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M E M O R A N D U M

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TO: Jim Ford, Montana Environmental Trust Group

FROM: Bob Anderson, Hydrometrics, Inc.
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SUBJECT: Upper Lake Drawdown Test Technical Memorandum –DRAFT

EXECUTIVE SUMMARY

The Montana Environmental Trust Group is conducting an Upper Lake drawdown test at the former Asarco smelter site (the plant site) in East Helena, Montana. Upper Lake is a relatively large surface water feature at the south (topographically and hydrologically upgradient) margin of the plant site. Leakage from Upper Lake has long been recognized as a source of recharge to the plant site groundwater system, where the interaction of groundwater with metals-contaminated soils has negatively impacted groundwater quality. The purpose of the Upper Lake drawdown test is to simulate, at least partially, the effects of eliminating recharge from Upper Lake on plant site groundwater levels, flow rates, and contaminant loading to groundwater. This information is being used in planning and implementation of remedial measures for the site.

The Upper Lake drawdown test has involved three distinct phases, including passive lake dewatering achieved by shutting off the diversion inflow from Prickly Pear Creek, lowering Prickly Pear Creek adjacent to the plant site, and pumping from the lake to expedite lake level drawdown. The first phase of the test began on 11/1/2011 and continued through 3/26/12. The creek lowering phase overlapped with the passive dewatering phase and occurred from 12/21/11 through 2/24/12. The third (lake pumping) phase was initiated on 3/26/12 and continues to date. Data collection during the test has included continuous water level monitoring at a total of 35 groundwater and surface water sites instrumented with pressure sensitive transducers, and manual measurements at an additional 20 sites. The water level data is intended to quantify the groundwater level declines across the plant site, and determine effects of the lake drawdown on hydraulic gradients and groundwater flow rates across the plant site.

As of September 13, 2012, the water level in Upper Lake had declined by 4.9 feet since the November 1, 2011 test startup. Groundwater levels during this time have declined by four to

five feet in the south portion of the plant site, three to four feet in the central plant site, and four to six feet in the northwest portion of the plant site. Water level declines in the south plant site are attributable to the proximity of this area to Upper Lake while the larger declines in the northwest plant site are attributable to the Upper Lake drawdown, as well as a lack of flow in Wilson Ditch. The lack of ditch flow in 2012 is related to the Upper Lake drawdown test as Wilson Ditch is fed by a headgate on Upper Lake. Water levels in the northeast portion of the plant site (beneath the slag pile) declined by less than one foot, suggesting the shallow groundwater system in this area has limited interaction with water levels in Upper Lake and the south plant area.

Current plans for the East Helena Smelter site include permanent elimination or reduction of recharge from Upper Lake to the plant site groundwater system, lowering the water level in Prickly Pear Creek adjacent to the plant site by removing a small dam, excavation of contaminated soils in the south plant area, placement of a low permeability zone to further limit groundwater flow through the plant site, and possible elimination of Wilson Ditch. Collectively, these actions are referred to as the South Plant Hydraulic Control (SPHC) project. In order to assess the effectiveness of the proposed SPHC, information gained from the Upper Lake drawdown test to date was used to estimate total declines in groundwater levels expected through implementation of the SPHC. Projected water level declines range from approximately ten feet in the south plant area, four to five feet in the central plant area, and up to six feet in the northwest plant area. Groundwater levels in the northeast plant area (beneath the slag pile), are expected to decline by two feet or less. Lowering the water table will not only reduce the total groundwater flow rate or flux through the plant site, but will also significantly reduce the magnitude of groundwater interaction with the most highly contaminated soils on the plant site. These two effects should combine to reduce the load (pounds/day) of contaminants in plant site and downgradient groundwater

Additional information gained from the Upper Lake drawdown test to date includes identification of potential preferential groundwater flow paths through the plant site, portions of the plant site where groundwater is more closely connected to Prickly Pear Creek, and general groundwater flow patterns through the site. Following completion of the water level recovery phase of the test (Fall 2012), effects of the Upper Lake drawdown test and projected effects of the SPHC on groundwater levels, flow rates and patterns, and groundwater quality will be evaluated further.

1.0 INTRODUCTION

Upper Lake has previously been identified as a source of recharge to the Upper Aquifer, or unconfined groundwater system overlying the Tertiary ash/clay layer at the former East Helena smelter site (the plant site). Indications that Upper Lake provides recharge to the plant site groundwater system include its location at the extreme southern (upgradient) end of the plant site, and the elevated lake level resulting from construction of raised ground levels and berms around the lake perimeter. Although these physical attributes indicate that Upper Lake increases recharge to the plant site Upper Aquifer (as compared to pre-lake conditions), the magnitude of recharge attributable to Upper Lake has not previously been quantified. In order to assess the rate of groundwater recharge from Upper Lake to the plant site groundwater system, METG initiated an Upper Lake drawdown test to document the plant site groundwater system response to variations in the Upper Lake water level. The Upper Lake drawdown test was initiated in fall 2011 and continues to date. This technical memorandum describes the Upper Lake drawdown testing procedures and results to date. Interpretation of the test results is also presented along with preliminary implications of the potential effectiveness of the proposed South Plant Hydraulic Control (SPHC) interim measures. Additional data review and interpretation will occur following the water level recovery (partial lake refilling) phase of the test, scheduled to begin in October 2012.

1.1 DRAWDOWN TEST OBJECTIVES

Design and planning of the Upper Lake drawdown test is covered in two memoranda submitted to METG by Hydrometrics (dated August 5, 2011 and October 19, 2011), with subsequent input from the project team. Besides quantifying effects of Upper Lake dewatering on plant site groundwater levels, the drawdown test is also intended to provide additional information on the overall plant site hydrogeologic system. Specific objectives of the drawdown test as outlined in the August 5th memorandum include:

1. Quantify the Plant Site groundwater system response to lowering of the Upper Lake water level.

2. Identify potential preferential groundwater flow paths through the plant site based on the magnitude and timing of groundwater level responses in individual wells.

3. Refine plant site aquifer hydraulic conductivity estimates based on the groundwater level response to lake dewatering in various portions of the site, if test data allows.

This memorandum focuses on objective #1 to aid in planning and implementation of the SPHC activities. Objectives 2 and 3 are also discussed as relevant to the SPHC project, and will be evaluated further in support of other interim and corrective measures activities and as available information allows.

1.2 BACKGROUND

Upper Lake lies within the Prickly Pear Creek floodplain at the south end of the former smelter or plant site (Figure 1). The lake area and associated marsh system to the immediate south lie within an area of recent active channel migration, resulting in the lake/marsh area being largely underlain by alluvial sands and gravels. Based on available information, the sand/gravel is overlain by 2 to 5 feet of silt/clay. Since the lake/marsh area is part of the active creek floodplain, Prickly Pear Creek has meandered through the area in the recent past. Based on review of historic aerial photos and observations of the lake at its current drawn down level, two former creek channels are evident in the lake/marsh area as shown on Figure 1. Due to the relatively high permeability of former channel sediments, the channels may represent preferential flow paths for shallow groundwater through the lake/marsh area and northward through the plant site. One of these channels extends through the west half of the lake and projects northwestward through the west plant site while the second former channel traverses the east half of the lake and projects through Tito Park (Figure 1).

Upper Lake was initially formed by diversion of water from Prickly Pear Creek into what originally was most likely a large marsh complex with limited open water. The original lake was considerably smaller in size than its present day configuration, with the lake area (and elevation) increased through continued placement of fill north of the lake (Tito Park area), and construction of an earthen berm (east berm) between the lake and Prickly Pear Creek around 1985. These "improvements" were implemented in part to provide a suitable water source for operation of the Acid Plant and other facility processes. The Upper Lake water level is controlled by two large outlet culverts in the east berm, with outflow through the culverts returning to Prickly Pear Creek. During the irrigation season, lake water typically is also diverted into Wilson Ditch through a headgate on the west side of the lake. Figure 1 shows the present-day (pre-drawdown test) Upper Lake configuration and various features relevant to this discussion.

With enlargement and raising of the lake level during (and prior to) the mid-1980s, leakage from the lake to the plant site is expected to have increased due to the greater hydraulic gradient and wetted surface area of the lake. Regular dredging of sediments from the northwest portion of the lake (to facilitate pumping for plant make-up water) would also have increased the leakage rate as compared to current conditions. Since the 2001 plant shutdown, Upper Lake has partially filled in with fine grained (low permeability) sediments, reducing the rate of leakage as compared to pre-2001 conditions. Thus, the rate of leakage and groundwater recharge from Upper Lake to the plant site groundwater system has most likely varied over time.

1.3 DEVELOPMENT OF UPPER AND LOWER LAKE

The earliest records uncovered to date regarding Upper Lake include reference to 1938 and 1959 measurements of the lake depth, and various activities associated with sediment control from upstream placer mining activities. At that time, Upper Lake and Lower Lake were physically connected as one lake with the two sections referred to as the south and north lakes, respectively. In the 1930s, upstream placer mining operations on Prickly Pear Creek caused turbidity problems in the creek and the plant site water system. In 1934, a ten-foot wide ditch was excavated from Prickly Pear Creek to the south end of Upper Lake to utilize the lake as a settling basin. This resulted in infilling of Upper Lake with sediment and a reduction in the lake depth and area. This information shows that Upper Lake was a significant water feature as far back as the 1930s with the lake depth, surface area and lakebed conditions varying over time. These variations in lake conditions would have affected leakage from the lake to the plant site groundwater system over the past several decades.

In 1985, the inlet channel and diversion structure on Prickly Pear Creek were improved by Asarco to better control inflow to Upper Lake. The east berm and outflow culverts were also constructed at that time resulting in an increase in the normal operating level of the lake, and presumably increased leakage from the lake to the plant site groundwater system. With shutdown of the smelter in 2001 and cessation of lake dredging, siltation of the lake bottom increased, thereby causing a reduction in the rate of leakage from the lake.

Figure 2 includes a sequence of aerial photographs from 1955 to 2011 showing the Upper Lake expansion over time. Key points of interest in the photos include:

- In 1955, Upper Lake and Lower Lake were connected by a narrow channel. Upper Lake was significantly smaller in size and restricted to the far western portion of the current lake area as compared to the later photos.
- By 1964, the area between the two lakes had been filled in. The Upper Lake surface area is notably larger than in 1955.
- The 1976, 1978 and 1980 photos look very similar to 1964 with no significant changes apparent in Upper or Lower Lake.
- Between 1980 and 1987, the enlarged inlet channel and east berm become evident and the Upper Lake level increases as shown by the expanded surface area.
- Between 1987 and 2011 the surface area (and water level) in Upper Lake shows a steady increase, possibly due to siltation of the lake bottom after the 2001 plant shutdown.

This evolution of the Upper (and Lower) Lake surface area and water level has undoubtedly affected groundwater flow through the plant site over the past several decades.

1.4 GENERAL LAKE HYDROLOGY

Figure 3 shows the three general flow paths by which seepage exits Upper Lake. The first flow path is located in the northwest corner of the lake upgradient of the former acid plant. This location corresponds to one of the former creek channels noted in Figure 1 and is believed to represent a preferential flow path from Upper Lake to the plant site. Lake seepage along this flow path flows northwestward through the former acid plant area and associated contaminated soils. The second flow path occurs northward through Tito Park to Lower Lake. Although flow between the two lakes most likely occurs throughout Tito Park, the rate of flow is probably greatest along any preferential flow paths, such as the former creek channel shown in Figure 1, and in the eastern part of Tito Park where the hydraulic gradient would be greatest due to the shorter distance between the two lakes. Installation of the acid plant sediment drying area (APSD) slurry wall (Figure 3) has undoubtedly altered the direction and possibly the rate of recharge from Upper Lake to the plant site since construction of the slurry wall in 2006.

The third main route for seepage out of the lake is through the east berm to Prickly Pear Creek. Seepage through this area is potentially significant due to the presumably coarse and permeable nature of the fill material used to construct the berm, and the potentially high gradient from the lake to the creek. Under normal conditions, The Upper Lake water level is three to five feet higher than the adjacent creek level, resulting in hydraulic gradients on the order of 0.1 feet/feet from Upper Lake to the creek. Based on the east dike dimensions (350 feet long and 3 feet high below the water level) and an assumed hydraulic conductivity of 200 ft/day, seepage rates through the dike may be on the order of 100 gallons per minute (gpm) or more when the lake is at full pool, or about 3920 feet elevation. An additional component of direct seepage from the lake when at full pool is westward seepage into the tertiary sediments forming the west lake shoreline. This seepage component is expected to be relatively small due to the lower hydraulic conductivity of the tertiary sediments as compared to the alluvial sediments or fill material present in the other seepage areas.

Figure 4 shows a schematic cross section from south to north through the Upper Lake area (see cross section trace on Figure 3). Key points on this figure include the alluvial (Qal) gravel underlying Upper Lake, and the continuous silt/clay layer (lake sediments) separating Upper Lake from the underlying gravels. The documented thickness of the silt/clay layer ranges from about 60 inches at the deeper north end of the lake, to about 40 inches at piezometer ULM-PZ-1 near the head of Upper Lake. Based on available information, the low permeability lakebed sediments are believed to inhibit downward leakage of the lake water to the underlying groundwater system, or upward seepage into the lake. Therefore, recharge from the lake to the plant site groundwater system occurs primarily via seepage through the north lake shoreline. As shown in Figure 4, the composition of the lake shoreline varies from relatively high permeability fill material on the upper bank, to low permeability silt/clay on the lower portion of the bank. This causes the rate of leakage to decrease as the lake level drops below the fill/silt contact.

The lack of subsurface leakage into or out of Upper Lake (at least at lower lake levels) is confirmed by measurements recorded on July 11, 2012. At that time, the lake water level was relatively stable at 3915.75 feet, similar to that shown for 7/24/12 on Figure 4. Upper Lake was being dewatered through pumping at that time with the pumping rate at 30 gpm. Surface water inflow from a small creek into the south end of the lake was measured at 36 gpm. The close correlation between the creek inflow rate and the pumping outflow rate under steady state water level conditions suggests minimal seepage into or out of the lake was occurring at that time (evaporation is assumed to be negligible given the small surface area of the lake at that time). Based on the saturated conditions in the alluvial gravels immediately north of Upper Lake (i.e., well DH-20 in Figure 4), this information suggests that groundwater underflow through the alluvial gravels underlying Upper Lake may persist even after Upper Lake has been permanently dewatered.

2.0 UPPER LAKE DRAWDOWN TEST PROCEDURES

The Upper Lake drawdown test involved three distinct phases, including passive lake dewatering achieved by shutting off the diversion inflow from Prickly Pear Creek, temporarily lowering Prickly Pear Creek adjacent to the plant site, and pumping from the lake to expedite lake level drawdown. The drawdown test schedule and monitoring program are summarized below.

2.1 UPPER LAKE DRAWDOWN TEST SCHEDULE

The Upper Lake Drawdown Test was initiated in fall 2011 with background (pre-drawdown) water level monitoring conducted in October. Following background data collection, the "passive" dewatering phase of the test began on 11/01/11 when the inlet diversion from Prickly Pear Creek to Upper Lake was shut off. Immediately prior to closing the diversion gates, measured inflow to Upper Lake from the creek was 30 cfs (13,440 gpm), which represents about half of the creek flow above the diversion gate at that time. Following closure of the diversion gates about 20 gpm flow remained in the Upper Lake inlet channel due to minor leakage around the gates. The diversion gates have remained closed with about 20 gpm leakage or less since 11/01/11 (Table 1).

