TECHNICAL MEMORANDUM

Pump Down Program Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

PREPARED FOR:	Tyco Fire Products LP
COPY TO:	U.S. Environmental Protection Agency Wisconsin Department of Natural Resources
PREPARED BY:	CH2M HILL, Inc.
DATE:	January 12, 2018
DOCUMENT CONTROL NO.:	690992.258

On behalf of Tyco Fire Products LP (Tyco), CH2M HILL, Inc. prepared this Pump Down Program (PDP) Work Plan (work plan) in response to the U.S. Environmental Protection Agency (USEPA) November 28, 2017 letter and discussions during the December 20, 2017 meeting with USEPA and Wisconsin Department of Natural Resources (WDNR) representatives. This work plan presents the approach to complete the following items identified by USEPA for the PDP at the Tyco facility located at One Stanton Street, Marinette, Wisconsin (site; Figure 1).

- Analyze the source(s) of groundwater infiltration into the former Salt Vault (SV) and former 8th Street Slip (8SS)
- Reduce groundwater recharge to the former SV and former 8SS throughout the winter
- Resume aggressive pumping by April 15, 2018
- Achieve target elevation[1] no later than May 31, 2018
- Maintain target elevation[1] thereafter
- Schedule to meet the above

Pending approval of this work plan, activities are moving forward to meet the schedule as proposed in Section 6. This work plan includes project background information, PDP status, groundwater infiltration analysis, PDP alternatives evaluation, a summary of the work plan elements, and a summary schedule.

1.0 Background

In 1990, an Administrative Order on Consent (AOC) was entered into between Ansul (now Tyco) and USEPA. The AOC required Tyco to perform a Resource Conservation and Recovery Act facility investigation and corrective measures study. Numerous investigations were conducted to evaluate the extent of soil, sediment, and groundwater at and around the site. A result of the investigation was that an interim action was conducted at the location of the former SV and former 8SS. At the time of the interim action, the former SV area consisted of a concrete-based structure with concrete walls extending approximately 4 feet above the base. The approximate dimensions of the structure were 300 feet by 300 feet. Exposed soil and grassy areas surrounded the former SV structure on all sides.

[1] As discussed during the December 20, 2017 meeting with USEPA and in Section 5.4 below, use of a rolling target elevation based on actual measured river elevations instead of the fixed target elevation will be evaluated as a means to achieve the goal of eliminating the potential for outward migration of arsenic-containing groundwater while potentially reducing PDP extraction rates and achieving environmental protectiveness goals with greater sustainability.

The 8SS, a former logging slip, was open to the Menominee River at the northern end and had approximate dimensions of 700 feet long (north-south) and 75 to 125 feet wide. Exposed soil, grass, trees, and shrubs surrounded the former 8SS.

The required components of the interim action were conducted during 1998 and 1999 and included installing a coffer dam at the mouth of the former 8SS followed by installing a sheet pile wall surrounding the former 8SS area (to the top of bedrock approximately 40 feet below surface grade), a sheet pile wall along the northern portion of the former SV (to the top of bedrock), and a vibrated-beam slurry wall adjacent to the western and southern walls of the former SV from near ground surface to the top of bedrock. The slurry wall was connected to the sheet pile wall at the northern and eastern ends of the slurry wall. In addition, soft sediments were hydraulically dredged from the former 8SS, treated on the former SV (which had been covered with asphalt before sediment remediation work activities) and disposed offsite. During sediment dredging, carriage water was returned to the former 8SS (contained area) and subsequently removed and treated.

By 2001, surface water in the former 8SS was removed, the former 8SS was filled with clean fill material, and the area was covered with asphalt. It is important to note that until the area was covered with asphalt, surface water infiltration occurred in the contained area and resulted in increasing water levels in this area. As part of the asphalt cover activities, a corrugated pipe outfall was constructed on the western wall of the former SV that also penetrated the slurry wall to allow for surface water drainage from the area to the river. Long-term monitoring of a network of wells was conducted through 2006 that documented the interim barrier wall was performing as required, at which time USEPA agreed to ceasing the semiannual barrier monitoring program.

In 2009, Tyco and USEPA entered into a second AOC regarding implementing remedial actions at the site and adjacent Menominee River. The AOC required implementing institutional controls, placing soil covers in select areas, removing sediment and semi-consolidated materials along with monitored natural attenuation, installing a barrier wall surrounding the site, and installing a groundwater collection and treatment system (GWCTS) to prevent flooding of the plant site. Tyco completed implementation of the institutional controls, a portion of the soil cover component, and installation of a slurry wall along the western, southern, and eastern portions of the site in 2009. In 2010, Tyco completed cover placement activities, installation of a sheet pile wall along the northern portion of the site, and installation and operation of a GWCTS. Primary sediment dredging, treatment, and disposal operations to achieve the remedial objective of removing sediments and semi-consolidated material with arsenic concentrations equal to or greater than 50 parts per million were conducted in 2012 and 2013. All components were completed as designed and met the criteria established in the USEPA Statement of Basis (September 12, 2007) and the 2009 AOC.

