indicates a general flow direction to the north, parallel to Armell's Creek, with localized groundwater depressions around capture wells 5S, 10S, SRP-5, SRP-6, SRP-7, and SRP-8. Absent from the map are depressions around capture wells 106A, 107A, and 108A, which were temporarily down for maintenance. Well 68A was in operation during the period reflected in the map; but the pump was tripped off when the water level was recorded. Pumping well 68A only operated approximately 45% of the time in December 2012.

The shallow potentiometric surface was updated to reflect pumping conditions one month after new capture system startup (Figure 4-6). The general direction of groundwater flow remains to the north; but notable increases in groundwater depressions are evident around

existing wells 107A and 108A and new well 122A. A lower water table is also present around new capture wells 117A and 118A. At the south end of the 5M Area, shallow low-yield well 114S exhibits a groundwater level elevation that is lower than pre-startup conditions but does not appear to have appreciably augmented the capture radius created by existing well SRP-8. The water level at well 68A is representative of pumping conditions in the April 2013 potentiometric surface; whereas, the water level in well 10S indicates that the pump was off. Wells 5S, 5M, 10S and 10M suffered some downtime after startup of the new capture system to repair a leaky valve discovered after startup at the junction of the new pipeline with the existing pipeline that services these wells and due to pump and/or electrical problems unrelated to construction of the new capture wells.

The shallow potentiometric surface map of the 5M Area, created based on water levels collected in early May 2013, is presented in Figure 4-7. The initial intent of the map was to illustrate the potentiometric surface when all capture wells in the 5M Area, including 5S and 10S, were operational. However, capture well 5S was not repaired at the time the water levels were recorded; and the May 2013 potentiometric map is very similar to that constructed with water levels recorded in April 2013.

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NORTH

SCALE
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LEGEND

105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

49S 3223.5
55D
48S 3223.2
SRP-4 3223.1
120A 3225.0
3225
121A 3225.9
50S 3222.8
SRP-5 3223.1
AB-20S
56D
3228.7 15S
15D
56M-P
AB-9S/M
102A 3228.9
OT-11
122A 3226.8
3226.9
AB-8S
SRP-6 3222.8
109A 3228.0
AB-7S
AR-5PE
3230
116M
118A 3230.6
57M-P
108A 3230.3
5M
5S 3218.6
91S 3230.2
115M
101A
107A 3230.0
110D
SRP-7 3223.7
96A
95D
94A
97A 3231.9
AB-4S
58M
OT-13
93A
106A 3234.3
AB-3S
58M-P
113M
114S 3233.3
AB-2S
SRP-8 3225.0
CA-18
92A
105A
3235
63S
OT-12
59M-P
AB-1S
59M
98M
99D
100A 3236.2
60M-P
10S
10M
3228.0
103D
104A 3238.1
67M
68A 3236.9
62S
61M 3237.6
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	**DECEMBER 2012 SHALLOW POTENTIOMETRIC SURFACE**	FIGURE **4-5**

Hydrometrics, Inc.
Consulting Scientists and Engineers

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(In Feet)
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105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

3225
3230
3235

49S 3225.0
55D
48S 3224.6
SRP-4 3224.5
120A 3226.0
121A 3226.5
50S 3225.4
SRP-5 3225.1
AB-20S
56D
56M-P
AB-9S/M
15S
15D 3229.6
102A 3230.8
OT-11
122A 3206.7
117A 3222.4
AB-8S
109A 3229.2
SRP-6 3223.1
AB-7S
AR-5PE
116M
118A 3226.0
57M-P
108A 3223.2
5M
5S 3229.2
91S 3229.7
115M
101A
107A 3214.0
110D
SRP-7 3223.8
AB-4S
58M
96A
95D
97A 3233.4
94A
OT-13
93A
106A 3233.3
AB-3S
58M-P
113M
114S 3231.9
AB-2S
SRP-8 3225.1
CA-18
92A
105A
63S
OT-12
59M-P
AB-1S
59M
98M
99D
100A 3237.3
60M-P
10S
10M 3237.3
104A 3239.6
103D
67M
68A 3232.7
61M
62S 3238.5
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	**APRIL 2013 SHALLOW POTENTIOMETRIC SURFACE**	FIGURE **4-6**

Hydrometrics, Inc.
Consulting Scientists and Engineers

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LEGEND

105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

3225
3230
3235

49S 3224.8
55D
48S 3224.2
SRP-4 3224.0
120A 3225.4
121A 3226.1
50S 3224.6
SRP-5 3224.0
AB-20S
56D
56M-P
AB-9S/M
15S 3229.4
15D
102A 3230.6
OT-11
122A 3206.7
117A 3225.0
AB-8S
109A 3229.0
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AB-7S
AR-5PE
116M
118A 3226.6
57M-P
108A 3223.9
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5S 3229.1
91S 3229.6
101A
115M
107A 3213.9
110D
SRP-7 3223.8
AB-4S
58M
96A
95D
97A 3233.1
94A
106A 3233.3
AB-3S
OT-13
93A
58M-P
113M
114S 3232.0
AB-2S
SRP-8 3225.1
CA-18
92A
105A
63S
OT-12
59M-P
AB-1S
59M
98M
99D
100A 3237.1
60M-P
10S
10M 3228.8
104A 3239.4
103D
67M
68A 3237.4
61M
62S 3238.5
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	**MAY 2013 SHALLOW POTENTIOMETRIC SURFACE**	FIGURE **4-7**

Hydrometrics, Inc.
Consulting Scientists and Engineers

4.2.4.2 McKay Coal Potentiometric Surface

Similar to the shallow potentiometric surface, the McKay coal potentiometric surface was mapped using water levels recorded in late November and early December 2012. This potentiometric surface map is presented in Figure 4-8 and illustrates groundwater flow conditions in the McKay coal prior to startup of the new capture wells. Note the McKay coal has been eroded away by Armells Creek under much of the 5M Area. The approximate limit of the McKay coal seam, based on lithologic information gathered during well drilling and installation, is drawn on the map. The general groundwater flow pattern in the coal is similar to that of the shallow unit above. Flow is to the north in the direction of Armells Creek. Prior to startup of new McKay capture wells 113M, 115M, and 116M major influences to the flow pattern as a result of capture system pumping are observed at wells 10M, 98M, 59M, 58M, and 5M.

Figure 4-9 shows the McKay coal potentiometric surface for the 5M Area in April 2013, approximately one month after capture system startup. While each of the three new capture wells (113M, 115M, and 116M) created observable groundwater depressions in the potentiometric surface, the cumulative effects of all capture wells are not observed in the April 2013 map due to down time at existing wells 10M, 59M, 58M, and 5M. Wells 5M and 10M were not pumping due to the leaky valve, discussed previously. Wells 58M and 59M have also experienced some unexpected downtime in April and May 2013.

A final potentiometric surface map was drawn for the McKay coal with water levels recorded on May 6, 2013 (Figure 4-10). Capture wells 10M and 59M were in operation at the time the water level measurements were taken; however, problems persisted at 5M and 58M. Groundwater flow patterns inferred from the May 2013 map suggest that, despite downtime at wells 5M and 58M, groundwater in the Mckay coal still flows toward active capture wells, notably new wells 115M and 116M. Repair efforts at 5M and 58M are ongoing.