The second phase of the test included lowering the Prickly Pear Creek stage above the Smelter Dam to assess the plant site groundwater and Upper Lake level response. The creek level was lowered by as much as eight feet (3915 feet to 3907 feet elevation) by incrementally opening the lower gates on the smelter dam. The creek lowering phase began on 12/21/11 and ended (by closing the lower gates) on 2/24/12. The creek level at the smelter dam has remained at 3915 to 3916 feet since 2/24.

The third phase of the drawdown test involved pumping water from Upper Lake to expedite the lake drawdown. After several months of passive dewatering, the rate of lake level decline slowed considerably leading to the need for pumping. Pumping was initiated on March 26, 2012 with the primary pump intake located in the west half of Upper Lake and a secondary pump located in the east half of the lake. The primary pump has operated more or less continuously since 3/26/12 with relatively few interruptions. The secondary pump was operated on a periodic schedule (typically during normal working hours each day) from 3/26/12 through 4/9/12, after which use of the secondary pump was discontinued. For the

TABLE 1. UPPER LAKE DRAWDOWN TEST SCHEDULE

Test Phase/Milestone	Begin	End	Comments
Background Monitoring	10/1/11	10/31/11	Documents background water level trends leading up to test.
Shut Off Prickly Pear Creek Inflow	11/01/11		Closed PP Ck diversion to Upper Lake inlet channel
Passive Drawdown Phase	11/01/11	3/26/12	Prickly Pear Ck inlet diversion shut off and lake allowed to passively dewater through seepage to subsurface.
Prickly Pear Creek Drawdown Phase	12/21/11	2/24/12	Prickly Pear Creek stage lowered at smelter dam on 12/21/11 to assess effect on groundwater levels. Creek level raised back up on 2/24/12. PP Ck diversion inlet remains closed.
Upper Lake Pumping	3/26/12	Ongoing	Includes continuous pumping from Upper Lake to expedite lake dewatering with diversion inlet remaining closed.

majority of the pumping period, each pump typically discharged between 80 to 120 gpm, with the discharge water piped to an infiltration basin near Prickly Pear Creek. Currently, the primary pump is operating continuously at approximately 15 gpm to maintain a steady state lake level.

2.2 MONITORING PROGRAM

The drawdown test monitoring program is focused primarily on measurement of water levels throughout and peripheral to the plant site. Water levels are measured continuously at a total of approximately 35 groundwater and surface water sites instrumented with pressure sensitive transducers. The continuous water level data is augmented with bi-weekly manual measurements at an additional 20 sites. The water level data is intended to quantify the groundwater level declines across the plant site, and determine effects of the lake drawdown on hydraulic gradients and groundwater flow rates across the plant site. Figure 5 shows the drawdown test monitoring network.

3.0 DRAWDOWN TEST RESULTS

The drawdown test water level monitoring results (to date) are summarized below, with data evaluation and interpretation presented in the following section (Section 4.0). For discussion purposes, the water level data are discussed separately by area, including the south plant area or south zone (Tito Park, Upper Lake, Lower Lake and Phase I/II CAMU area), the central plant zone, and the north plant zone (Figure 5). Water level declines measured during the course of the drawdown test (10/31/11 to 9/13/12) are discussed for each area. The plant site water level changes measured since the start of the test are referred to as water level declines as opposed to water level drawdown, since the measured water level changes likely include some component of seasonal (and potentially longer-term) water level trends, in addition to any lake drawdown-induced water level changes. As discussed in the following section, water level data from late summer/fall 2012 as well as water level recovery data will be required prior to full evaluation of lake drawdown-induced groundwater level changes on portions of the plant site.

3.1 SOUTH PLANT AREA

Primary water level monitoring sites in the south plant area include Upper and Lower Lake, Prickly Pear Creek at (immediately upstream of) the smelter dam, and nine monitoring wells in and around Tito Park. In addition, all 11 CAMU monitoring wells (MW wells on Figure 5) are included in the south plant area for discussion purposes. The primary water level monitoring sites are described in Table 2.

Water level declines measured between 11/01/11 (when diversion inflow to Upper Lake was shut off) through 9/13/12 in the south plant area ranged from 5.10 feet at well APSD-9 (located immediately north of Upper Lake), to 0.93 feet at well APSD-8 (between Lower Lake and Prickly Pear Creek). Water level declines at other notable sites include 4.84 feet at Upper Lake, 3.46 feet at Lower Lake, 3.58 feet at well DH-20 (between Upper Lake and the Acid Plant area), and 3.29 feet in well DH-3 (west of Upper Lake). Hydrographs for select south zone wells are included in Figure 6.

As shown on Figure 6, south plant water levels responded very quickly to the onset of Upper Lake dewatering, especially at wells APSD-9 and APSD-10 along the north Upper Lake shoreline. By mid-November, the Upper Lake water level stabilized at about 3918 feet and remained stable through December, while Lower Lake and groundwater levels throughout the south plant area continued to decrease.

Lowering Prickly Pear Creek above the smelter dam as of 12/20/11 had a notable effect on water levels. Most notable is well APSD-8 (located between Lower Lake and the creek, Figure 5), which dropped about 3.5 feet during the creek lowering phase of the test and fully recovered within about a week after the creek level was raised back up on 2/24/12. As shown on Figure 6, water levels at all other sites were influenced by the creek lowering including well DH-20, located on the west side of the plant site. Interestingly, the Upper Lake water level showed very little response to creek lowering, indicating leakage from the lake to the creek through the east berm is minimal, at least at reduced lake levels of about 3918 feet or lower.

The Upper Lake water level was generally stable from mid-November (about two weeks after inflow to the lake was shut off) through mid-March. With the onset of pumping from the lake on March 26, 2012, the Upper Lake level again began to drop, followed by similar declines in Lower Lake and the south plant monitoring wells. As shown on Figure 6, Upper Lake, Lower Lake and groundwater within Tito Park (APSD wells on Figure 6) have all

TABLE 2. DRAWDOWN TEST WATER LEVEL MONITORING SITES AND WATER LEVEL DECLINES FROM 10/31/11 THROUGH 9/13/12

Monitoring Site	Location	Depth Below Ground Surface (feet)	Net Water Level Decline (feet) 10/31/11 -9/13/12
South Plant Site			
Upper Lake	South Plant Area	NA	4.84
Lower Lake	South Plant Area	NA	3.46
APSD-8	Between Lower Lake and PP Ck	15	0.93
APSD-9	Tito Park	16	5.10
APSD-10	Tito Park	16	4.99
APSD-12	Tito Park	15.5	3.79
DH-3	West of Upper Lake	54	3.29
DH-20	Northwest of Upper Lake	31	3.58
MW-6	Between Plant Site and Phase I CAMU	40	3.88
MW-11	West of Phase II CAMU	70	0.38
Central Plant Site			
DH-19R	Former Acid Plant	25	3.35
DH-4	North of Lower Lake	23	0.95
DH-42	Former Acid Plant	34	3.55
DH-2	West of Plant Site	65.5	3.62
DH-71	North of Former Acid Plant	34	3.78
DH-73	Former Zinc Plant area	48	3.52
DH-68	South end of slag pile	50	0.42
EH-204	West of Plant Site	65	5.48
North Plant Site			
DH-17	Northcentral Plant Site	41	5.18
DH-66	NW of Ore Storage Building	48	5.50
DH-49	North Plant Site	34	5.55
DH-51	North Plant Site	34	5.02
DH-6	Between slag pile and Highway 12	25	3.65
DH-15	Between slag pile and Highway 12	50	3.65

NA-Not Applicable

converged to a similar elevation of about 3915 feet. This convergence of water levels has greatly reduced the hydraulic gradient, and thus groundwater flow, through Tito Park.

3.2 CENTRAL PLANT AREA

The central plant area covers the majority of the former plant site including the acid plant, speiss-dross plant, and the majority of the slag pile (Figure 5). Primary water level monitoring sites in this area are listed in Table 2 with hydrographs for select sites shown in Figure 7. Water level declines between 10/31/11 and 9/13/12 in this area ranged from 5.48 feet at well EH-204 (west of the Lower Ore Storage area), to 0.42 feet at DH-68 (south end of slag pile). Significant water level declines were also recorded at well DH-71 (3.78 feet) located between the acid plant and lower ore storage area, DH-2 (3.62 feet), completed in tertiary sediments west of the plant site, and DH-42 (3.55 feet) completed in the former acid plant area. Generally, water level declines are greatest on the west side of the plant site compared to the east side (beneath the slag pile). In fact, the water level at slag pile well DH-68 showed virtually no response to the Upper Lake or Prickly Pear Creek drawdown (Figure 7). Likewise, water levels at well DH-4, also located on the east side of the plant and only a few tens of feet north of Lower Lake, has also shown minimal response to the Upper Lake dewatering although DH-4 did show some response to the creek lowering phase of the test (Figure 7). The general lack of water level response at DH-4 and DH-68 suggests limited hydraulic interaction between the south plant groundwater system and the east side of the plant site. The lack of hydraulic continuity to the north of Lower Lake has previously been noted by the steep hydraulic gradients mapped in this area. These results suggest that the SPHC may have a lesser impact on groundwater levels beneath the east portion of the site (beneath the slag pile) as compared to the south and west portions of the plant site.

Groundwater levels in the former acid plant area (DH-19R and DH-42, Figure 7) have declined about 3.5 feet as of 9/13/12 and continue to decline to date. Post-SPHC groundwater levels in this area are of particular interest since the former acid plant contains some of the highest subsurface soil contaminant concentrations on the site.

3.3 NORTH PLANT AREA

North zone wells are shown on Figure 5 and listed in Table 2. Hydrographs for select wells are shown in Figure 8. Groundwater levels in the northern portion of the plant site show a steady decline from prior to the onset of the Upper Lake drawdown through mid-September 2012, although water levels at all sites increased temporarily in June in response to spring runoff. Overall water level declines in this area range from 3.30 feet at wells DH-6/15 near Prickly Pear Creek, to 5.55 feet at DH-49 in the northwest corner of the site.

Besides being some of the largest water level declines recorded during the lake drawdown test, the 2012 north plant site water level trends are notable in their contrast from previous years. Figure 9 shows long-term water level trends at north plant site wells DH-66 and DH-17. Water levels in these wells, and throughout the northwest portion of the site, have historically been lowest in winter and spring, and highest during late summer and fall. In contrast, water levels on the east side of the plant site are typically highest in spring and early summer, consistent with Prickly Pear Creek water levels. Continuous water level hydrographs from several wells located immediately north and west of the plant site, including EH-205/210, SP-4, EH-60/61/103 (Figure 5), show a definite correlation in groundwater levels and the presence or absence of flow in Wilson Ditch (Figure 10). Therefore, the lack of a late summer water level rise in in the northwest plant site wells in 2012 is attributable to the lack of flow in Wilson Ditch. Thus, in evaluating results of the Upper Lake drawdown test and ramifications of the SPHC, the effects of lake removal and creek lowering as well as possible elimination of flow in Wilson Ditch must be taken into account.

One other potential influence on the 2012 water level trends and drawdown test results is the lack of precipitation during summer 2012. The lack of precipitation has undoubtedly had some influence on groundwater levels, along with dewatering of Upper Lake and Wilson Ditch. To assess the possibility that climatic conditions are a primary cause of the significant water level declines in the northwest plant site, long-term water levels from north plant site well DH-66 were plotted against corresponding water levels from County monitoring well "Airport N-N" located north of the plant site near the Helena Airport. The Airport N-N well is located near the Helena Valley irrigation canal and historically has exhibited similar summer season water level increases as the northwest plant site wells. As shown in Figure 11, 2012 water level trends at the Airport N-N well exhibit the same summer season increase as seen in previous years, while the DH-66 trend does not. The consistent trends at Airport N-N in 2012 suggest that climatic conditions have not significantly affected seasonal trends at this well, and climatic conditions most likely are not responsible for the lack of late summer water level increases in DH-66 and other northwest plant site wells. Thus, the Upper Lake drawdown and lack of flow in Wilson Ditch are the most likely causes of the significantly lower northwest plant site groundwater levels in 2012.

Groundwater levels in the north plant site showed no apparent response to lowering of Prickly Pear Creek above the smelter dam, although they do correlate closely with creek levels downstream of the dam. Wells DH-6/DH-15 exhibit a strong correlation with the Prickly Pear Creek water level due to their proximity to the creek. As shown in Figure 8, all the north area wells correlate fairly well with DH-6/15. For example, an increase in the creek level during January 2012 due to an ice jam just upstream of Highway 12 caused water levels to rise about one foot in DH-6/15, with a similar although more subdued response apparent in all the north plant site wells. The groundwater level response to spring runoff (June) is also apparent in the north plant site hydrographs. This information shows the close interaction of the north plant site groundwater with the segment of Prickly Pear Creek downstream of the Smelter Dam.

Figure 12 shows the magnitude of measured water level declines as of 9/13/12 throughout the plant site. As presented above, water level declines have been greatest (4 to 5 feet) in the south plant site (due to the proximity to Upper Lake), and in the north plant site (up to 6 feet) due in part to the lack of flow in Wilson Ditch. Water level declines in the 3 to 4-foot range extend from Lower Lake and Tito Park on the east, westward through the acid plant area and west of the plant site. Conversely, measured water level declines are less than one foot in the east plant site beneath the slag pile. With the possible exception of the north plant site, the water level patterns shown on Figure 12 highlight those areas most sensitive to the Upper Lake drawdown. These areas, namely the south and west portions of the plant site, are expected to show the greatest response in water level drawdown from the SPHC. Water level declines will also be greatest in the northwest portion of the site if recharge from Wilson Ditch is eliminated through the SPHC. The water level declines plotted on Figure 12 reflect the net change in water levels between 10/31/11 and 9/13/12. As such, effects of lowering Prickly Pear Creek at the smelter dam, which ended on 2/24/12, are not reflected in Figure 12. If the creek had remained at the lowered stage, measured water declines would have been greater than the currently measured levels.

4.0 EVALUATION OF TEST RESULTS

The drawdown test data collected to date has undergone a preliminary evaluation with respect to insights into the plant site groundwater system and implications for the SPHC activities. Projections of plant site groundwater levels under permanent lake dewatering and Prickly Pear Creek relocation/lowering as proposed under the SPHC program have been made, and possible effects on groundwater flow rates and patterns through the plant site assessed.

4.1 PROJECTED WATER LEVELS

Relocation and lowering of Prickly Pear Creek through removal of the smelter dam is a key component of the SPHC and will have significant impacts on south plant site groundwater levels. Although the creek lowering phase of the Upper Lake drawdown test lasted for only about two months (from 12/20/11 through 2/24/12), information obtained during that period provided insight into the combined effects of lake dewatering and creek lowering on groundwater levels. Figure 13 shows the south plant site hydrographs along with the Prickly Pear Creek stage at the smelter dam from 12/20/11 (start of creek lowering) through 7/24/12. During the latter half of the creek lowering phase (1/30/12 through 2/20/12), the creek level was maintained at a relatively steady elevation of about 3911 feet. Water levels at well APSD-8, located between the creek and Lower Lake, stabilized around 3913 feet during this period, or about 2 feet higher than the creek. Based on this relationship, it can be assumed that the APSD-8 water level will stabilize about 2 feet higher than the post-SPHC creek level of 3906 feet at the current dam location, or at about 3908 feet. In actuality, the APSD-8 water level may stabilize less than 2 feet above the creek level since the 2-foot difference recorded during the drawdown test was most likely affected by water levels in adjacent Lower Lake. With elimination of Lower Lake, water levels at APSD-8 will most likely stabilize less than 2 feet above the creek level. Therefore, the groundwater level at APSD-8 is estimated to be between 3906 and 3908 feet following lake dewatering and permanent creek lowering.