In December 2013, Tyco submitted the required 5-year technical review document to USEPA. The document provided the status of the remedies as well as documentation supporting the conclusion that the remedies are working as designed to prevent migration of groundwater to the Menominee River to the extent practicable. However, USEPA did not agree with the conclusions of the report regarding the functioning of the containment structure. As a consequence, USEPA and Tyco developed the April 23, 2014 Agreement on Resolution of 2013 5-year Review Technical Issues (AOR). The AOR allowed Tyco to work with the USEPA Great Lakes Legacy Act Program to complete a betterment project to remove remaining sediment with arsenic concentrations exceeding 20 parts per million and eliminate the long-term natural attenuation monitoring component of the 2009 AOC. Tyco completed the betterment project in 2015.

The AOR required Tyco to undertake the following steps:

- Complete dye testing along the sheet pile barrier wall in the Main Plant Area of the site to determine if the barrier wall in this area had visible leakage below the water line

- Sample sediment within the dredged area at select locations every 5 years[2]
- Calculate the potential amount of groundwater migration from the upland area that would impact the ability to maintain the remedial objective of 20 parts per million
- Implement a PDP to reduce water levels in the former SV and former 8SS to a specified target elevation
- Submit a Barrier Wall Groundwater Monitoring Plan Update (BWGMPU)[3] that incorporates components of the AOR

Tyco agreed to complete the components of the AOR even though limited information was available at the time on the technical ability to reach and maintain the target elevation required in the PDP area. Therefore, Tyco made the following assumptions regarding site conditions and potential system operation:

- No substantial groundwater movement into or out of the former SV and former 8SS was occurring, meaning that the target elevation potentially could be maintained with limited withdrawal from these areas once the target elevation was met.
- The existing extraction system could maintain the target elevation long-term.
- The groundwater treatment system could manage the PDP water long-term. (The groundwater treatment system was not designed to manage a high volume of groundwater containing the significantly elevated arsenic concentrations that were expected from the pump down area.)

Tyco submitted a technical memorandum to USEPA entitled *Supplemental Evaluation: Potential Recontamination of Menominee River Sediments due to Groundwater Migration from the Main Plant Area* (July 30, 2014). USEPA provided comments to the document on October 30, 2014. Tyco subsequently addressed USEPA comments and submitted a revised evaluation on April 22, 2015 to fulfill the required AOR task.

Based on the dye testing plan presented in the BWGMPU, WDNR required procurement of a permit prior to performing dye testing activities. Because of delays in obtaining the necessary permit and discussions with USEPA, Tyco agreed to perform a pilot dye test in the Menominee River to obtain requested information for the permit. The pilot dye test was completed in September 2017, and the results of the pilot dye test were submitted to USEPA in November 2017. Based on discussions during the December 20, 2017 meeting, USEPA agreed that performing a full-scale dye test was not likely to be able to identify seepage from the barrier wall and that alternative evaluation methods should be assessed and considered for replacing the dye testing requirement.

Although compliance with the target elevation was not required until December 31, 2017, Tyco was unsure about the length of time that would be needed to meet the target elevation. Therefore, Tyco elected to implement an aggressive PDP in 2016 using a temporary extraction system with offsite disposal of recovered groundwater. The primary objectives of the 2016 aggressive PDP were to determine whether recovery of groundwater would successfully reduce groundwater levels to or below the target elevation, whether the existing permanent extraction system would be able to manage groundwater levels long-term, and what options for groundwater extraction were available should the assumptions prove invalid regarding no substantial groundwater movement into or out of the pump down areas or the ability to maintain the target elevation. In addition, implementation of the PDP in

---

[2] Initial sediment sampling, in accordance with the BWGMPU, will be conducted in 2018. The results will be presented in the 2018 5-year review document.

[3] Tyco submitted, and USEPA approved, a Baseline Groundwater Monitoring Plan in 2009 for implementation at the site. A Barrier Wall Groundwater Monitoring Plan was submitted, approved by USEPA, and implemented in 2011. A BWGMPU was submitted to USEPA in 2014 that incorporated AOR requirements, subsequently revised to address USEPA comments, approved by USEPA in 2015, and implemented.

2016 would allow for an extended period (including 2017) to evaluate data collected during the aggressive pump down period, evaluate extraction and treatment options necessary/available to manage groundwater elevations long-term, and complete extraction of groundwater to reach the target elevation criteria if reducing the groundwater levels proved difficult because of low extraction rates or other causes.