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NORTH

SCALE
(In Feet)
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LEGEND

105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

49S
55D
48S
SRP-4
120A
121A
50S
SRP-5
AB-20S
56D
3226.5
56M-P
AB-9S/M
15S
15D
102A
OT-11
122A
AB-8S
3230
SRP-6
109A
AB-7S
AR-5PE
116M
3230.6
118A
3230.3
57M-P
3209.5
5M
5S
108A
91S
3230
115M
3231.5
101A
107A
110D
SRP-7
96A
95D
97A
94A
AB-4S
58M
3216.0
Approximate Limit
of McKay Coal seam.
The coal has been eroded
by Armells Creek.
OT-13
93A
106A
AB-3S
3232.7
113M
58M-P
3234.3
114S
AB-2S
SRP-8
CA-18
92A
105A
63S
OT-12
59M-P
AB-1S
59M
3220.2
3235
3228.7
98M
99D
100A
60M-P
3235.6
10S
10M
3225.5
104A
103D
67M
3238.0
68A
61M
3237.7
62S
3239.6
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	**DECEMBER 2012 MCKAY POTENTIOMETRIC SURFACE**	FIGURE **4-8**

Hydrometrics, Inc.
Consulting Scientists and Engineers

UPDATE TIME: 8:54 AM
JBERGIN\BIL\20130530\i:\LAND PROJECTS\PPL\DWG\1210013\1210013B002.DWG

NORTH

SCALE
(In Feet)
0 200

LEGEND

105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

49S
55D
48S
SRP-4
120A
121A
50S
SRP-5
AB-20S
56D
56M-P
3226.6
AB-9S/M
15S
15D
102A
OT-11
122A
117A
AB-8S
109A
SRP-6
AB-7S
AR-5PE
116M
3209.5
118A
3230
57M-P
3227.7
3230.0
108A
5M
5S
91S
101A
115M
3217.6
SRP-7
107A
110D
96A
95D
97A
94A
AB-4S
58M
3231.3
Approximate Limit
of McKay Coal seam.
The coal has been eroded
by Armells Creek.
OT-13
93A
106A
AB-3S
3216.4
113M
114S
58M-P
3232.3
AB-2S
SRP-8
3235
CA-18
92A
105A
63S
OT-12
59M-P
AB-1S
59M
3236.5
98M
3218.8
99D
100A
60M-P
3235.8
10S
10M
3236.1
104A
103D
67M
3238.5
68A
61M
3238.8
62S
3239.8
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	**APRIL 2013 MCKAY POTENTIOMETRIC SURFACE**	FIGURE **4-9**

Hydrometrics, Inc.
Consulting Scientists and Engineers

UPDATE TIME: 8:54 AM
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NORTH

SCALE
(In Feet)
0 200

LEGEND

105A MONITORING WELL
98M CAPTURE WELL
3228.9 GROUNDWATER ELEVATION
POTENTIOMETRIC LINE
GROUNDWATER DEPRESSION
FLOW DIRECTION

49S
55D
48S
SRP-4
120A
121A
50S
SRP-5
AB-20S
56D
56M-P
3225.8
AB-9S/M
3225
15S
15D
102A
122A
117A
OT-11
AB-8S
109A
SRP-6
AB-7S
AR-5PE
116M
3216.4
118A
57M-P
3227.0
3226.9
5M
5S
108A
91S
101A
115M
3216.2
SRR-7
107A
110D
96A
95D
97A
94A
3230
AB-4S
58M
3230.5
Approximate Limit
of McKay Coal seam.
The coal has been eroded
by Armells Creek.
OT-13
93A
106A
AB-3S
58M-P
3232.2
3215.6
113M
114S
AB-2S
SRP-8
CA-18
92A
105A
3220
63S
OT-12
59M-P
AB-1S
59M
3220.3
98M
3224.5
3235
99D
100A
60M-P
3235.7
10S
10M
3214.9
104A
103D
3238.4
67M
68A
61M
3238.7
62S
3239.9
14M

CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION	MAY 2013 MCKAY POTENTIOMETRIC SURFACE	FIGURE 4-10

Hydrometrics, Inc.
Consulting Scientists and Engineers

4.2.5 Capture Volumes

Groundwater capture volumes are typically estimated for a given well by multiplying measured flow rates by elapsed pumping times. Flow rates are measured by isolating flow to the sample ports and recording the amount of time it takes to fill a container of known volume. Because flow measurements are taken under discharge to the atmosphere, rather than against the pressurized system, they tend to overestimate actual volumetric capture rates. Elapsed pumping times are recorded by automated hour-meters installed at the wellhead of each pumping well. As noted above, capture rates/volumes are underestimated when hour meters fail to record run time due to excessive pump cycling.

Best estimates of initial volumes of captured groundwater at the new wells in the 5M Area are presented in Table 4-1. The estimates include groundwater captured from March 21, 2013 through May 30, 2013. Based on available data, the seven new capture wells collected 2.4 million gallons of groundwater during the evaluation period; and the average system flow rate for the seven wells was 23.4 gpm. Periods of pump cycling that were not registered by hour meters resulted in no recorded capture volume. This includes the entire initial startup period for well 118A, all of March and April at well 114S, and all of March and April at well 115M. As noted above, flow at each of the pumping wells except for 122A was valve-controlled on May 6, 2013 to more closely match estimated well yields. As a result, the pumps operated with less cycling and hour meters were able to provide a more accurate record of run time. Note that average pumping rates at individual wells were higher in May 2013, after the valves were adjusted.

Table 4-1. Capture Volumes at New 5M Area Capture Wells (March 21 through May 31, 2013)

WELL #:	113M		114S		115M		116M		117A		118A		122A	
Month	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*	Estimated Total Gallons	Estimated average gallons per minute*
March (21 - 31)**	4,939	0.31	0	0.00	100	0.01	44,072	2.78	48,376	3.05	0	0.00	228,335	14.42
April	5,150	0.12	0	0.00	0	0.00	24,738	0.57	118,072	2.73	0	0.00	647,942	15.00
May	47,438	1.06	61,854	1.39	157,045	3.52	203,971	4.57	267,461	5.99	0	0.00	560,423	12.55
Total	57,527	0.6	61,854	0.7	157,145	1.5	272,781	2.6	433,909	4.2	0	0.0	1,436,700	13.9

System Total (gallons) **2,419,916**
2013 System Average GPM **23.4**

* = total gallons pumped per month divided by total minutes in month
** = well down part of the month for construction, maintenance, or repair

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Seven new capture wells and two new monitoring wells were installed in the 5M Area west of the Plant Site at the PPL Colstrip-SES. The monitoring wells (120A and 121A) exhibit groundwater quality that is not indicative of process water impacts. The capture wells (113A, 114S, 115M, 116M, 117A, 118A, and 122A) began recovering groundwater impacted by process water in late March 2013. In the two-month period following capture system startup, an estimated 2.4 million gallons of impacted groundwater were collected; and the new system pumped at an average collective rate of 23.4 gpm. Operational changes made to most of the new capture wells in early May 2013 increased pump run times; thus, it is expected that both the cumulative groundwater collection volume and individual capture rates estimated in this report are lower than those that can be expected during future operation of the new wells.

Observations made in this report elucidate the temporal nature of groundwater capture system wells. Pump cycling and temporary down time for maintenance create variable groundwater flow patterns within the capture well network. The new capture wells add density to the existing 5M Area well network that buffers down time and limits flow of impacted water beyond the system in multiple groundwater horizons.

5.2 RECOMMENDATIONS

The following recommendations are made for the new monitoring and capture wells and for the 5M Area in general, based on the body of work presented above.

- New monitoring wells 120A and 121A should remain as monitoring wells and be sampled at PPL's typical semi-annual frequency. Monthly water level measurements should be made at these wells.
- Pumping rates, water levels, hour meter readings, and field SC measurements should continue at the new capture wells at PPL's typical frequency. This includes multiple water level and hour meter readings and at least one measurement of flow rate and field SC monthly. Data observations should be used to refine operation of new and

existing capture wells in the 5M Area to maximize drawdown and capture rates but minimize pump cycling and down time.

- Capture volumes and average groundwater pumping rates should be estimated and reported yearly in PPL's Annual Hydrologic Monitoring Data Report.
- Potentiometric surface maps for both the shallow and McKay groundwater horizons should be presented yearly in PPL's Annual Hydrologic Monitoring Data Report.
- No new monitoring or capture wells are recommended at this time. However, if monitoring data collected in the previous recommendations indicates changes in groundwater quality or flow patterns, additional capture wells and/or monitoring wells should be considered.

6.0 REFERENCE

Hydrometrics, Inc. (January 1995). *Investigation of the Quality of Groundwater and Surface Water in the Colstrip Plant Site and 1&2 Evaporation Pond Areas.* Pumping test results are in Appendix C of this reference.