After raising the creek level back to normal dam operating levels (about 3915.5 feet), water levels in Lower Lake and the Tito Park wells continued to decline in response to the Upper Lake drawdown. As of July 2012, groundwater levels in the Tito Park area had all fallen to within 0.5 feet of the creek level (Figure 13). Therefore, with long-term elimination of groundwater recharge from Upper and Lower Lake, groundwater levels throughout the Tito Park area are expected to stabilize close to or slightly higher than the final Prickly Pear Creek water level. Projected overall post-SPHC water level declines are shown for select sites on Figure 12.

Figures 14 and 15 show two east-west schematic cross sections through the south plant area. Both cross sections show the site stratigraphy, the pre-drawdown test (10/31/11) groundwater levels, the 7/24/12 groundwater levels, and the range of projected post-SPHC groundwater levels. Figure 14 also shows total arsenic and selenium (where available) soil concentrations with depth. As shown on Figure 14 (and discussed above), groundwater levels to date have declined on the order of five feet from Upper Lake dewatering alone, with an additional five feet of decline expected from permanent lowering of the creek. The water level declines measured to date have already lowered the groundwater table below the zone of highest soil contaminant concentrations, and achieving the final projected groundwater levels would further dewater the contaminated soils. The Figure 15 cross section lies slightly north of Figure 14 and includes Lower Lake (note that cross section traces for Figures 14 through 17 are shown on an inset map on Figure 14). Following the Prickly Pear Creek relocation and lowering, groundwater levels are expected to stabilize near the bottom of Lower Lake.

It is important to note that the projected post-SPHC water levels in the south plant area are based on preliminary post-SPHC creek channel locations and elevations upstream of the current dam location. If final creek elevations or locations change appreciably from the preliminary plans, the post-SPHC groundwater levels may be affected. Also, water level drawdown in response to the temporary bypass channel may be different from that estimated for the final creek relocation. The greater distance of the proposed bypass channel from the plant site, as compared to the final creek channel location, may reduce the observed level of groundwater drawdown on the plant site while the temporary bypass is in operation.

Figure 16 shows similar information along a cross section extending from Upper Lake northwestward through the west side of the plant and the former acid plant. As expected, projected post-SPHC water level declines will be greatest in the south plant area and are expected to decrease overall to the north. Water level declines as of 9/13/12 have already dewatered some of the most highly contaminated soils in the acid plant area (see abandoned well DH-19, Figure 16), with additional water level declines expected in this area. As mentioned in the previous section, post-SPHC water levels in the northwest plant site will depend on the presence or absence of flow in Wilson Ditch in the future.

Figure 17 includes a cross section extending due north from Upper Lake through Lower Lake and the slag pile. In contrast to the significant drawdown projected in the south plant area, this figure also shows the lack of measured and projected groundwater drawdown on the east plant site beneath the slag pile. Also of note is the very steep hydraulic gradient between Lower Lake and well DH-4 to the immediate north. As previously mentioned, a zone of low permeability material is believed to be present in this area restricting northward flow from Lower Lake towards DH-4.

It should be noted that the projected water levels through the west side of the plant site and through the acid plant do not take into account potential effects of a low permeability zone or cutoff wall around the south plant area as proposed in the SPHC plans. Placement of a cutoff wall downgradient of the south plant could further reduce groundwater flow rates and water levels in the acid plant area depending on the system design, and on the magnitude of groundwater underflow from the Upper Lake area towards the plant site.

4.2 EFFECTS ON GROUNDWATER FLOW PATTERNS

In addition to changes in groundwater levels, potential alterations in groundwater flow patterns and rates have been evaluated from the preliminary drawdown test data. Figures 18 and 19 present the plant site groundwater potentiometric surface for October 2010 and July 24, 2012, respectively. Although the two maps show a similar overall pattern to the potentiometric surface, a few key differences are apparent. As expected, the most obvious differences occur in the south plant site. For instance, the 3920 foot potentiometric contour on the October 2010 map extends northward around the north shoreline of Upper Lake with the Upper Lake water level at 3920.6 feet (Figure 18). In July 2012 (Figure 19) the 3920 contour is located approximately 1700 feet further south. This change alone has resulted in a significant decrease in the hydraulic gradient through Tito Park and an apparent corresponding decrease in the groundwater flux.

Although much less dramatic, the potentiometric contours on the west plant site have also shifted southward from October 2010 to July 2012 due to the water level declines documented in this area. This pattern is evident in the 3900 and 3905 potentiometric contours. Although subtle, these patterns do reflect real changes in the acid plant area groundwater levels. Also of note is the lack of change in the potentiometric surface in the eastern portion of the plant site beneath the slag pile. This is consistent with previous observations suggesting relatively little change in groundwater levels in this area in response to the lake dewatering and creek lowering.

It should be noted that the July 2012 potentiometric surface only reflects the effects of partial dewatering of Upper Lake, and does not account for future creek lowering and placement of a low permeability zone downgradient of the south plant area. These components of the SPHC program will result in significant differences in the post-SPHC potentiometric surface as compared to the July 2012 surface. As previously noted, groundwater levels in the south plant area are expected to closely approximate the final creek levels following permanent lowering of the creek. This will effectively eliminate the northward "bulge" in the potentiometric surface caused by Upper and Lower Lake and the elevated creek level behind the smelter dam.

Another possible effect of the SPHC on plant site groundwater flow patterns is a more westward component of groundwater flow through the northern portion of the plant site. Currently, groundwater flows in a northwesterly direction beneath the slag pile and northwest portion of the site. With little impact expected for water levels in the eastern portion of the site and additional drawdown expected for the western portion of the site, groundwater flow in the north plant area may assume a more westerly orientation. Indications of an increased gradient towards the west can already be seen in the current drawdown test results. As shown on Figure 7, water level declines on the west plant site (see well DH-42, Figure 7), and the lack of response in well DH-68 located on the south portion of the slag pile, have resulted in a reversal in hydraulic gradients between these areas.

A third possible effect of the SPHC is a decrease in apparent westward flow from the south plant area towards the Phase I CAMU. Drawdown test water level trends at CAMU wells

MW-6, MW-2 and MW-3 correlate closely with those at south plant site monitoring well DH-20, while other CAMU wells (with the possible exception of MW-10) show no correlation. Figure 20 shows this relationship for select CAMU wells. Lowering the south plant groundwater levels should reduce or possibly eliminate potential westward flow in this area, depending on the post-SPHC groundwater levels on the south plant site.

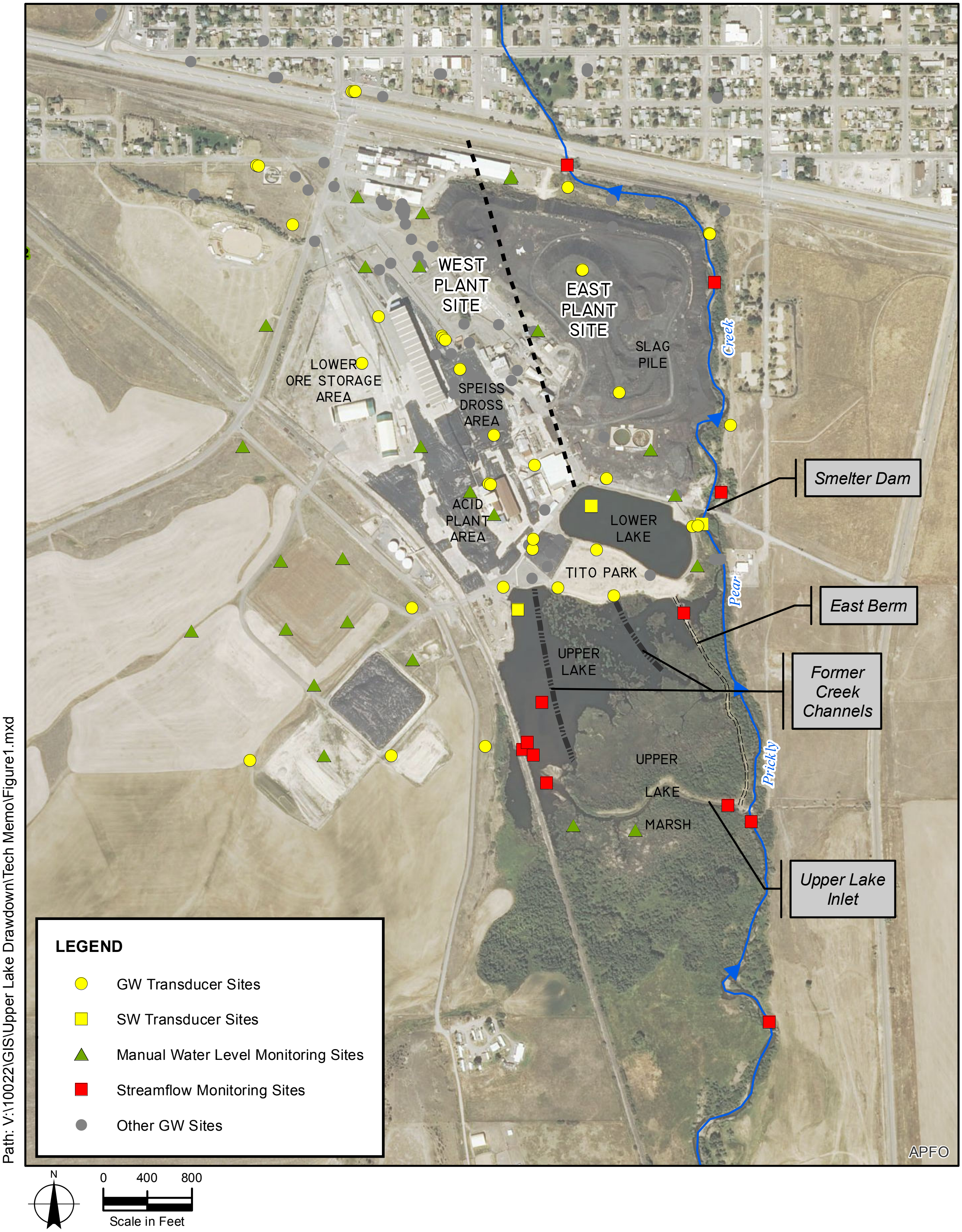
5.0 SUMMARY AND RECOMMENDATIONS

The Upper Lake drawdown test results to date show groundwater levels have declined on the order of 3 to 5 feet in the south, west and northwest plant areas, and less than a foot on the east side of the plant beneath the slag pile. As of mid-September, water levels continue to decline across the site. Water level declines of an additional five feet or more are expected in the south plant area in response to dewatering of Upper Lake and permanent lowering of Prickly Pear Creek under the SPHC project. The groundwater level declines already realized through the lake drawdown test have dropped the water table below the zone of highest soil contaminant levels in certain areas, with post-SPHC water level drawdown expected to further dewater contaminated soils in the south plant and acid plant areas. Lowering of the water table is not only expected to reduce contact between the plant site groundwater and soil contaminants, but should also reduce the rate of groundwater flow, or flux, through the plant site. Together, these two factors should result in a reduction of contaminant leaching to groundwater and contaminant loads, in pounds per day, emanating from the plant site.

Dewatering of Upper Lake/Lower Lake and lowering the Prickly Pear Creek level by approximately 8 feet at the current smelter dam location as proposed under the SPHC project will result in a more uniform potentiometric surface through the south plant area and eliminate the northward “bulge” in the potentiometric surface caused by Upper and Lower Lake. The result will be a reduction in seepage from the northwest portion of Upper Lake to the west plant site, and a reduction in seepage from the east and west ends of Lower Lake which currently provides recharge to Prickly Pear Creek and the west plant site, respectively. Other potential changes in the plant site groundwater flow patterns include an increased westerly component to groundwater flow in the northern portion of the site (due to greater effect on groundwater levels in the west plant area than the east), and a reduction in potential westward flow from the south plant site towards the Phase I CAMU cell. Effects on northwest plant site groundwater levels will depend in large part on future flow conditions in Wilson Ditch.

One outstanding question related to the Upper Lake drawdown test is the volume and fate of groundwater underflow beneath Upper Lake onto the plant site. The rate of groundwater underflow from beneath Upper Lake towards the plant site should be evaluated further to determine how this source may affect post-SPHC groundwater flow through the plant site. Depending on the results, appropriate measures could be incorporated into design of the low permeability zone/groundwater cutoff wall proposed in the SPHC to further reduce groundwater flow through the plant site, if necessary. Gaining a better understanding of this groundwater underflow component will also prove useful in assessing construction dewatering requirements for the SPHC.

Based on the findings to date, continuation of the pumping phase of the Upper Lake drawdown test through September 2012 is recommended. Continuing the test through September will provide a full year of drawdown test data, which will aid in discerning seasonal (and longer-term) water level trends from lake drawdown-induced effects. With cessation of pumping, the Upper Lake water level should recover from the current 3916 level to about 3918 feet. Plant site groundwater levels should be recorded during the lake recovery period to provide additional information on the groundwater response to lake dewatering. Groundwater level trends recorded during both the lake drawdown and recovery phase of the test will help delineate possible areas of increased permeability, preferential groundwater flow paths, and post-SPHC hydraulic gradients and groundwater fluxes through the site. Information presented in this memorandum can be updated following the water level recovery phase of the test. Based on information collected to date however, the Upper Lake drawdown test results indicate that the SPHC project will effectively lower plant site groundwater levels, thus reducing potential leaching of contaminants from soils to groundwater, and will most likely reduce overall groundwater flow rates through the plant site.