The aggressive pumping program used temporary aboveground piping to existing extraction wells (not connected to the permanent treatment system), peristaltic pumps, temporary storage tanks, and offsite disposal. This program reached the target elevation in July 2016. The remainder of the 2016 pumping program was used to evaluate various operational scenarios of the extraction wells to assess recharge and drawdown rates. Because the aggressive pumping system was not designed for winter operation, the system was temporarily decommissioned in October 2016 for the winter period. Groundwater monitoring was completed during the winter shutdown period as prescribed in the BWGMPU and evaluated to develop a path forward for long-term operations.

In a May 2017 conference call with USEPA, Tyco presented an evaluation of the data collected during the 2016 pump down operation and subsequent interim shutdown period monitoring. During the discussion, Tyco provided information on outstanding technical issues related to the groundwater extraction and long-term treatment/management of the extracted groundwater. The outstanding technical issues included:

- The limited ability of the existing onsite groundwater treatment system to effectively treat groundwater from the PDP area was unknown. It is important to note the treatment system upgrades were not in place during 2016 operations.
- Alternatives to use if the existing treatment system is unable to treat the groundwater even with upgrades.
- Design and installation of a conveyance system for extracted groundwater. Conveyance systems cannot be designed and installed until after the method (and associated location) of ultimate management/disposition of the extracted groundwater is determined.

Following the discussion, USEPA responded to the Tyco proposal in correspondence dated June 26, 2017. Additional discussion regarding the proposed approach occurred on July 25, 2017, at which time Tyco provided further details regarding the proposed approach. USEPA provided a written response to the meeting presentation on August 10, 2017.

Tyco recommenced pumping on August 7, 2017, with the intent to conduct further testing of the existing groundwater treatment system's ability to treat extracted groundwater. Remaining recovered groundwater was to be disposed at the Waste Management Vickery facility via deep well injection. However, Tyco was notified by the pump down contractor on August 4, 2017, that mechanical issues with an injection well prevented disposal at the Vickery facility. The loss of this offsite disposal capacity forced a reduction in pumping at the site because extracted groundwater could not be continuously managed offsite. The extraction of groundwater from the PDP area ceased on October 9, 2017, primarily because of the sustained inability to dispose of water at the Vickery facility. To ensure existing extracted groundwater could be removed from the site, Tyco diverted some tanker trucks normally used for transportation and disposition of existing groundwater treatment system concentrate (reject water) to assist in managing and disposing of the groundwater extracted during PDP operations. As a result, Tyco was able to remove and dispose of the collected groundwater by October 27, 2017.

During the 2017 PDP operations, 129,558 gallons of groundwater was recovered, with approximately 96,690 gallons disposed offsite. An additional 32,868 gallons of groundwater was treated through the onsite groundwater treatment system as part of the system testing program.

2.0 PDP Status

Tyco submitted a status report documenting the 2017 PDP activities and testing of the existing groundwater treatment system on December 6, 2017 (Attachment 1).

3.0 Groundwater Infiltration Analysis

After attaining and maintaining the target elevation in both the former SV and former 8SS in summer 2016, the temporary PDP system was shut down in October 2016. Subsequently, groundwater elevations in the PDP areas returned to levels consistent with adjacent containment areas over a period of approximately 280 days. In accordance with USEPA's November 28, 2017 letter, an analysis of the source(s) of groundwater infiltration into the former SV and former 8SS has been conducted, as discussed in Section 3.1.

In 2017, Tyco implemented improvements in the PDP area to reduce stormwater infiltration and groundwater recharge across the site. These activities involved significant repairs and modifications within the former SV and surrounding areas. Section 3.2 summarizes the mitigative measures that have been implemented to date to limit recharge from rainfall.

3.1 Infiltration Analysis

Between June and October 2016, the temporary PDP achieved and sustained groundwater elevations below the target elevation of 577.9 feet above mean sea level (amsl) in the former SV and former 8SS. Before shutdown on October 24, 2016, the average groundwater elevations in former SV and former 8SS were 576.8 and 575.7 feet amsl, respectively. These elevations were achieved through the pumping of four temporary extraction wells (EW-10, EW-11, EW-13, and EW-14) in the former SV and two temporary extraction wells in the former 8SS (EW-8 and EW-9) (Figure 2). Before shutdown, the combined extraction rates from the former SV and former 8SS were approximately 1.5 and 1.1 gallons per minute (gpm), respectively.

Figure 3 presents hydrographs depicting the mean water level as measured from shallow monitoring wells within the former SV and former 8SS as well as from monitoring wells in adjacent areas and site staff gauge from the start of the PDP in June 2016 through November 2017. While groundwater elevations were relatively stable before shutdown on October 24, 2016, extraction rates were continuing to decline slightly, suggesting the 1.5 and 1.1 gpm rates may be an overestimation of the steady state long-term rates required to maintain the groundwater elevations observed, and that some contribution from drainage of dewatered soil may still have been occurring.