Hydrometrics, Inc. (January 2010). *Trailer Park Well Installation/Conversion and Pipeline Installation Report* . Pumping test results are in Appendix C of this reference.

Hydrometrics, Inc. (October 2012). *Work Plan 5M Area New Well Installation and Capture Conversion.*

Theis, C. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Am. Geophys. Union Trans., vol. 16,* 519-524.

PPL MONTANA, LLC
COLSTRIP STEAM ELECTRIC STATION

FINAL REPORT – CAPTURE SYSTEM CONSTRUCTION, STARTUP, AND PERFORMANCE IN THE 5M AREA -- COLSTRIP STEAM ELECTRIC STATION

Pursuant to: ADMINISTRATIVE ORDER ON CONSENT REGARDING IMPACTS RELATED TO WASTEWATER FACILITIES COMPRISING THE CLOSED-LOOP SYSTEM AT COLSTRIP STEAM ELECTRIC STATION, COLSTRIP, MONTANA SECTION XI - SUBMISSIONS

CERTIFICATION:

I, the undersigned, hereby certify that this document was prepared under my direction and to the best of my knowledge the information contained herein is correct and accurate.

Michael Holgerson | Environmental Compliance Professional | 6/7/13

Name | Title | Date

APPENDIX A. MONITORING WELL LOGS

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 113M

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: SE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: McKay Coal

Hole Diameter (in): 0 - 24' (10"); 24 - 38' (8")

Total Depth Drilled (ft): 38

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.86 - 38
Surface Casing Used?	Y	8-inch Steel	+2 - 24
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	27 - 38
Sand Pack?	Y	10/20 Silica Sand	26 - 38
Annular Seal?	Y	Bentonite Chips	+1 - 26
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 606949.94 Easting: 2701660.51

Static Water Level Below MP: 18.48 Surface Casing Height (ft): 2

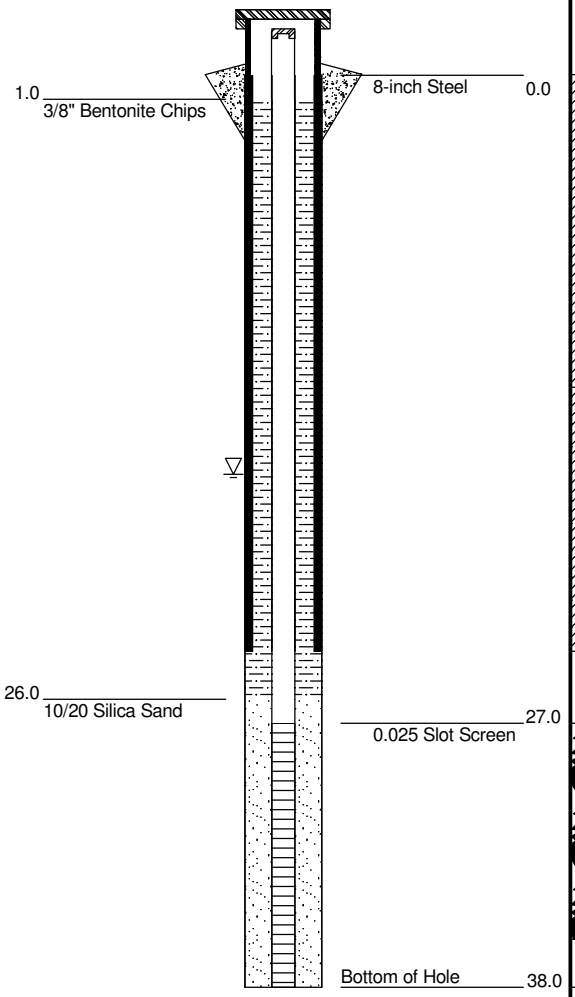
Date: 11-27-2012 Riser Height (ft): 1.86

MP Description: Top of PVC Ground Surface Elevation (ft): 3250.2

MP Height Above or Below Ground (ft): 1.86 MP Elevation (ft): 3252.06

Remarks: Hole opened with vac truck to 11' to clear utilities; drilled to 24' with 7-7/8" bit, ream out with 10" bit; set 8-inch steel and pour bentonite while driving. Developed with Rig Bailer. Yield estimate is 2 gpm. SC = 6700 umhos/cm after development. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 13.0' **Clay, Silt, and Gravel** [Spoils]
dry to slightly moist, moderate yellowish brown [10YR 5/4] fines with multi-colored gravels (<10%), loose, becomes sandy from 7 - 10'

13.0 - 24.0' **Sand and Clay** [Alluvium]
slightly moist to wet at 15', pale yellowish brown [10YR 6/2], very loose; 50/50 from 13 - 15', becomes very sandy at 17' (clay to < 10%)

24.0 - 27.0' **Siltstone** [Bedrock]
dry, dark yellowish orange [10YR 6/6] and pale yellowish brown, firm; injecting water at 25'

27.0 - 36.0' **Coal** [McKay Coal]
black, hard, cleated, wet, making water

36.0 - 38.0' **Siltstone** [Bedrock]
dry, medium light gray [N6], firm to stiff

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 114S

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: SE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 8"

Total Depth Drilled (ft): 25

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.1 - 25
Surface Casing Used?	Y	8-inch Steel	+2 - 3
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	16 - 25
Sand Pack?	Y	10/20 Silica Sand	10 - 25
Annular Seal?	Y	Bentonite Chips	+1 - 10
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 606923.66 Easting: 2701666.96

Static Water Level Below MP: 19.29 Surface Casing Height (ft): 2

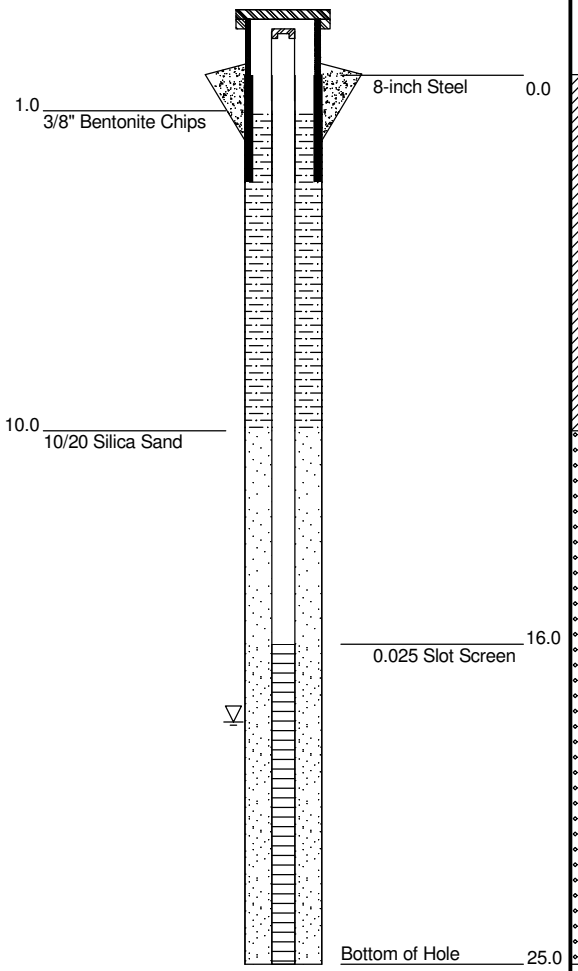
Date: 11-27-2012 Riser Height (ft): 1.1

MP Description: Top of PVC Ground Surface Elevation (ft): 3251.5

MP Height Above or Below Ground (ft): 1.1 MP Elevation (ft): 3252.6

Remarks: Hole opened with vac truck to 10' to clear utilities; bailed with rig bailer; yield is low; SC = 5700 to 6330 umhos/cm during development.
Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 10.0' **Clay and Gravel** [Spoils]
pale yellowish brown [10YR 6/2], loose; gravel < 10%, clinker origin to 1"; becomes sandy at 10'

10.0 - 25.0' **Sand** [Alluvium]
some clay (decreases with depth), poorly sorted pale yellowish brown, very loose