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**PRIMARY SITE FEATURES
FOR UPPER LAKE DRAWDOWN TEST
EAST HELENA FACILITY**

FIGURE

1

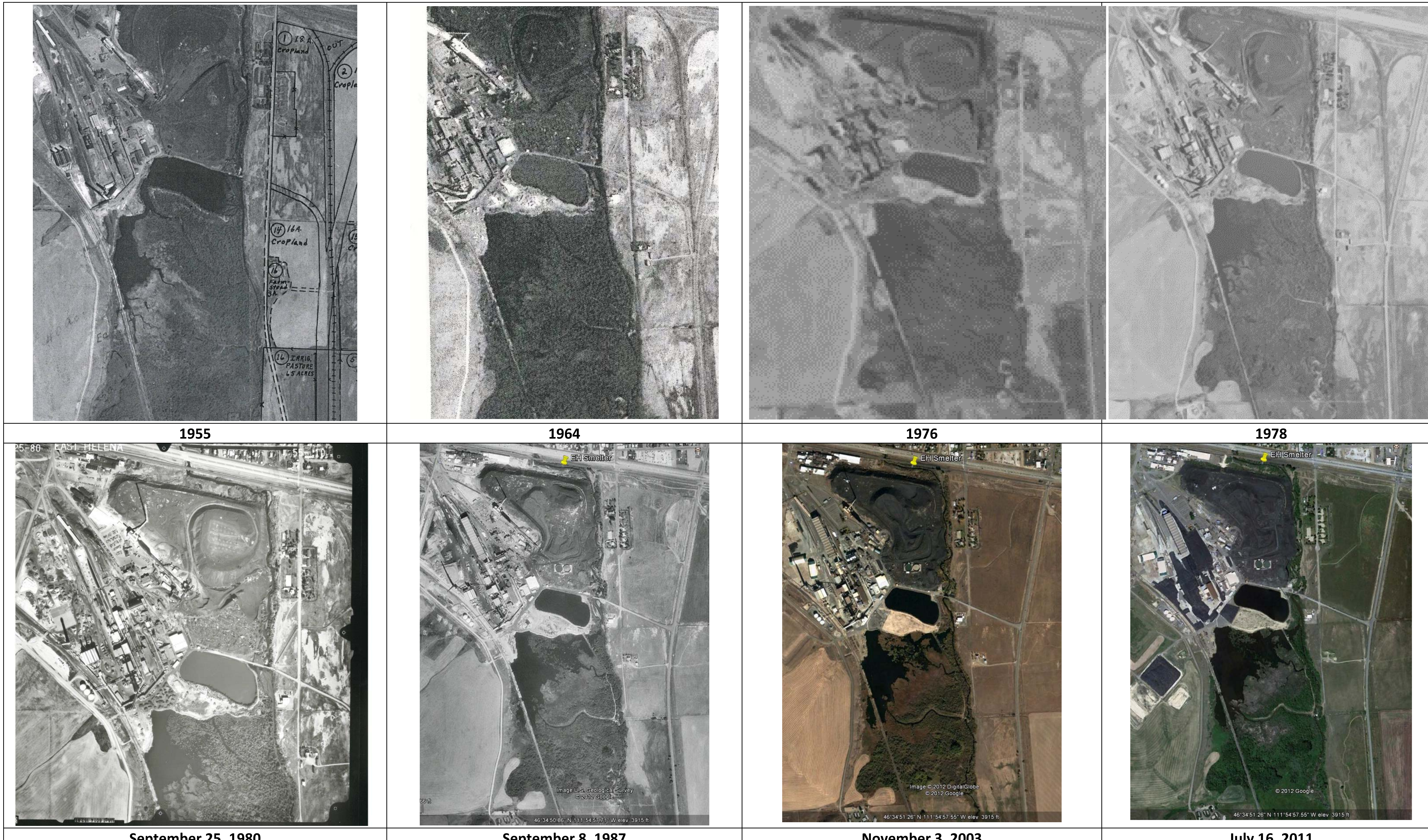
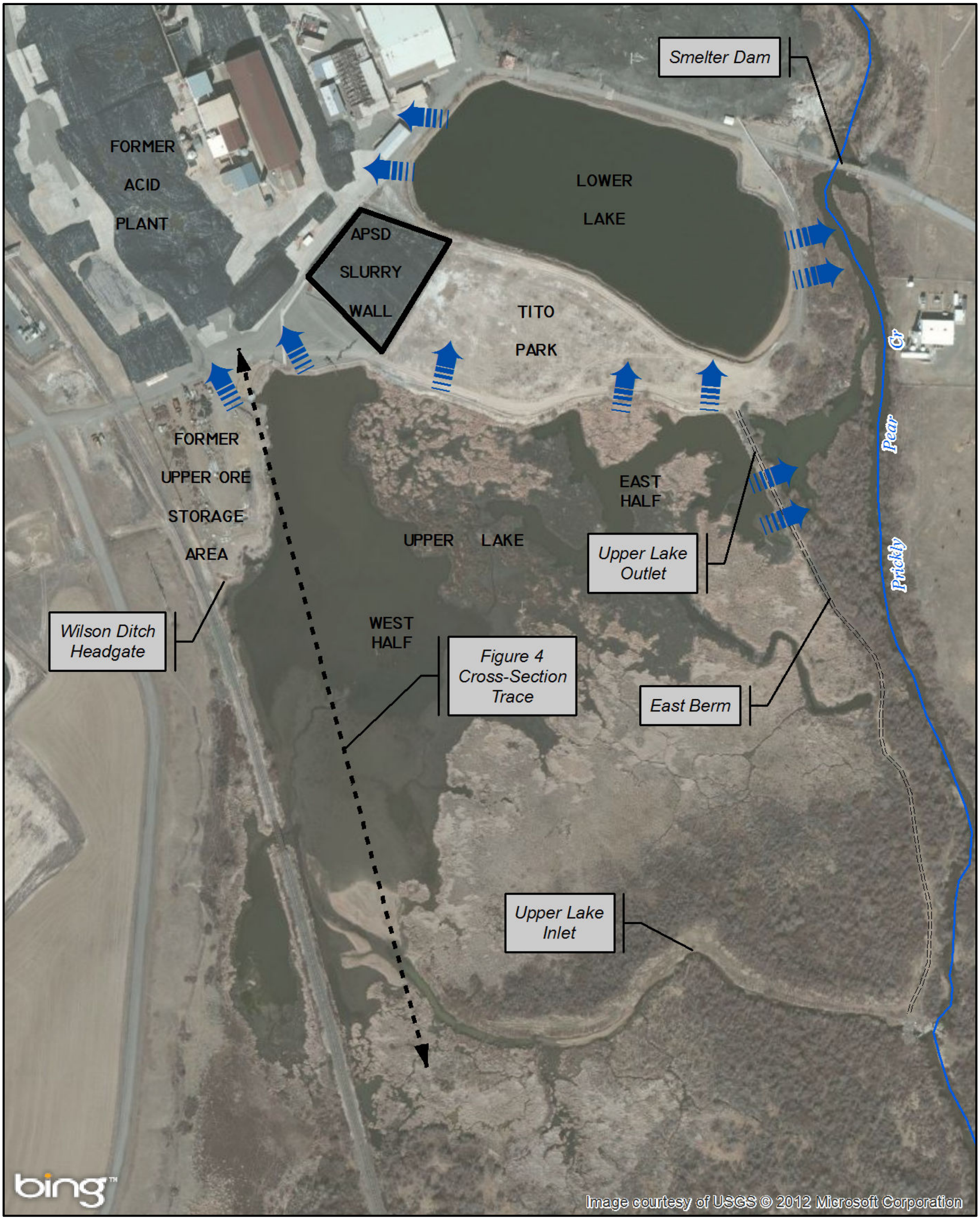


FIGURE 2. PROGRESSION OF UPPER LAKE EXPANSION SINCE 1955.



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N

0 150 300

Scale in Feet

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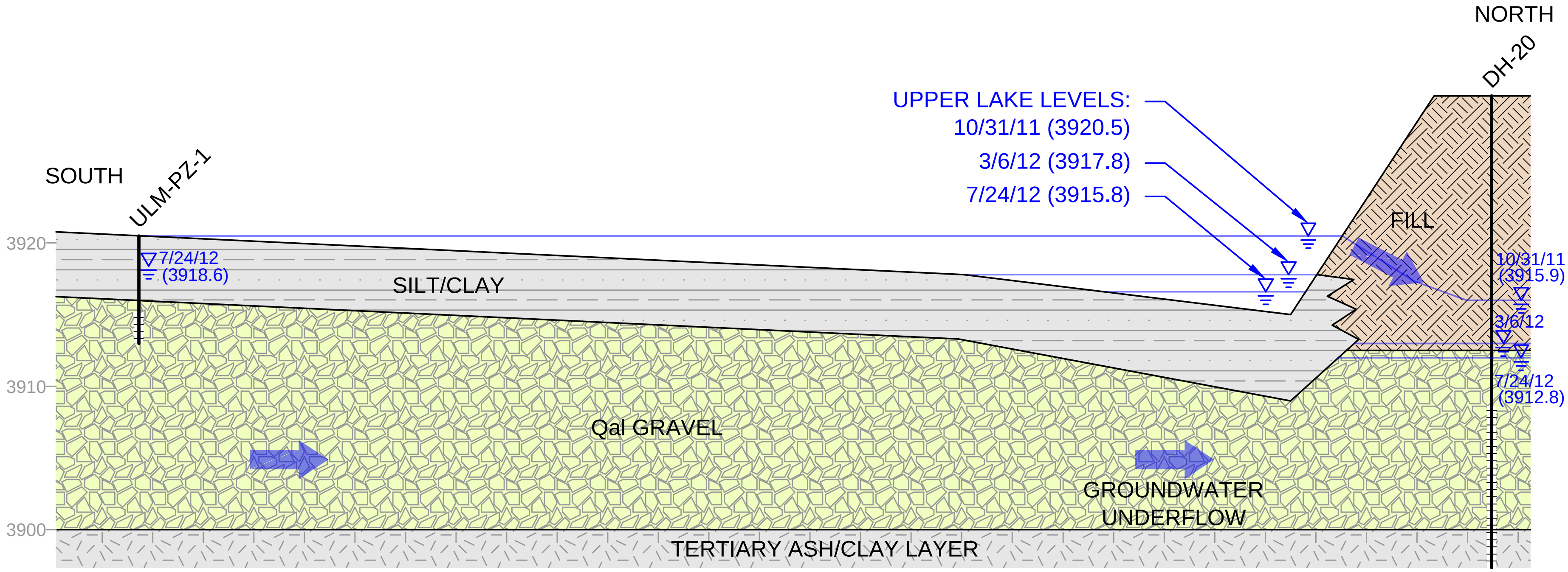
PRIMARY UPPER (AND LOWER) LAKE LEAKAGE PATHWAYS
AT MAXIMUM LAKE LEVELS
EAST HELENA FACILITY

FIGURE
3



LEGEND

- FILL
- SILT/CLAY
- GRAVEL/COBBLE
- ASH/CLAY

GROUNDWATER FLOW DIRECTION

HORIZONTAL SCALE 1"=200'

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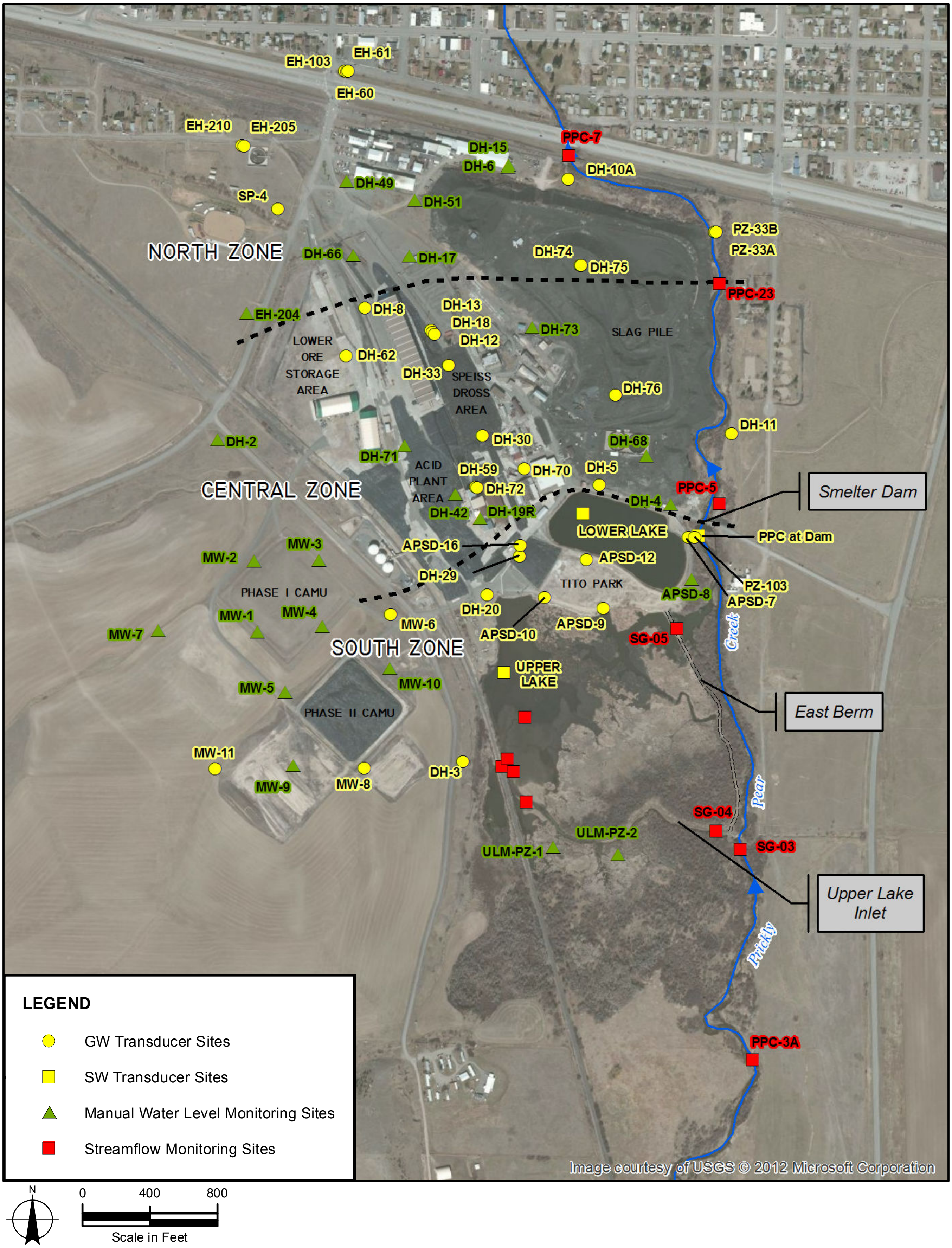
SCHEMATIC CROSS SECTION THROUGH UPPER LAKE - WEST HALF

FIGURE **4**



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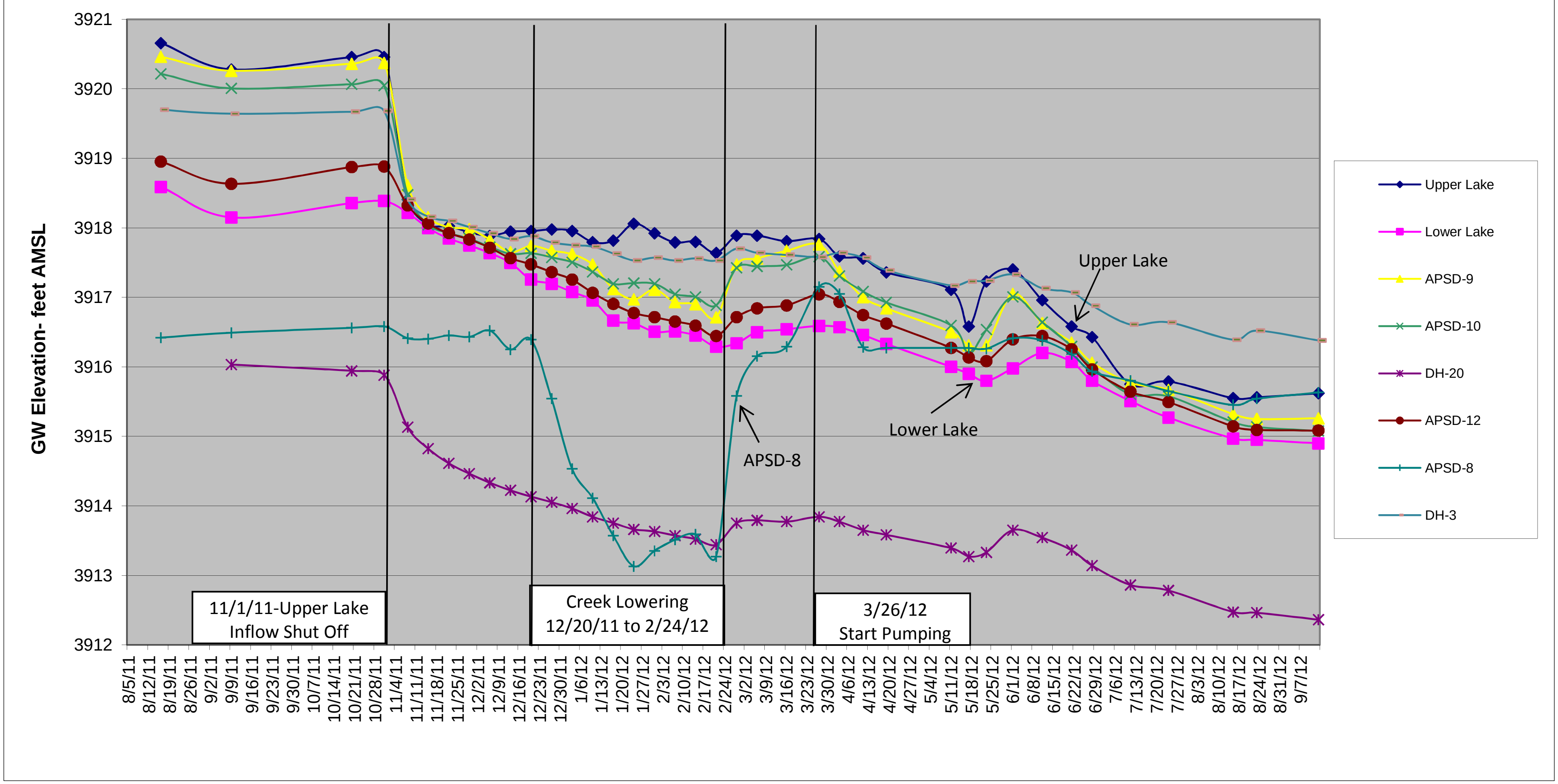
WATER LEVEL MONITORING SITES
FOR UPPER LAKE DRAWDOWN TEST
EAST HELENA FACILITY

FIGURE

5

Figure 6. South Plant Site Groundwater Levels



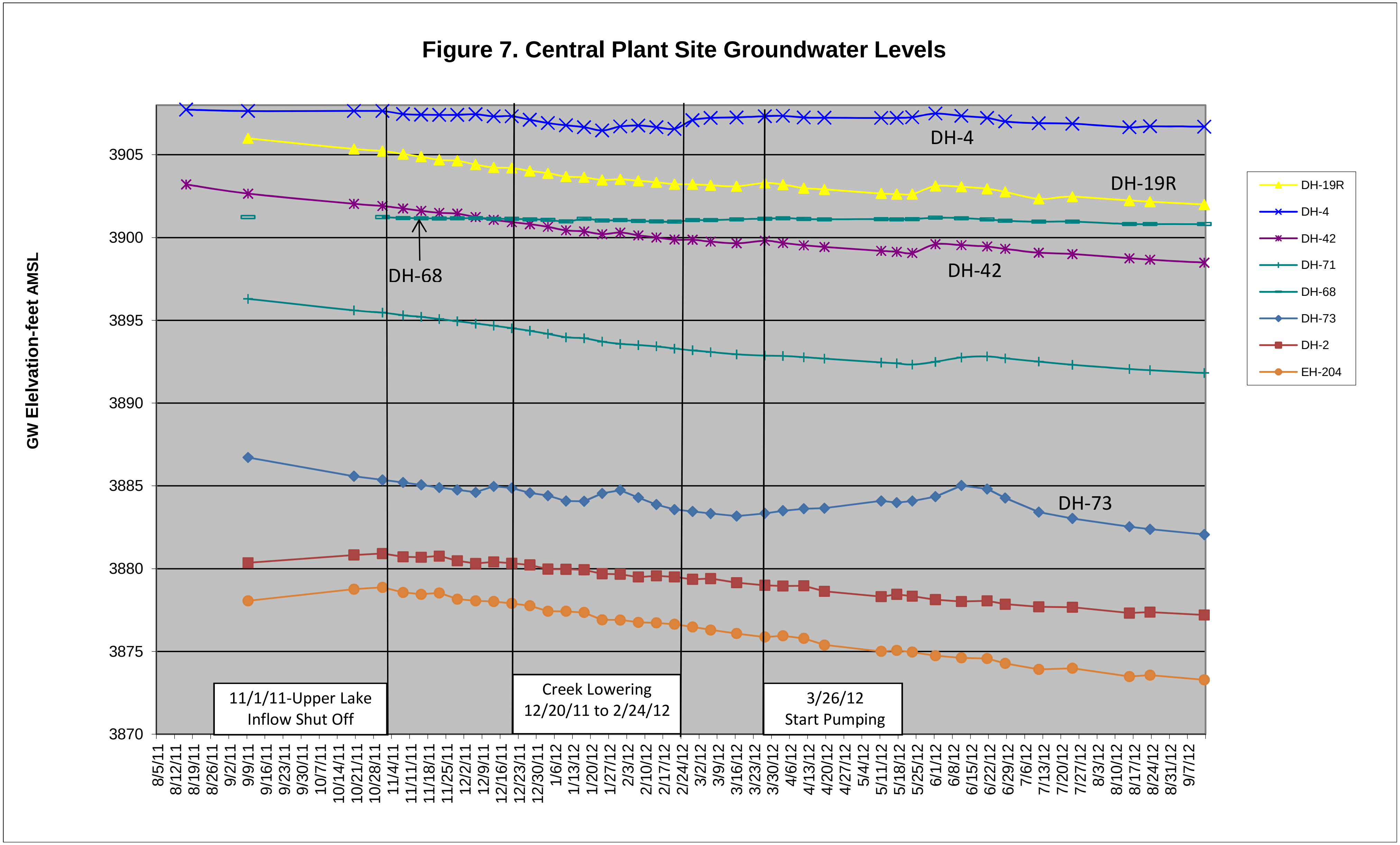


Figure 7. Central Plant Site Groundwater Levels
GW Elevation-feet AMSL
3905
3900
3895
3890
3885
3880
3875
3870
DH-4
DH-19R
DH-68
DH-42
DH-73
11/1/11-Upper Lake Inflow Shut Off
Creek Lowering 12/20/11 to 2/24/12
3/26/12 Start Pumping
DH-19R
DH-4
DH-42
DH-71
DH-68
DH-73
DH-2
EH-204
8/5/11
8/12/11
8/19/11
8/26/11
9/2/11
9/9/11
9/16/11
9/23/11
9/30/11
10/7/11
10/14/11
10/21/11
10/28/11
11/4/11
11/11/11
11/18/11
11/25/11
12/2/11
12/9/11
12/16/11
12/23/11
12/30/11
1/6/12
1/13/12
1/20/12
1/27/12
2/3/12
2/10/12
2/17/12
2/24/12
3/2/12
3/9/12
3/16/12
3/23/12
3/30/12
4/6/12
4/13/12
4/20/12
4/27/12
5/4/12
5/11/12
5/18/12
5/25/12
6/1/12
6/8/12
6/15/12
6/22/12
6/29/12
7/6/12
7/13/12
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8/10/12
8/17/12
8/24/12
8/31/12
9/7/12

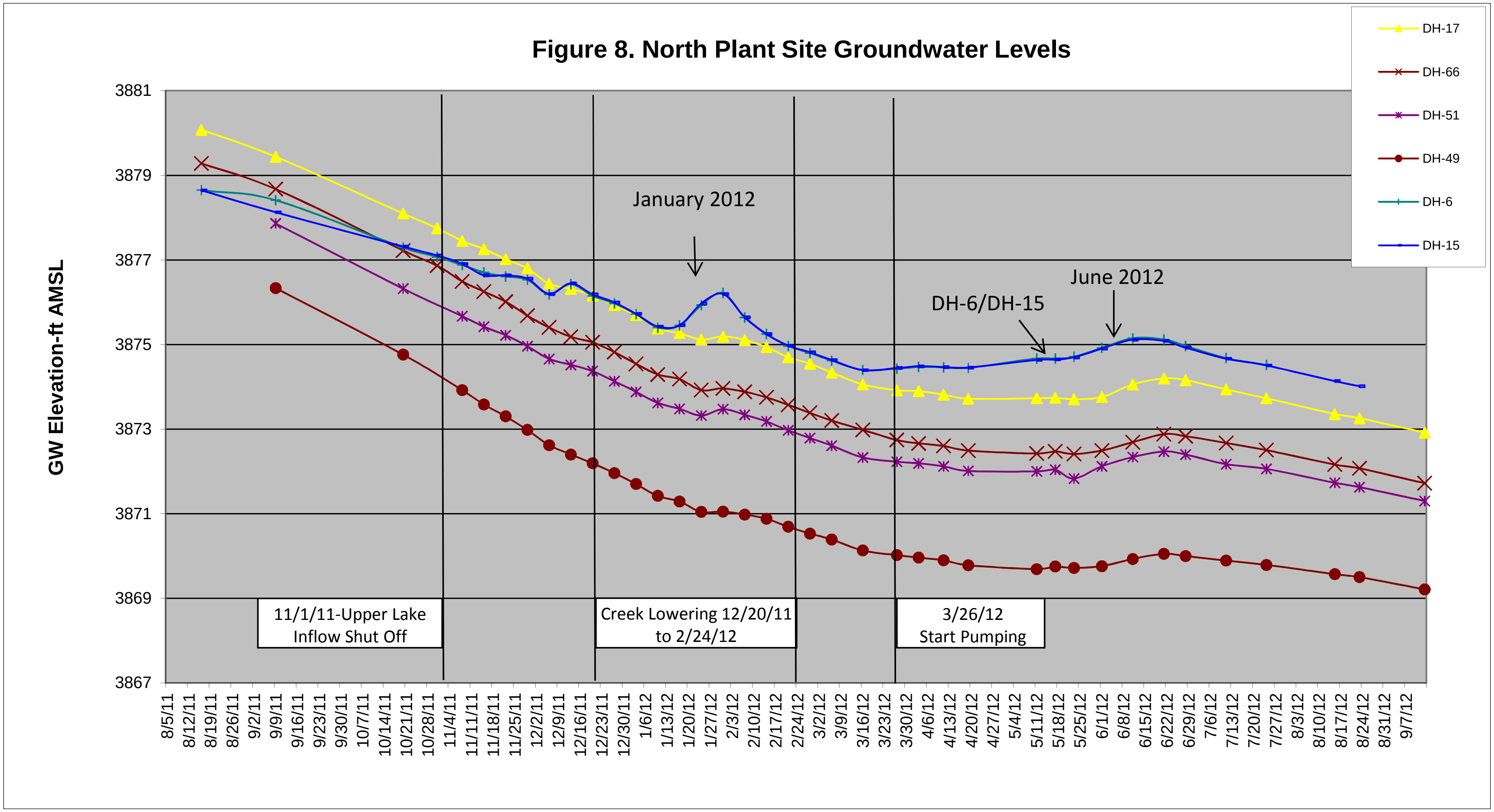


Figure 8. North Plant Site Groundwater Levels
GW Elevation-ft AMSL
3881
3879
3877
3875
3873
3871
3869
3867
DH-17
DH-66
DH-51
DH-49
DH-6
DH-15
January 2012
June 2012
DH-6/DH-15
11/1/11-Upper Lake Inflow Shut Off
Creek Lowering 12/20/11 to 2/24/12
3/26/12 Start Pumping
8/5/11
8/12/11
8/19/11
8/26/11
9/2/11
9/9/11
9/16/11
9/23/11
9/30/11
10/7/11
10/14/11
10/21/11
10/28/11
11/4/11
11/11/11
11/18/11
11/25/11
12/2/11
12/9/11
12/16/11
12/23/11
12/30/11
1/6/12
1/13/12
1/20/12
1/27/12
2/3/12
2/10/12
2/17/12
2/24/12
3/2/12
3/9/12
3/16/12
3/23/12
3/30/12
4/6/12
4/13/12
4/20/12
4/27/12
5/4/12
5/11/12
5/18/12
5/25/12
6/1/12
6/8/12
6/15/12
6/22/12
6/29/12
7/6/12
7/13/12
7/20/12
7/27/12
8/3/12
8/10/12
8/17/12
8/24/12
8/31/12
9/7/12