Siltstone [Bedrock]
dry, dark yellowish orange [10YR 6/6], firm; tagged at 25'

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 115M

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: McKay Coal

Hole Diameter (in): 8"

Total Depth Drilled (ft): 39

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.51 - 39
Surface Casing Used?	Y	8-inch Steel	+2 - 5
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	29 -39
Sand Pack?	Y	10/20 Silica Sand	28 - 39
Annular Seal?	Y	Bentonite Chips	+1 - 28
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 607354.32 Easting: 2701623.01

Static Water Level Below MP: 16.48 Surface Casing Height (ft): 2

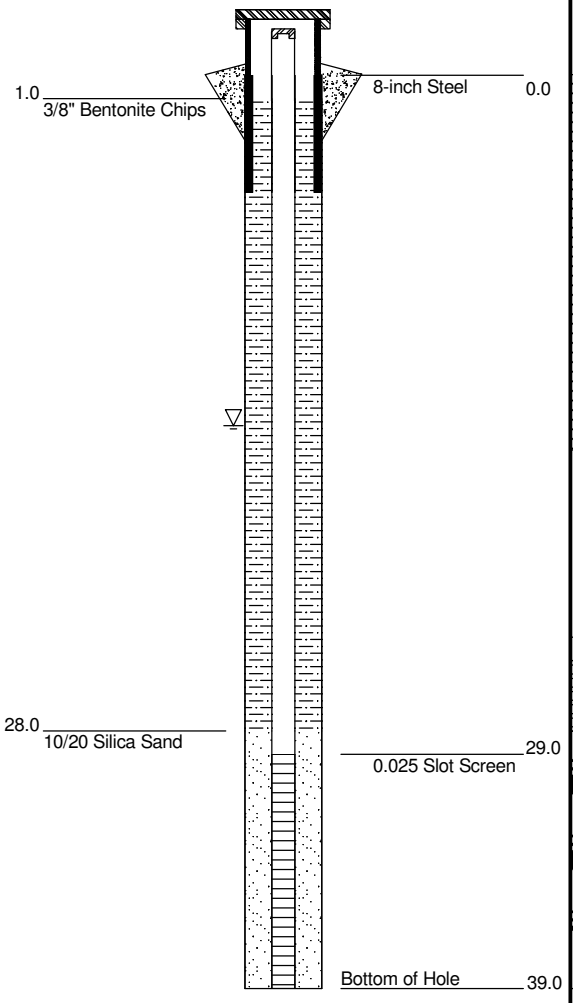
Date: 11-27-2012 Riser Height (ft): 1.51

MP Description: Top of PVC Ground Surface Elevation (ft): 3246.5

MP Height Above or Below Ground (ft): 1.51 MP Elevation (ft): 3248.01

Remarks: Hole opened with vac truck to 9.5' to clear utilities; developed with rig bailer; yield is 5 gpm; SC = 9300 umhos/cm after development.
Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 16.0' **Silt and Clay** [Spoils]
minimal trace gravel at 8', dry to slightly moist at 5', wet at 12', pale to moderate yellowish brown [10YR 5/4], loose, roots, non-plastic; injecting water at 12'

16.0 - 24.0' **Siltstone** [Bedrock]
dry, light olive gray [5Y 6/1] to pale yellowish brown [10YR 6/2] and dark yellowish orange [10YR 6/6], firm to stiff

24.0 - 25.0' **Sandstone** [Bedrock]
pale yellowish brown, soft to stiff, poorly sorted

25.0 - 28.0' **Siltstone/Claystone** [Bedrock]
dry, pale yellowish brown, stiff

28.0 - 36.5' **Coal** [McKay Coal]
wet, black, hard, cleated

36.5 - 39.0' **Siltstone** [Bedrock]
dry, light brownish gray [5YR 6/1] to medium light gray [N7]

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 116M

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: McKay Coal

Hole Diameter (in): 0 - 20' (10"); 20 - 37' (8")

Total Depth Drilled (ft): 37

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+0.6 - 37
Surface Casing Used?	Y	8-inch Steel	+2 - 24
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	27 - 37
Sand Pack?	Y	10/20 Silica Sand	25.5 - 37
Annular Seal?	Y	Bentonite Chips	+1 - 25.5
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 607555.91 Easting: 2701605.53

Static Water Level Below MP: 14.72 Surface Casing Height (ft): 1

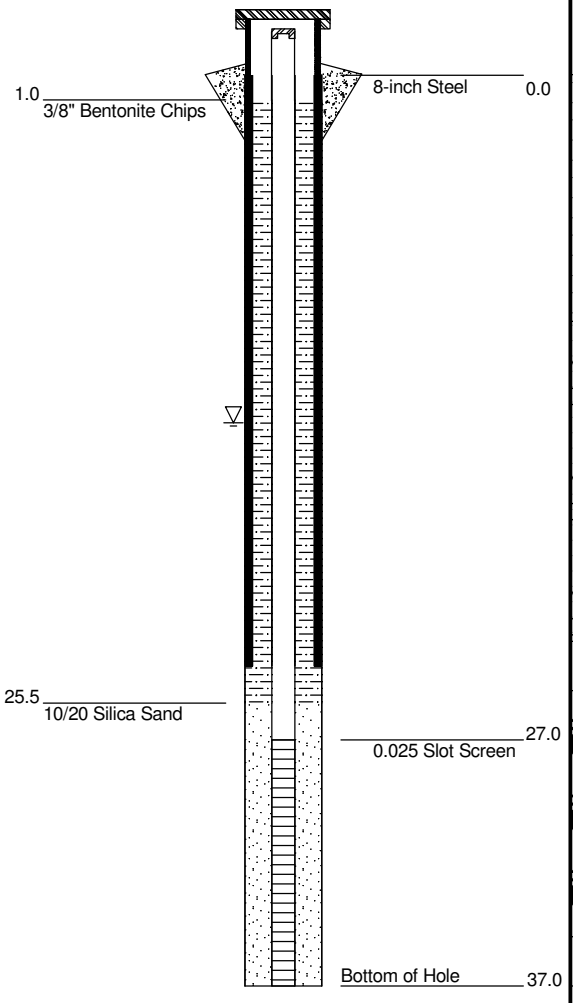
Date: 11-27-2012 Riser Height (ft): 0.6

MP Description: Top of PVC Ground Surface Elevation (ft): 3244.7

MP Height Above or Below Ground (ft): 0.6 MP Elevation (ft): 3245.3

Remarks: Hole opened with vac truck to 10.5' to clear utilities; hole drilled with 10" bit, set 8-inch steel casing to 20'; casing pulled back during completion; developed with rig bailer; SC = 7200 umhos/cm. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 10.0' **Silty Sand** [Fill/Alluvium]
slighlty moist, less silt with depth, increasing moisture with depth, dark yellowish orange [10YR 6/6] to light brown [5YR 5/6], loose, roots in top 1', spoils in top 5'

10.0 - 23.0' **Sand and Gravel** [Alluvium]
some clay/silt fines, wet, moderate yellowish brown [10YR 5/4] fines and multi-colored gravel; size up to 2" , poorly sorted, mostly clinker origin, some coal gravel; mostly flat, some spherical, sub-round to sub-angular; less to no fines with depth, less sand with depth; injecting water at 20'.

23.0 - 25.0' **Siltstone** [Bedrock]
dry, pale yellowish brown [10YR 6/2] and light olive gray [5Y 5/2], non-plastic, firm

25.0 - 35.0' **Coal** [McKay Coal]
wet, black, hard

35.0 - 37.0' **Siltstone** [Bedrock]
fine sandy, light olive gray to medium light gray [N6], medium firm

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 117A

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 0 - 20' (10"); 20 - 25' (8")

Total Depth Drilled (ft): 25

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.41 - 25
Surface Casing Used?	Y	8-inch Steel	+2 -4
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	15 - 25
Sand Pack?	Y	10/20 Silica Sand	10 - 25
Annular Seal?	Y	Bentonite Chips	+1 - 10
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 607862.86 Easting: 2701597.19

Static Water Level Below MP: 16.27 Surface Casing Height (ft): 2

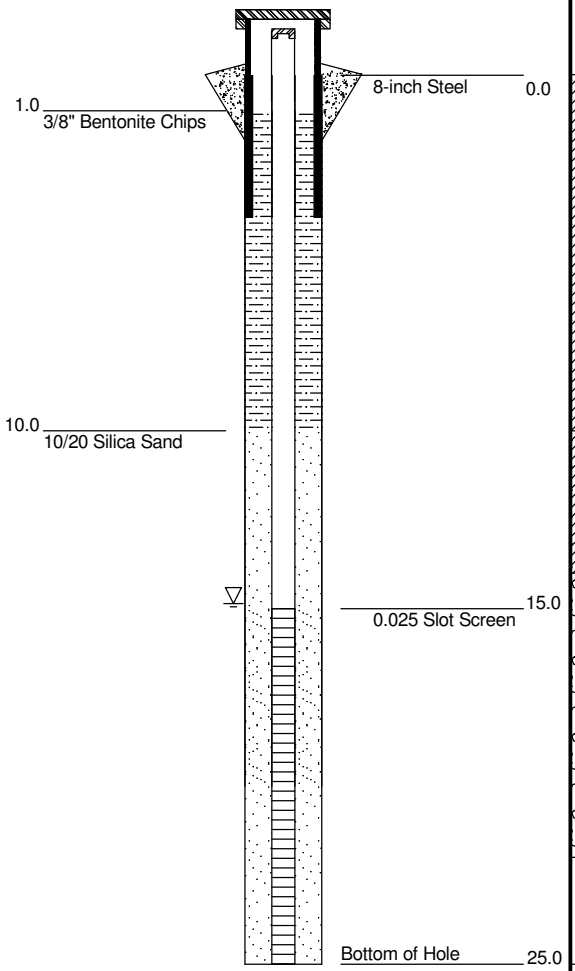
Date: 11-27-2012 Riser Height (ft): 1.41

MP Description: Top of PVC Ground Surface Elevation (ft): 3241.8

MP Height Above or Below Ground (ft): 1.41 MP Elevation (ft): 3243.21

Remarks: Hole opened with vac truck to 10' to clear utilities; hole drilled with 10" bit, set 8-inch steel casing to 20'; casing pulled back during completion; developed with rig air/ yield is 2.5 gpm; SC = 11,800 umhos/cm after development. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 10.0' **Silt and Clay** [Fill]
trace gravel at 5', dry to slightly moist, dark yellowish brown to light olive gray, loose; some re-worked junk coal, soft

10.0 - 14.0' **Sand and Clay** [Alluvium]
moist to wet, pale yellowish orange [10YR 8/6], non-plactic, loose

14.0 - 22.0' **Sand and Gravel** [Alluvium]
wet, pale yellowish brown [10YR 6/2], light brown, and moderate reddish brown [10R 4/6], poorly sorted, loose; sand to < 15% at 17', gravels up to 2"; sandstone, coal and clinker origin; sub-round, mostly flat to moderately spherical

22.0 - 25.0' **Siltstone** [Bedrock]
pale yellowish brown, medium firm

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 118A

Date Hole Started: 11-19-2012 Date Hole Finished: 11-19-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 8"

Total Depth Drilled (ft): 25

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.32 - 25
Surface Casing Used?	Y	8-inch Steel	+2 - 3
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	15 - 25
Sand Pack?	Y	10/20 Silica Sand	10.5 - 25
Annular Seal?	Y	Bentonite Chips	+1 - 10.5
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 607588.78 Easting: 2701708.68

Static Water Level Below MP: 16.26 Surface Casing Height (ft): 2

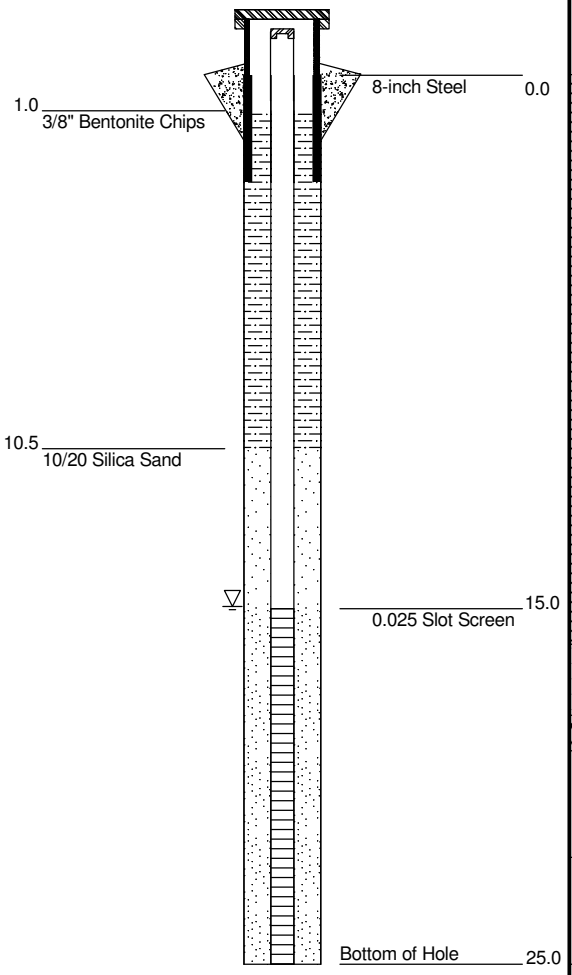
Date: 11-27-2012 Riser Height (ft): 1.32

MP Description: Top of PVC Ground Surface Elevation (ft): 3245.5

MP Height Above or Below Ground (ft): 1.32 MP Elevation (ft): 3246.82

Remarks: Hole opened with vac truck to 10' to clear utilities; developed with rig bailer; yield is 3 gpm; SC = 12,550 umhos/cm. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 16.0' **Silt and Clay** [Fill]
slightly moist, pale to moderate yellowish brown, loose, moderate plasticity, rolls to 1/8"; trace white precipitates, injecting water at 12'

16.0 - 18.0' **Sand** [Alluvium]
wet, pale yellowish brown, fine to medium fine grained, poorly sorted

18.0 - 19.0' **Sand and Gravel** [Alluvium]
wet, pale yellowish brown sand with multi-colored clinker gravels

19.0 - 22.0' **Siltstone** [Weathered Bedrock]
wet to dry with depth, pale yellowish brown, soft and loose; groundwater yield increases in this interval

22.0 - 25.0' **Siltstone** [Bedrock]
As above, hardness to firm

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 119A

Date Hole Started: 11-21-2012 Date Hole Finished: 11-21-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 10"

Total Depth Drilled (ft): 35

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.62 -35
Surface Casing Used?	Y	8-inch Steel	+2 - 4
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	25 - 35
Sand Pack?	Y	10/20 Silica Sand	12 - 35
Annular Seal?	Y	Bentonite Chips	+1 - 12
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 608998.53 Easting: 2701643.61

Static Water Level Below MP: 17.55 Surface Casing Height (ft): 2

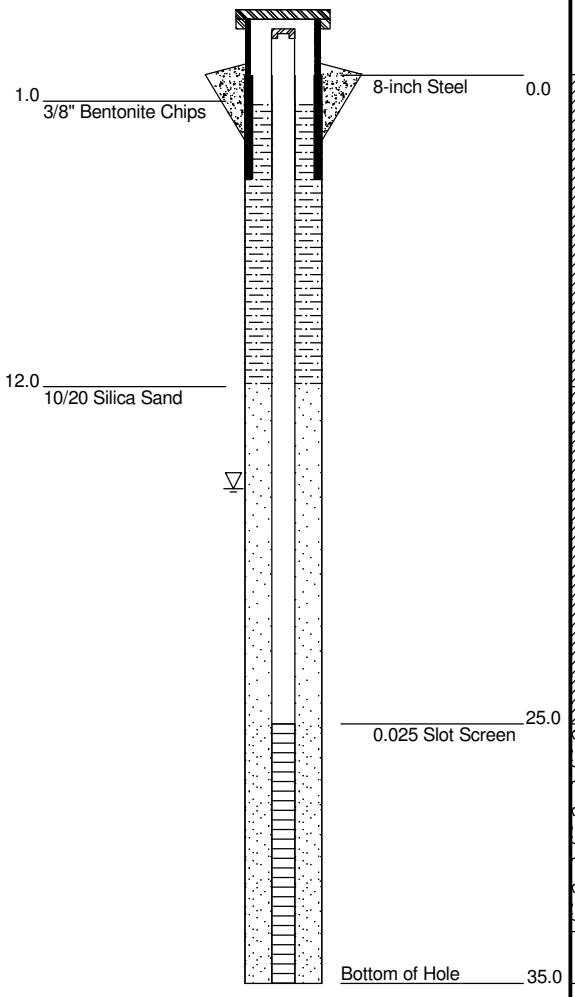
Date: 11-27-2012 Riser Height (ft): 1.62