Figure 9. Long-Term Seasonal Trends in Select North Plant Site Wells

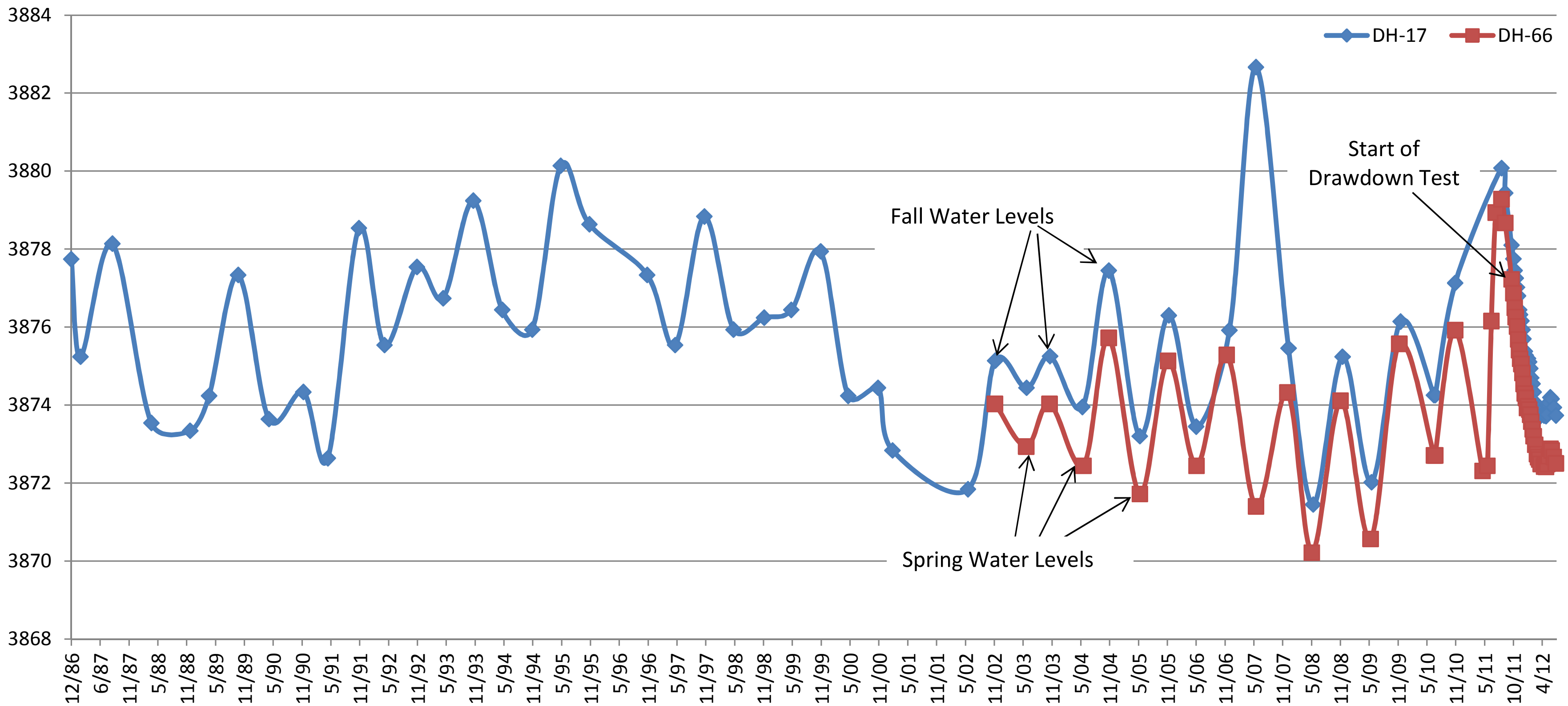
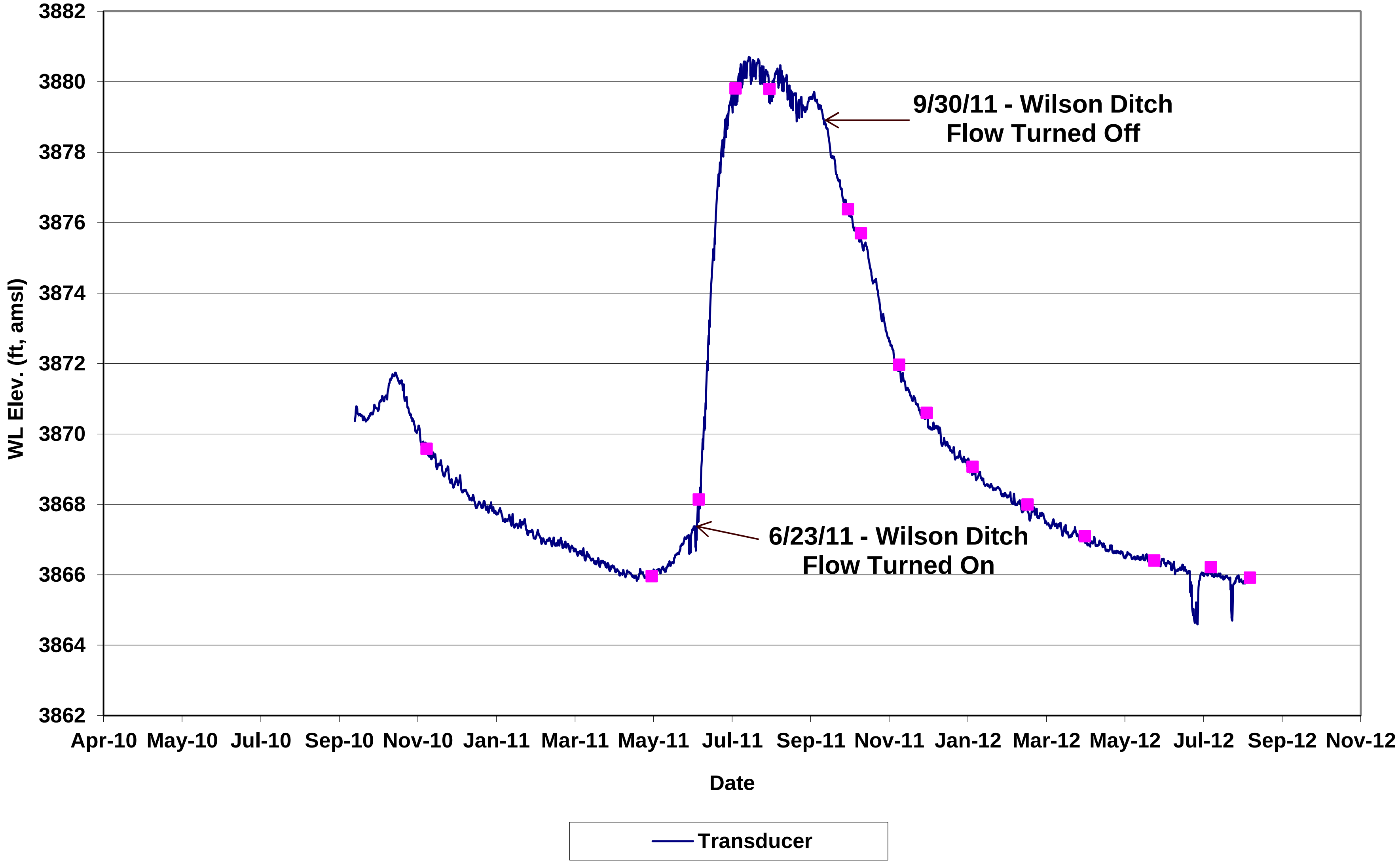


FIGURE 10. CONTINUOUS WATER LEVEL HYDROGRAPH FOR MONITORING WELL EH-210



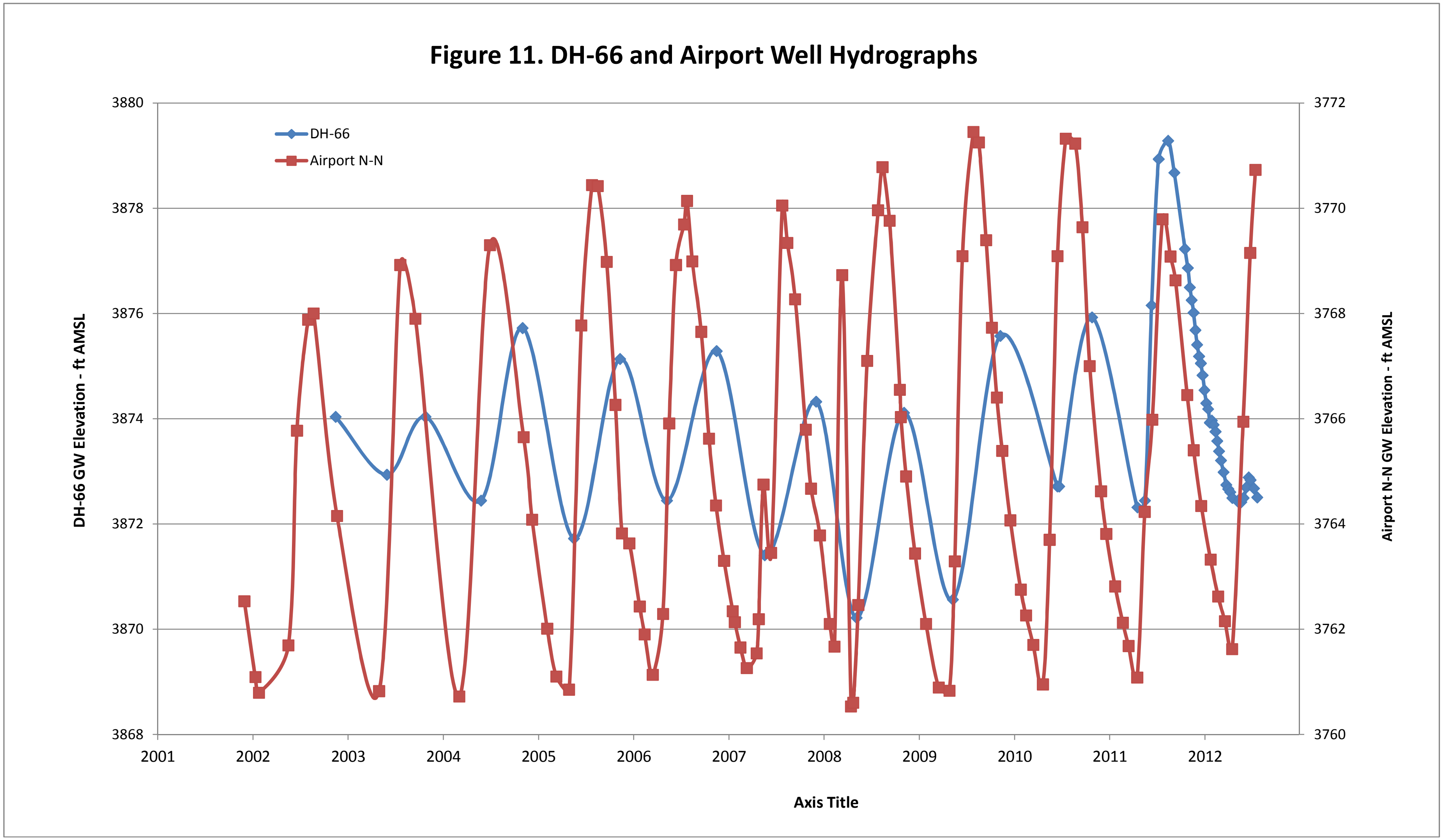
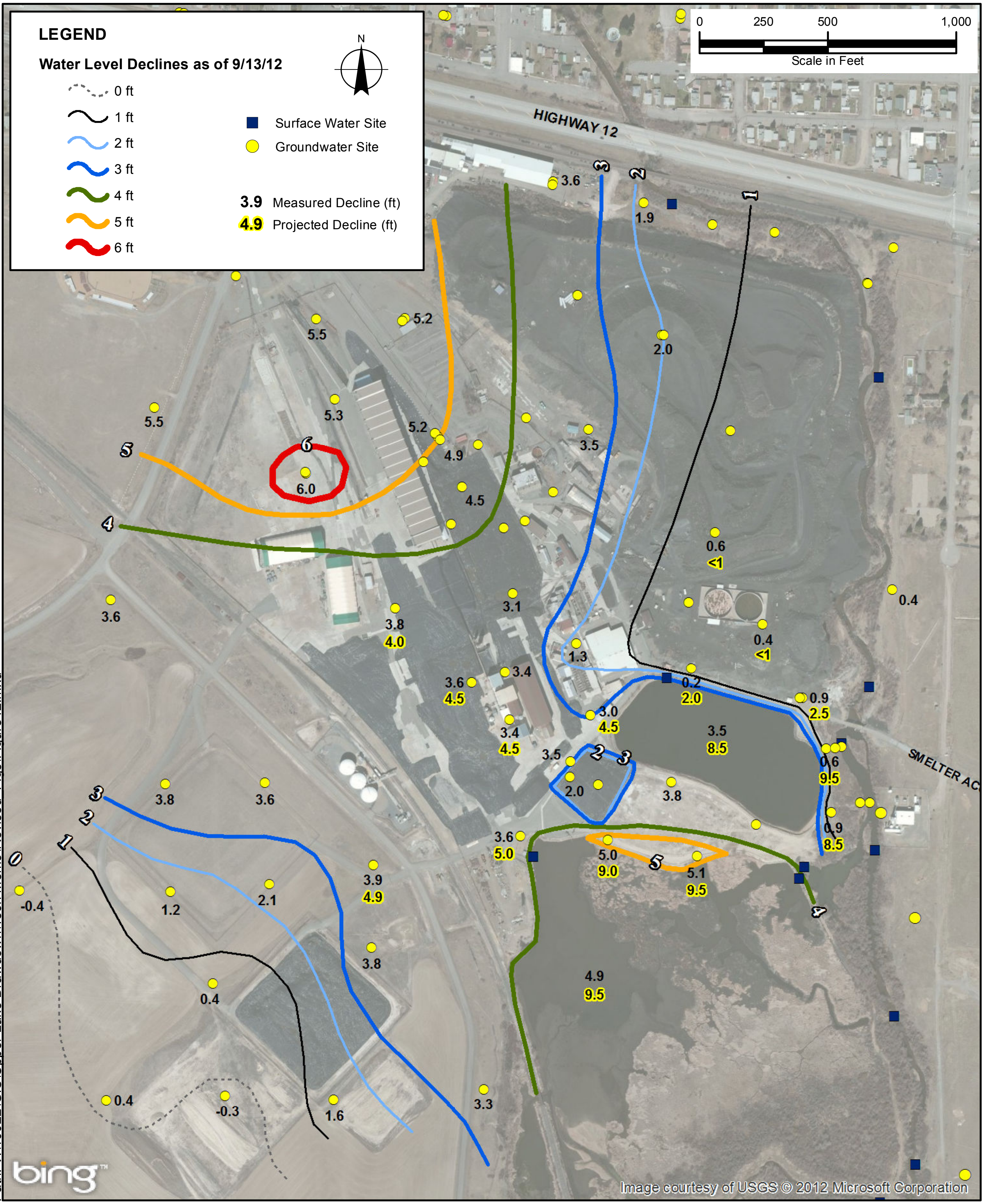


Figure 11. DH-66 and Airport Well Hydrographs
DH-66
Airport N-N
DH-66 GW Elevation - ft AMSL
Airport N-N GW Elevation - ft AMSL
Axis Title
3880
3878
3876
3874
3872
3870
3868
3772
3770
3768
3766
3764
3762
3760
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



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MEASURED WATER LEVEL DECLINES AS OF 9/13/12 AND PROJECTED DECLINES WITH PERMANENT CREEK LOWERING AND UPPER LAKE REMOVAL
UPPER LAKE DRAWDOWN TEST - EAST HELENA FACILITY