MP Description: Top of PVC Ground Surface Elevation (ft): 3237.7

MP Height Above or Below Ground (ft): 1.62 MP Elevation (ft): 3239.32

Remarks: Hole opened with vac truck to 10' to clear utilities; hole drilled with 10" bit, set 8-inch steel casing to 35'; developed with rig air; yield is 20 gpm; SC = 5,890 umhos/cm. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 12.0' **Silt and Clay** [Fill]
dry to moist w/depth, moderate yellowish brown, non-plastic, loose; gravel 5% from 0 - 5' ; trace gravel from 5 - 12', becomes sandy

12.0 - 25.0' **Sandy Clay** [Alluvium]
very moist, moderate yelllowish brown, loose, non-plastic; trace pea size clinker gravel increases with depth

25.0 - 33.0' **Sand and Gravel** [Alluvium]
wet, moderate and pale yellowish brown sand with multi-colored clinker gravels; 50/50 gravel/sand to 80/20 gravel/sand with depth; sub-round to sub-angular, size up to 4", mostly flat, some moderately spherical

33.0 - 35.0' **Siltstone** [Bedrock]
dry, medium light gray and greenish gray, firm

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 120A

Date Hole Started: 11-28-2012 Date Hole Finished: 11-28-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 0 - 20' (10"); 20 - 40' (8"); 40 - 41' (4")

Total Depth Drilled (ft): 41

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.46 - 40
Surface Casing Used?	Y	8-inch Steel	+2 - 5
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	20 - 40
Sand Pack?	Y	10/20 Silica Sand	14 - 18; 34 - 40
Annular Seal?	Y	Bentonite Chips	+1 - 14
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 608312.92 Easting: 2701424.28

Static Water Level Below MP: 13.57 Surface Casing Height (ft): 2

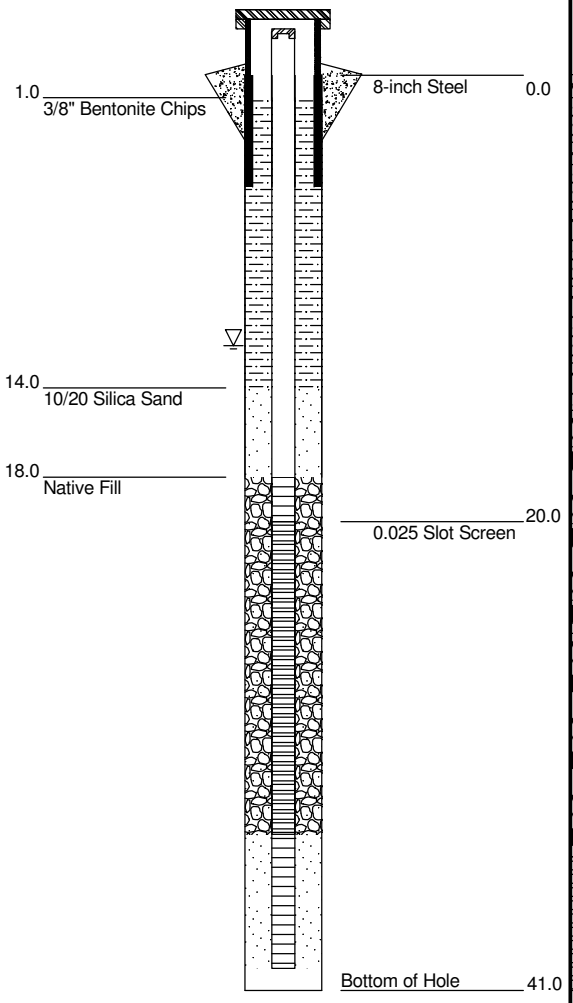
Date: 12-13-2012 Riser Height (ft): 1.46

MP Description: Top of PVC Ground Surface Elevation (ft): 3237.1

MP Height Above or Below Ground (ft): 1.46 MP Elevation (ft): 3238.56

Remarks: Hole reamed with 10" bit to 36'; set 8" steel; steel pulled back during completion; hole sloughed from 18 - 34'; developed with rig air; yield is 15 gpm; SC = 5,000 umhos/cm. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 1.0' **Silty Gravel** [Fill]
dry, pale yellowish brown [10YR 6/2], loose

1.0 - 4.0' **Silt,Sand, and Gravel** [Fill]
slightly moist, moderate yellowish brown, some woody debris; pea size gravel of clinker origin

4.0 - 15.0' **Sand and Gravel, some clayey** [Alluvium]
moist to very moist at 8', moderate yellowish brown [10yR 5/4], loose to very loose from 10 - 15'; poorly sorted, silty to clayey at 8', nearly 50% clay at 15', moderate plasticity

15.0 - 25.0' **Sand and Gravel** [Alluvium]
some clay to no clay at 25', sand to < 10% at 25', wet, pale to moderate yellowish brown sand with multi-colored clinker gravels

25.0 - 35.0' **Gravel** [Alluvium]
wet, multi-colored (e.g. light brown and grayish orange); gravels of clinker and sandstone origin, trace coal gravel (<5%) from 30 - 35', loose, size to 4"; larger gravel is angular to sub-angular, smaller gravel (<2") is sub-round to sub-angular

35.0 - 41.0' **Claystone/Siltstone** [Bedrock]
dry, light bluish gray [5B 7/1] with thin weathered dark brown carbonaceous shale at 35', medium firm to stiff; TD is beyond expected depth of McKay Coal

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 121A

Date Hole Started: 11-28-2012 Date Hole Finished: 11-28-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 0 - 20' (10"); 20 - 40' (8")

Total Depth Drilled (ft): 41

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.81 - 40
Surface Casing Used?	Y	8-inch Steel	+2 - 6
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	20- 40
Sand Pack?	Y	10/20 Silica Sand	12 - 20; 32 - 40
Annular Seal?	Y	Bentonite Chips	+1 - 12
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 608101.4 Easting: 2701380.56

Static Water Level Below MP: 13.22 Surface Casing Height (ft): 2

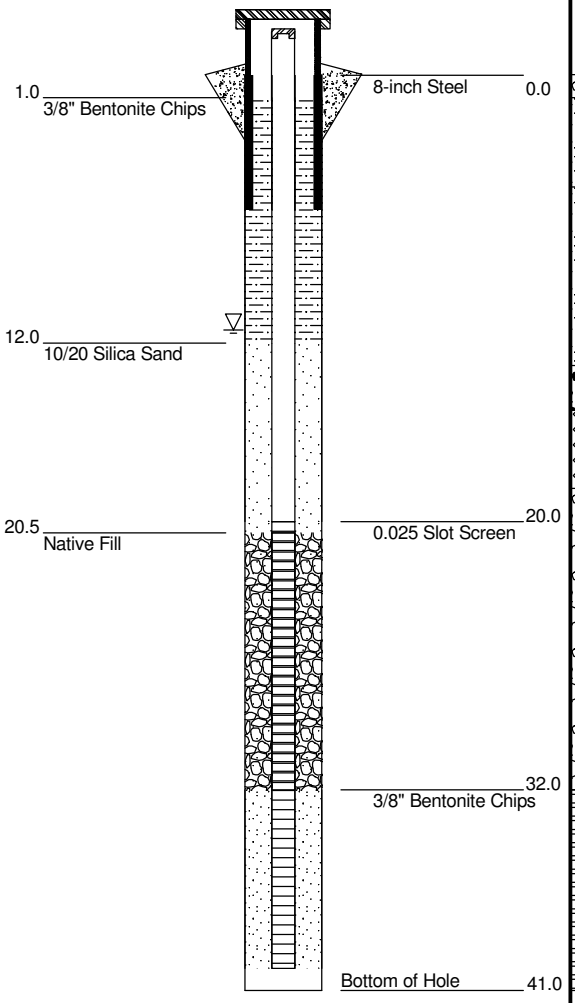
Date: 12-13-2012 Riser Height (ft): 1.81

MP Description: Top of PVC Ground Surface Elevation (ft): 3237.3

MP Height Above or Below Ground (ft): 1.81 MP Elevation (ft): 3239.11

Remarks: Hole reamed with 10" bit to 36'; set 8" steel; steel pulled back during completion; hole sloughed from 20 - 32'; developed with rig air; yield is 10 gpm; SC = 4500 umhos/cm. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 1.0' **Silty Gravel** [Alluvium]
dry, pale yellowish brown to grayish orange, loose, roots

1.0 - 5.0' **Silt/Sand** [Alluvium]
dry, grayish orange [10YR 7/4] and pale yellowish brown, loose, roots

5.0 - 13.0' **Silty Sand** [Alluvium]
moist, moderate yellowish brown [10YR 5/4], loose; some clayey at 9', non-plastic, trace coarse sand at 13'; injecting water at 9'

13.0 - 15.0' **Sandy Gravel** [Alluvium]
wet, moderate yellowish brown sand with light brown gravel, poorly sorted

15.0 - 18.5' **Sand** [Alluvium]
no gravel, wet, moderate yellowish brown, loose, poorly sorted very fine to medium grain

18.5 - 32.0' **Sand and Gravel** [Alluvium]
wet, moderate yellowish brown sand with multi-colored (light brown [5YR 6/4] and pale yellowish orange [10YR 8/6]) sandstone and clinker gravel; flat to moderately spherical, mostly sub-round, some sub-angular; sand to <10% at 20'

32.0 - 41.0' **Siltstone/Claystone** [Bedrock]
dry, pale yellowish brown from 32 - 33', light bluish gray from 33 - 41', medium firm to stiff with depth, very thin trace coal (<0.5') at 38'

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Billings, Montana

Monitor Well Log

Hole Name: 122A

Date Hole Started: 11-28-2012 Date Hole Finished: 11-28-2012

Client: PPL Montana LLC

Project: Plant Site

County: Rosebud State: MT

Property Owner: PPL Montana, LLC

Legal Description: NE1/4, SW1/4, Section 34, T 2N, R 41E

Location Description: West of Units 1&2 Flyash Pond

Recorded By: RJL

Drilling Company: Ron Askin Drilling

Driller: Ron And Doug Askin

Drilling Method: Air Rotary

Drilling Fluids Used: Water

Purpose of Hole: Install Monitor Well

Target Aquifer: First Water

Hole Diameter (in): 0 - 20' (10"); 20 - 50' (8")

Total Depth Drilled (ft): 50

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	4-inch, Sch 40, PVC	+1.59 - 39
Surface Casing Used?	Y	8-inch Steel	+2 -3
Screen/Perforations?	Y	0.025-inch slot, Sch 40 PVC	19 - 39
Sand Pack?	Y	10/20 Silica Sand	13 - 20; 33 - 39
Annular Seal?	Y	Bentonite Chips	+1 - 13; 39 - 50
Surface Seal?	Y	Bentonite Chips	
DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	N		
Boring Samples Taken?	N		

Northing: 607859.28 Easting: 2701447.02

Static Water Level Below MP: 16.71 Surface Casing Height (ft): 2

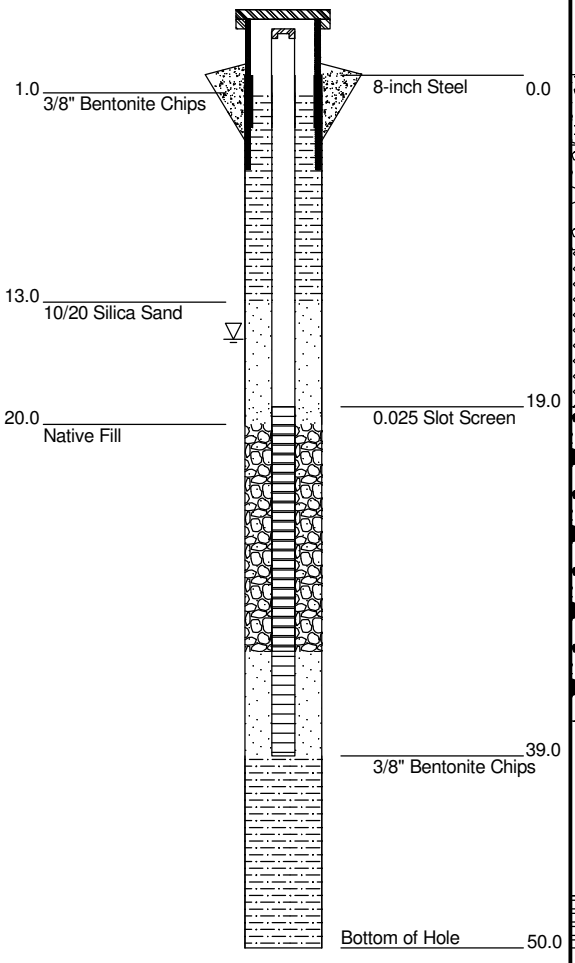
Date: 12-13-2012 Riser Height (ft): 1.59

MP Description: Top of PVC Ground Surface Elevation (ft): 3241.9

MP Height Above or Below Ground (ft): 1.59 MP Elevation (ft): 3243.49

Remarks: Hole reamed with 10" bit to 36'; set 8" steel; steel pulled back during completion; hole sloughed from 20 - 33'; developed with rig air; yield is 15 gpm; SC = 6700 umhos/cm after development. Coordinates: US State Plane Montana 2500NAD 1983; vertical NAVD88

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 4.0' **Road Mix** [Fill]
sand and clinker gravel, dry, light brown to pale red, loose but hard

4.0 - 10.0' **Silty,clayey, gravel** [Alluvium]
dry to slightly moist, dark yellowish orang to light brown; becomes sandy from 6 - 10'; injecting water

10.0 - 19.0' **Sand** [Alluvium]
very moist to wet, poorly sorted fine to medium grained; becomes clayey and gravelly at 16'; moderate yellowish brown with light brown gravels

19.0 - 37.0' **Sand and Gravel** [Alluvium]
20/80 sand/gravel, poorly sorted, wet, dark yellowish orange and pale yellowish brown sand with multi-colored gravels of sandstone and clinker origin, loose, hard; size up to 4"; sub-angular to sub-round, flat to moderately spherical