FIGURE
12

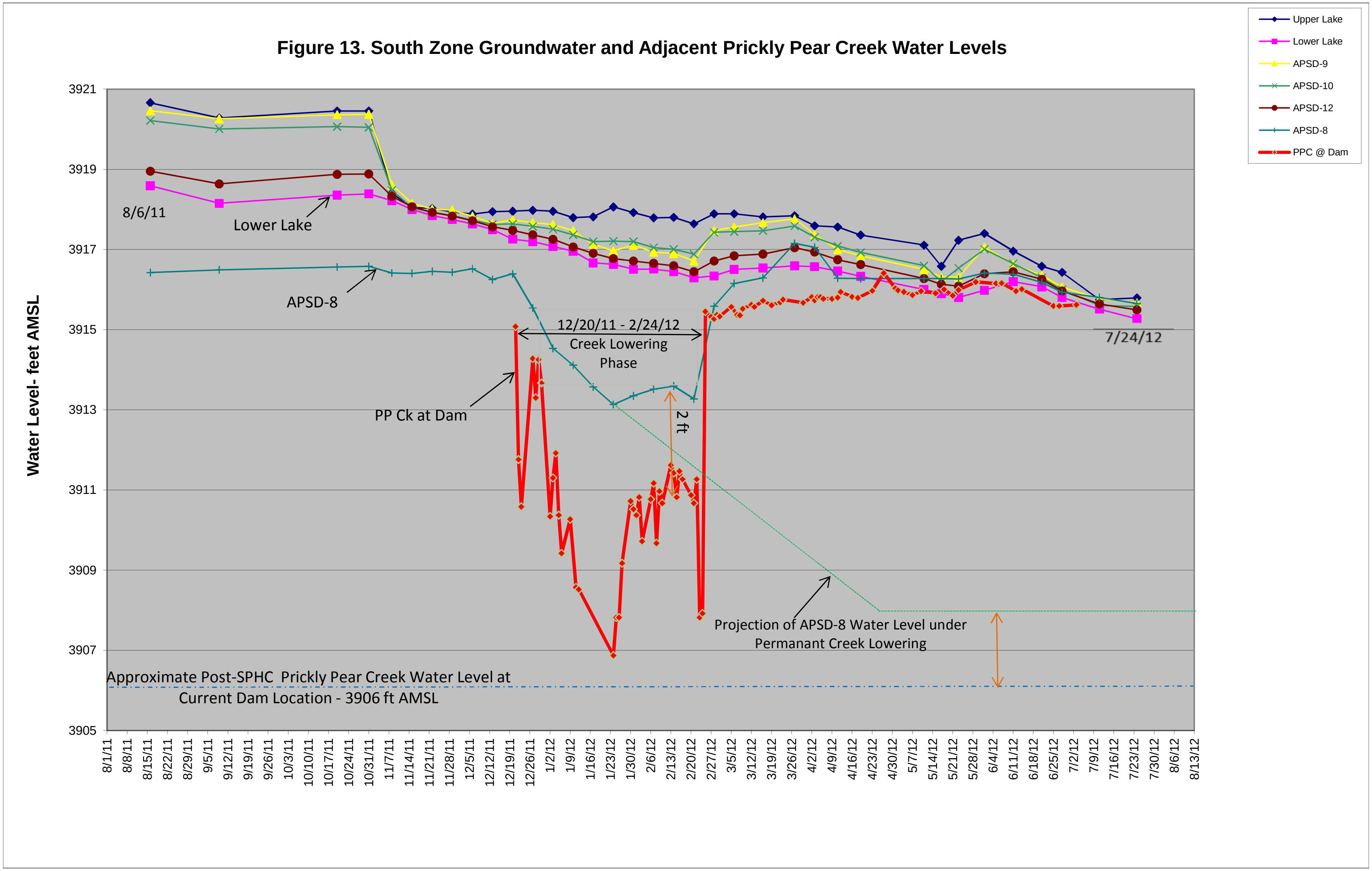

Figure 13. South Zone Groundwater and Adjacent Prickly Pear Creek Water Levels
Upper Lake
Lower Lake
APSD-9
APSD-10
APSD-12
APSD-8
PPC @ Dam
Water Level- feet AMSL
3921
3919
3917
3915
3913
3911
3909
3907
3905
8/6/11
Lower Lake
APSD-8
12/20/11 - 2/24/12
Creek Lowering
Phase
PP Ck at Dam
2 ft
7/24/12
Projection of APSD-8 Water Level under
Permanant Creek Lowering
Approximate Post-SPHC Prickly Pear Creek Water Level at
Current Dam Location - 3906 ft AMSL
8/1/11
8/8/11
8/15/11
8/22/11
8/29/11
9/5/11
9/12/11
9/19/11
9/26/11
10/3/11
10/10/11
10/17/11
10/24/11
10/31/11
11/7/11
11/14/11
11/21/11
11/28/11
12/5/11
12/12/11
12/19/11
12/26/11
1/2/12
1/9/12
1/16/12
1/23/12
1/30/12
2/6/12
2/13/12
2/20/12
2/27/12
3/5/12
3/12/12
3/19/12
3/26/12
4/2/12
4/9/12
4/16/12
4/23/12
4/30/12
5/7/12
5/14/12
5/21/12
5/28/12
6/4/12
6/11/12
6/18/12
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7/30/12
8/6/12
8/13/12

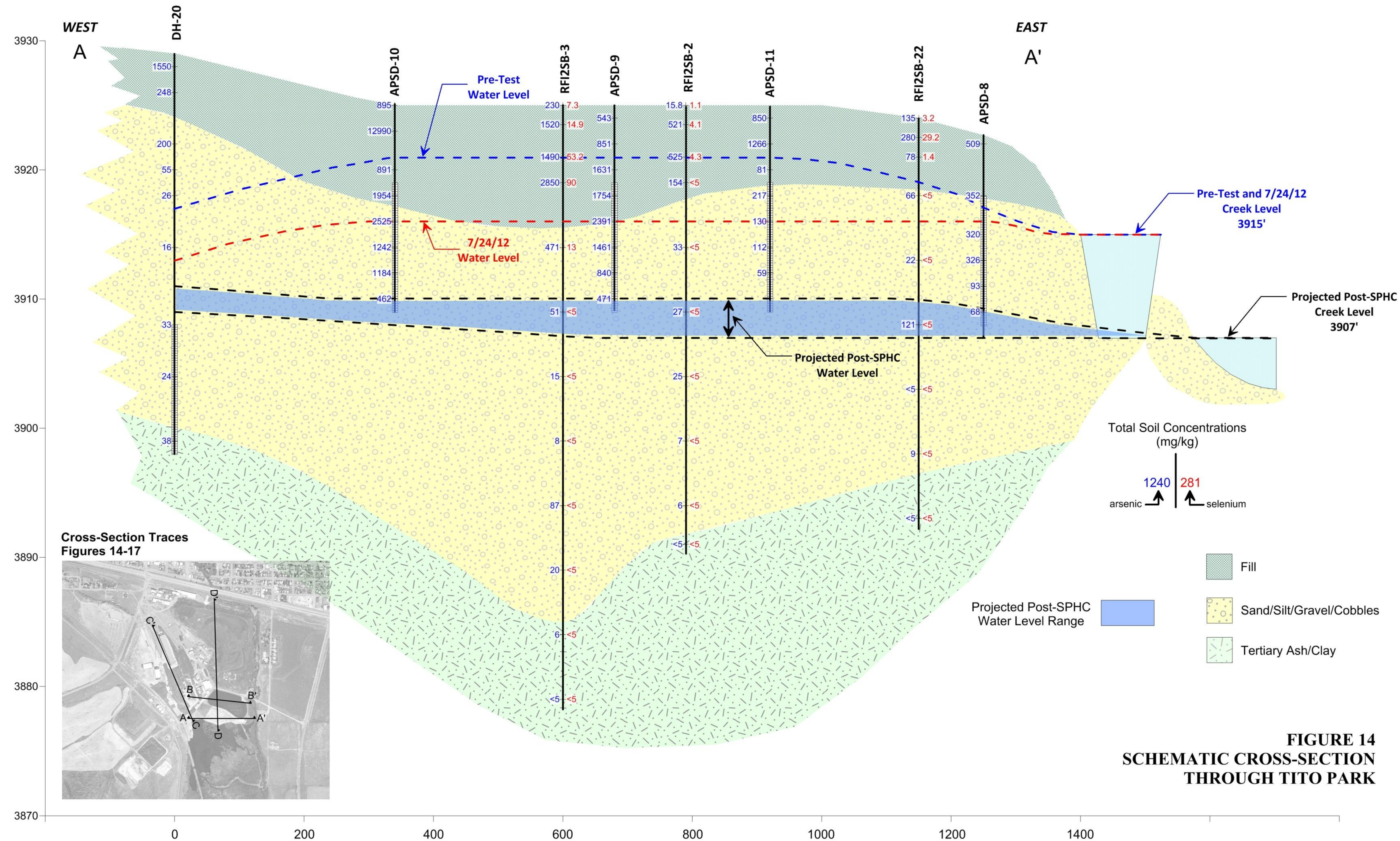

FIGURE 14
SCHEMATIC CROSS-SECTION
THROUGH TITO PARK

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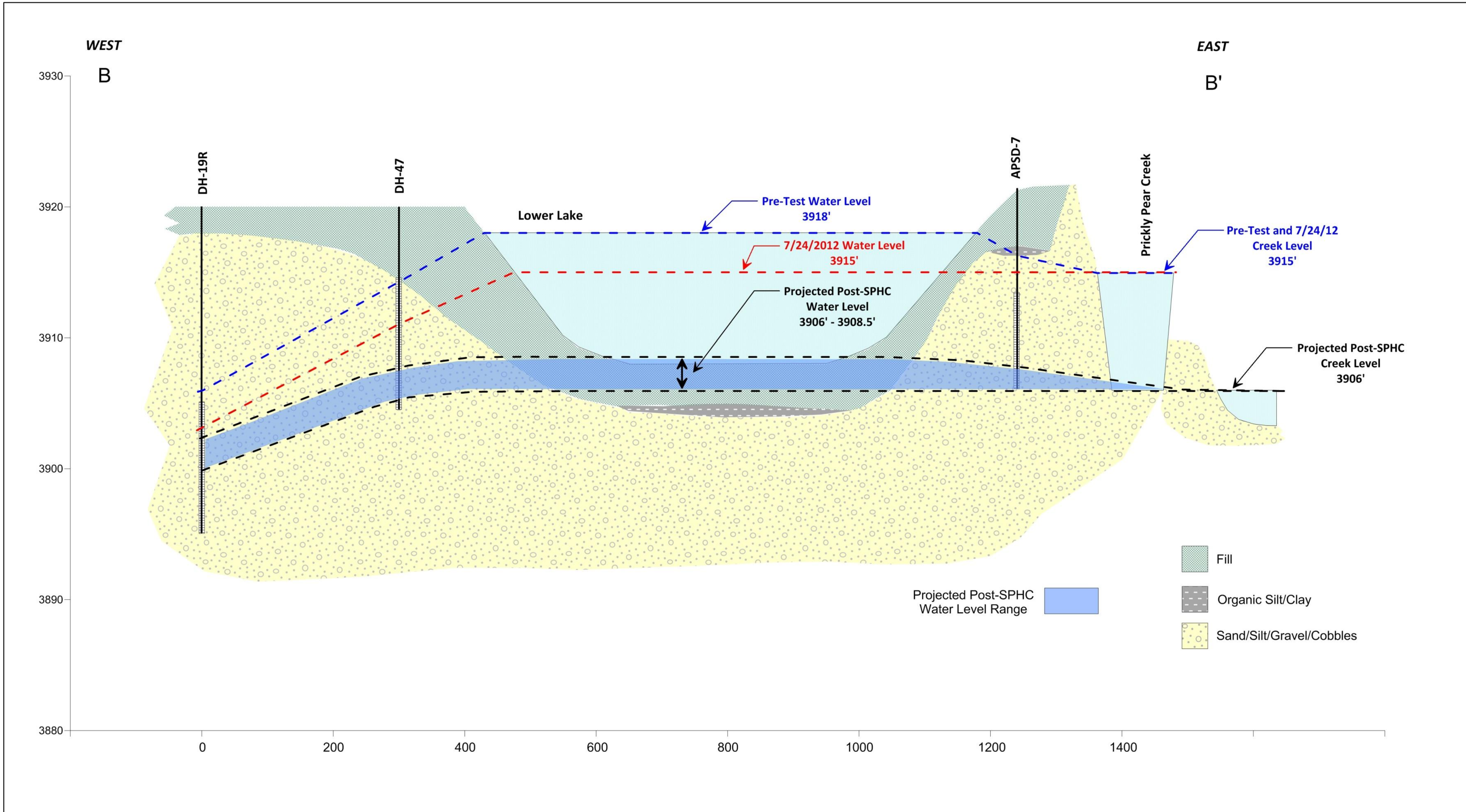

FIGURE 15
SCHEMATIC CROSS-SECTION THROUGH LOWER LAKE

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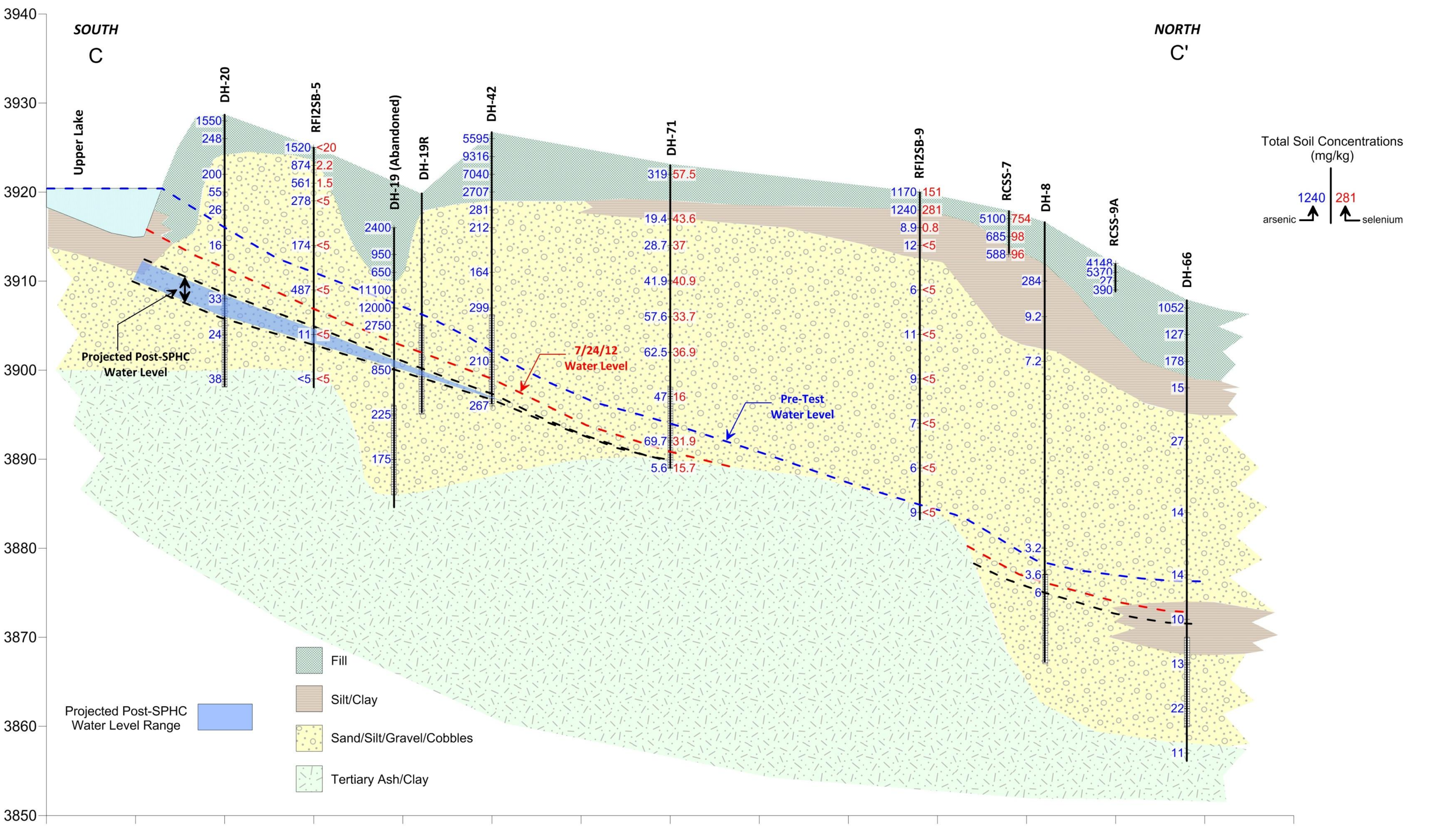