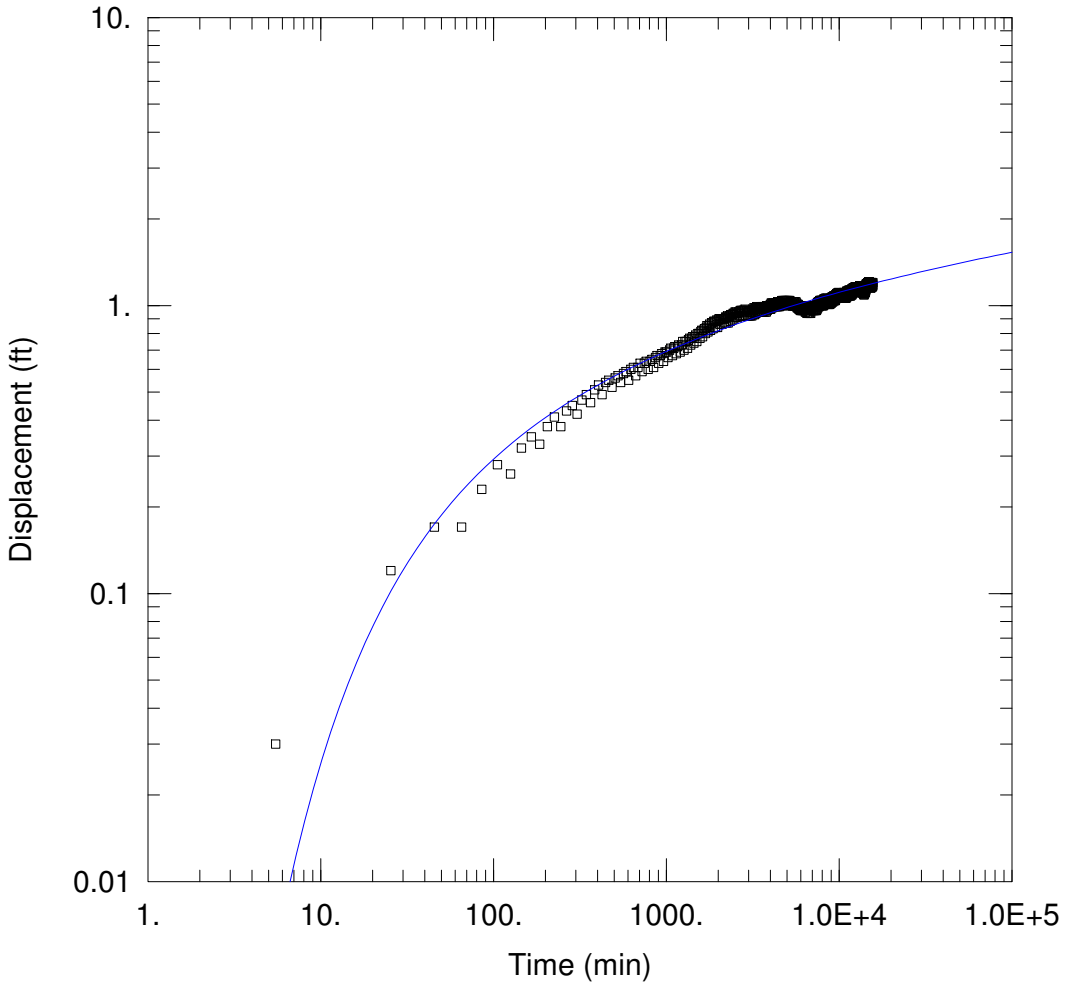
37.0 - 47.0' **Siltstone** [Bedrock]
some clayey, dry, light olive gray, then light bluish gray at 39', soft to very stiff at 40'; very fine sandstone, hard from 43 - 46'; very thin coal/car shale stringer at 46'

47.0 - 50.0' **Shale** [Bedrock]
dry, light bluish gray, firm to stiff

open hole makes more water as it is advanced beyond bottom of gravel/steel; SC of open hole is 4500 umhos/cm. Hole plugged from 39 - 50' with bentonite chips.

STANDARD_REV3 PLANT SITE AREA LOGS NOV 2012 FORWARD.GPJ HYDHLN2.GDT 1/7/13

APPENDIX B. ANALYTICAL PUMPING TEST SOLUTIONS



STARTUP OF CAPTURE WELL 113M

Data Set: H:\PROJECTS\PPLMT\Aquifer Testing\Plant Site Aquifer Tests\113M Startup.aqt
Date: 05/31/13 Time: 14:41:41

PROJECT INFORMATION

Company: Hydrometrics
Client: PPL MT
Project: 12100
Location: Colstrip, MT
Test Well: 113M
Test Date: 3/21/2013

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
113M	2701661.65	606950.04

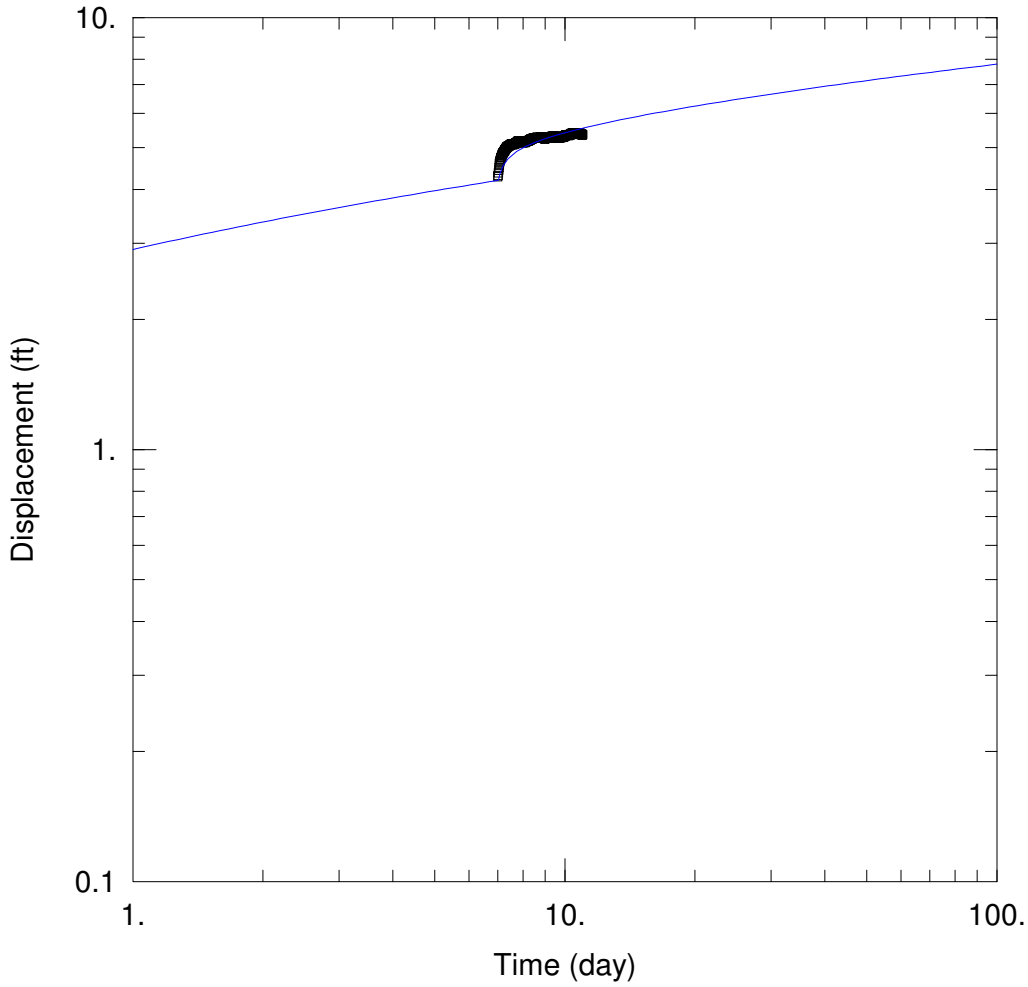
Observation Wells

Well Name	X (ft)	Y (ft)
▫ 58M-P	2701725.8	606986.02

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 84. ft^2/day
Kz/Kr = 1.
S = 0.00055
b = 9. ft



STARTUP OF CAPTURE WELL 118A, MULTIPLE PUMPING WELL SOLUTION WITH SRP-6

Data Set: H:\PROJECTS\PPLMT\Aquifer Testing\Plant Site Aquifer Tests\118A Startup.aqt
Date: 06/01/13 Time: 09:45:49

PROJECT INFORMATION

Company: Hydrometrics
Client: PPL MT
Project: 12100
Location: Colstrip, MT
Test Well: 118A
Test Date: 3/21/2013

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
118A	2701708.82	607587.85
SRP-6	2701709.18	607680.75

Observation Wells

Well Name	X (ft)	Y (ft)
AB7-S	2701717.44	607652.14

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 92. ft^2/day
S = 0.003
Kz/Kr = 1.
b = 7.5 ft