K:/PROJECT/12015/CSMs/Tito Park-UOS-LLake/ulake_northwest_xsec.srf

FIGURE 16
SCHEMATIC CROSS-SECTION
UPPER LAKE NORTHWEST
THROUGH WEST SE/LOSA AREA

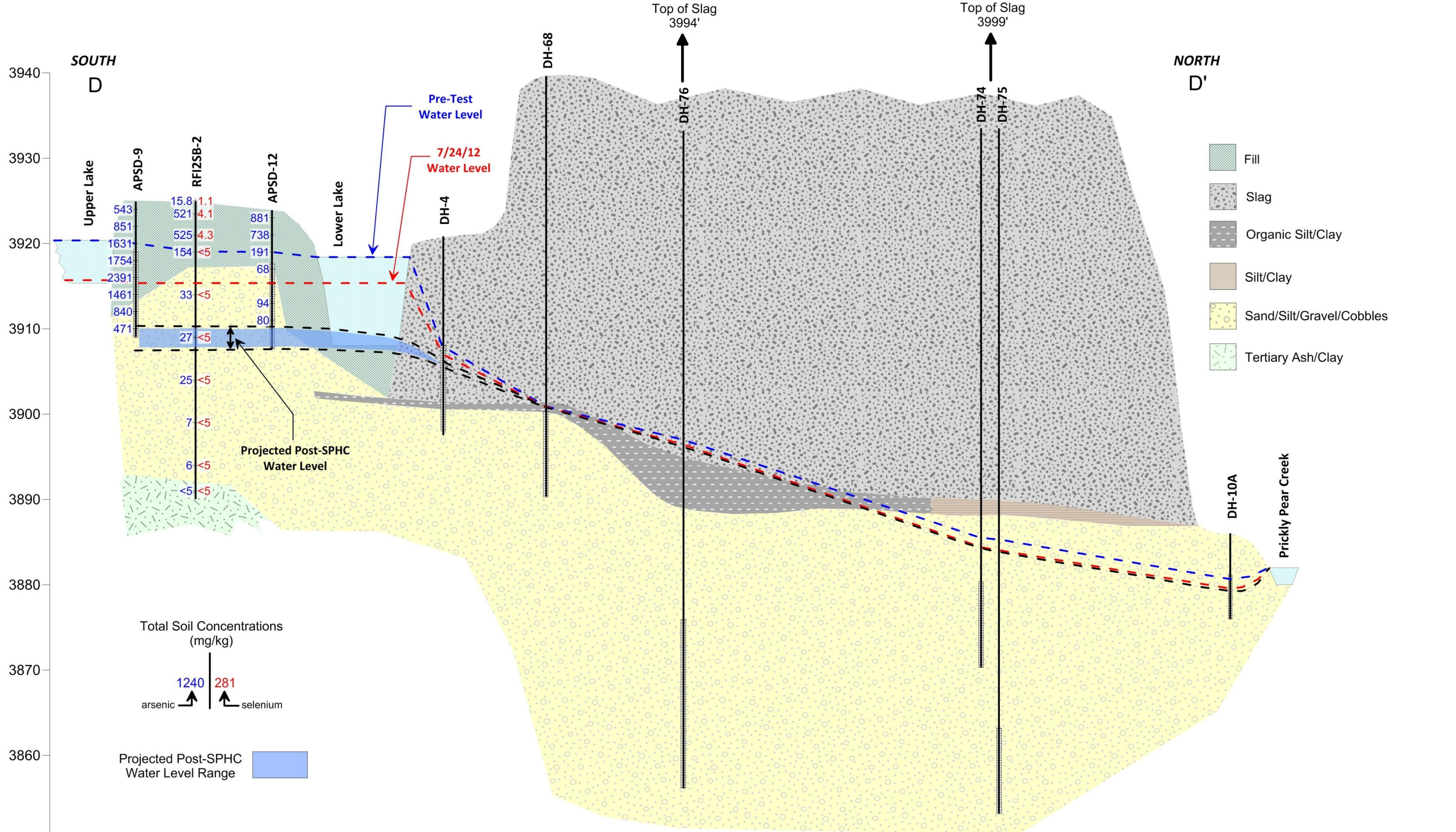
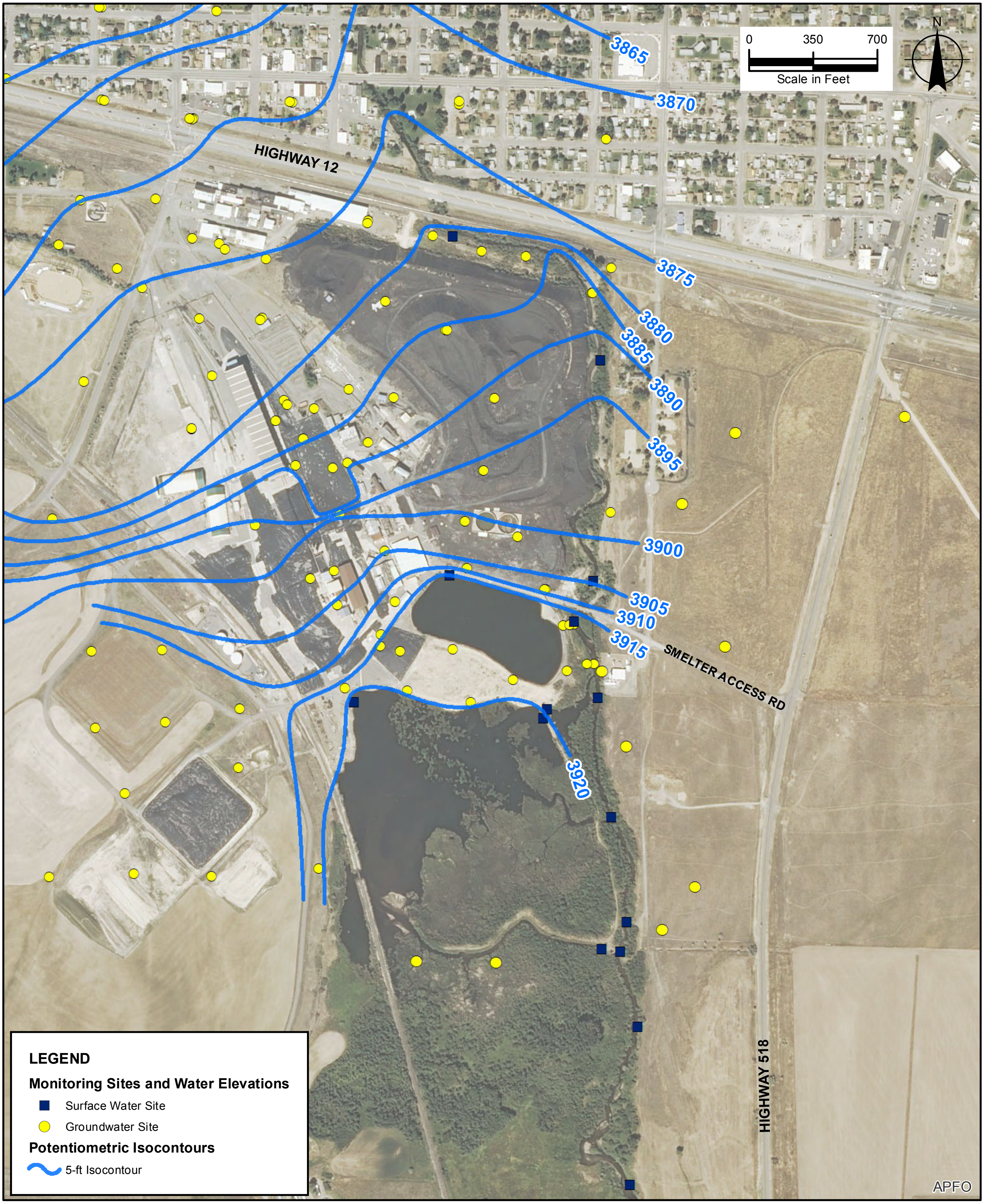


FIGURE 17
SCHEMATIC CROSS-SECTION
UPPER LAKE NORTH
THROUGH SLAG PILE

K:/PROJECT/12015/CSMs/Tito Park-UOS-LLake/ulake_north_xsec.srf



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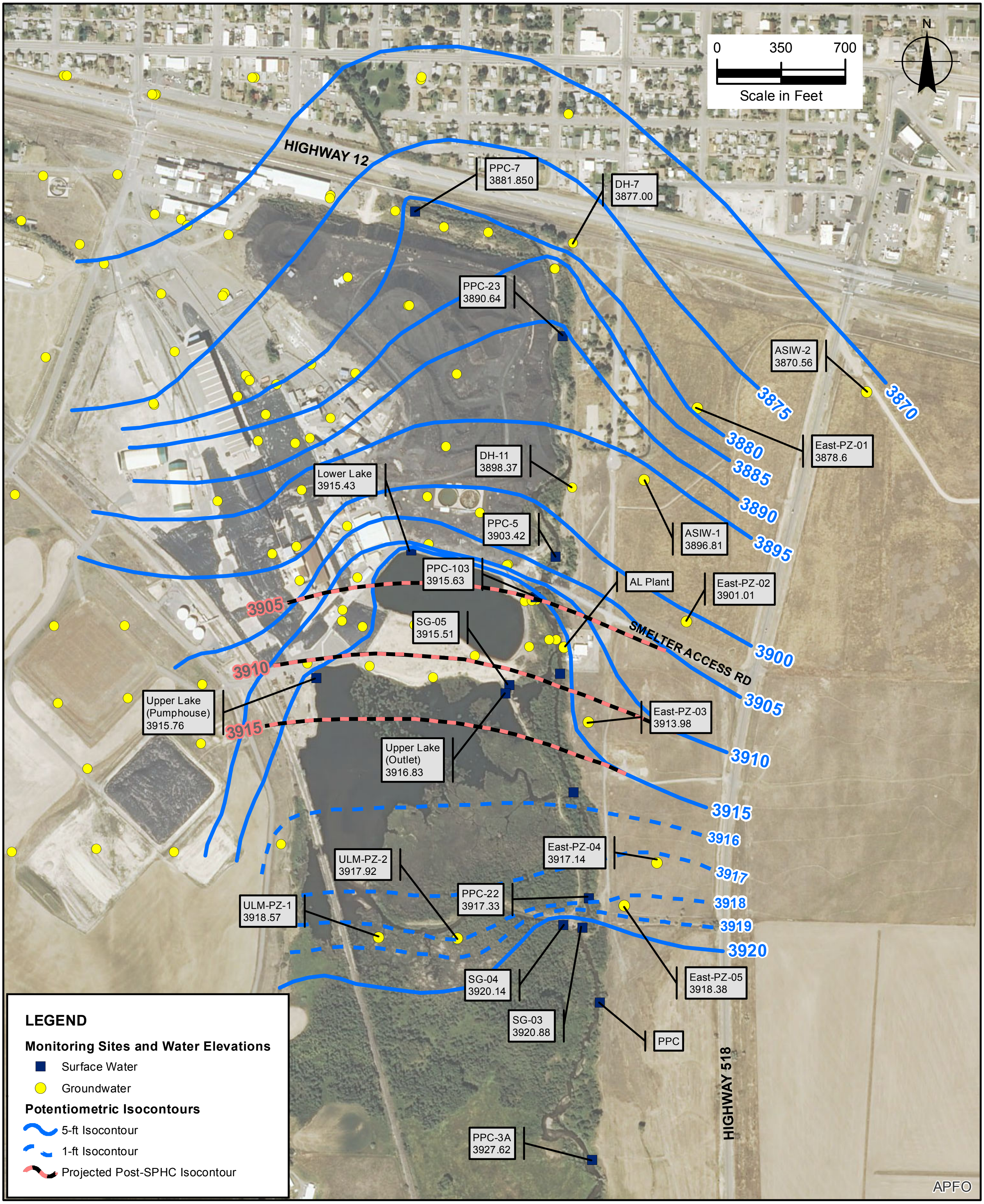
OCTOBER 2010 POTENTIOMETRIC MAP
UPPER LAKE DRAWDOWN TEST
EAST HELENA FACILITY

FIGURE

18



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JULY 24, 2012 POTENTIOMETRIC MAP
UPPER LAKE DRAWDOWN TEST
EAST HELENA FACILITY

FIGURE
19

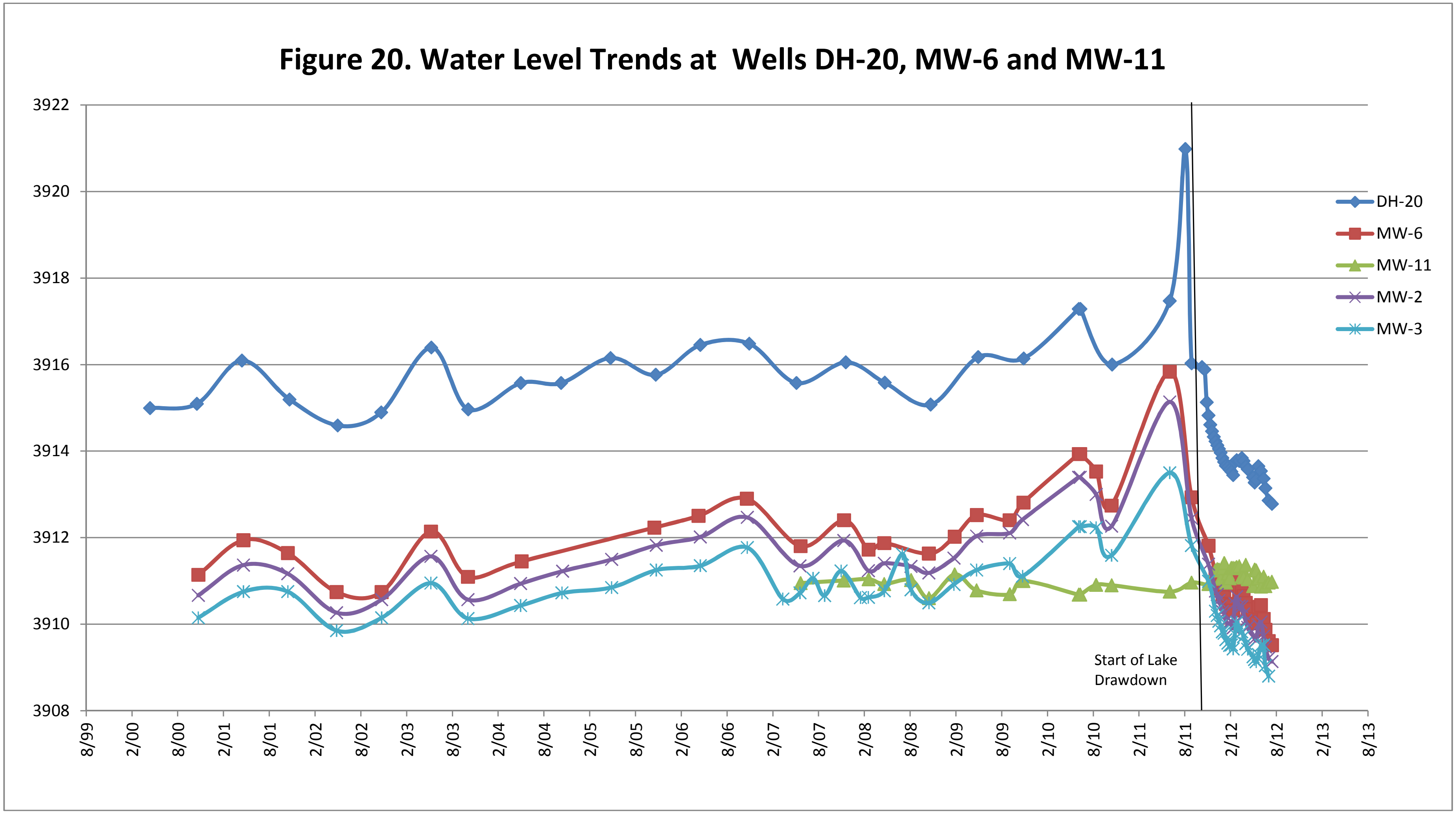

Figure 20. Water Level Trends at Wells DH-20, MW-6 and MW-11
3922
3920
3918
3916
3914
3912
3910
3908
8/99
2/00
8/00
2/01
8/01
2/02
8/02
2/03
8/03
2/04
8/04
2/05
8/05
2/06
8/06
2/07
8/07
2/08
8/08
2/09
8/09
2/10
8/10
2/11
8/11
2/12
8/12
2/13
8/13
DH-20
MW-6
MW-11
MW-2
MW-3
Start of Lake
Drawdown