As shown on Figure 3, recharge was observed after shutdown, the former SV returned to pre-PDP levels consistent with the Main Plant Area after approximately 280 days, and the former 8SS had not fully recharged to pre-PDP levels after 309 days but returned to levels consistent with the adjacent Wetlands Area after approximately 280 days. The fact that neither the former SV nor the former 8SS equilibrated to the adjacent river level following the PDP shutdown provides evidence that there is a limited hydraulic connection and that a significant exchange of groundwater is not likely to be occurring between the PDP areas and the Menominee River.

In general, the observed recharge to the former SV and former 8SS could be coming from three main sources:

- Rainfall infiltration through cracks and seams in the asphalt cap and through compromised stormwater conveyance structures
- Flow through the slurry wall sections (former SV only) or through joints in the sheet pile wall sections (former SV and former 8SS)
- Flow upwelling from the underlying glacial till

3.1.1 Estimates of Combined Infiltration Rates using Observed Recharge

A simple calculation was performed to estimate the combined flow (all sources) to the former SV and former 8SS given the observed rate of water level increases over the first 14 days following shutdown. This was done as a check against the measured extraction rates before shutdown. The estimate was performed using the following assumptions:

$$Q_{sc} = (\Delta H \cdot A \cdot S_y) \cdot \frac{7.48\ gal}{ft3} \div T$$

where: Q_{sc} = simple calculation of combined flow to the former SV or former 8SS (gpm); ΔH = water level rise since shutdown (feet); A = area of former SV or former 8SS (square feet); S_y = specific yield (assumed 0.02); and T = time since shutdown (minutes).

A mean water level rise (ΔH) of 1.43 feet in the former SV over the first 14 days following shutdown suggested flow (Q_{sc}) to the former SV under these head conditions (SV water level between 5.6 and 4.2 feet lower than adjacent Main Plant area) was approximately 1.1 gpm.

A mean water level rise of 0.64 foot in the former 8SS over the first 14 days following shutdown suggests flow (Q_{sc}) to the former 8SS under these head conditions (8SS water level between 3.9 and 3.3 feet lower than adjacent Wetlands area) was approximately 0.4 gpm.

Although the calculated estimates of Q_{sc} are lower than the estimated extraction rates prior to shutdown, they are generally consistent with one another. Lower estimated Q_{sc} is likely the result of the calculated combined flow representing a range of head conditions over the first 14 days where head differences (gradients) between the pump down areas and adjacent areas decreased over this time. Conversely, the measured extraction rates generally represent flows required to sustain the drawdown observed before shutdown. As gradients across the walls decrease, flow to the contained areas would be expected to decrease.

3.1.2 Estimates of Anticipated Infiltration Rate Given Containment System Design

While the slurry and sheet pile walls and the underlying glacial till represent low permeability barriers, these materials are not 100 percent impermeable. Given the design specifications and dimensions of the slurry and sheet pile wall sections and measured hydraulic conductivities of the glacial till, plus the strong inward gradients that were induced as part of the PDP, it is expected, based on Darcy's Law, that some amount of flow (Q) would occur to the former SV and former 8SS. Darcy's Law is as follows:

$$Q = K \cdot i \cdot A$$

where; Q = discharge in units of length cubed per unit time (L^3/T); K = hydraulic conductivity in units of length per unit time (L/T); i = hydraulic gradient in units of length per length (L/L); and A = cross sectional area in units of length squared (L^2).

Darcy's Law was used along with the wall's final dimensions and accepted design specifications and the measured gradients to estimate flows through the slurry wall sections of the former SV and contributions from the glacial till beneath the former SV and former 8SS during the PDP. In addition, vendor-supplied estimates of flow potential across the Adeka sealed sheet pile joints along with rainfall data were used to estimate contributions to the pump down areas through the sheet pile sections and from rainfall infiltration, respectively. The specific assumptions and calculations associated with these estimates are in Attachment 2. The sum of each of these flow components was estimated at 0.8 and 0.6 gpm for the former SV and former 8SS, respectively.

These estimates assume steady state conditions, which were unlikely to have been achieved during the 2016 PDP. Specifically, the estimates of 0.8 and 0.6 gpm do not include contributions from any ongoing drainage of dewatered soils that may have still been occurring at the end of the 2016 PDP. As mentioned above, the consistent decline in extraction rates observed right up to the end of the 2016 PDP suggest steady state pumping conditions had not been achieved and that the measured extraction rates of 1.5 gpm from the former SV and 1.1 gpm from the former 8SS likely included some contribution from drainage.

It should be noted that estimates of flow associated with each of the three potential sources (through the walls, upwelling from the till, and rainfall infiltration) that are shown in Attachment 2 were calculated only so the combined design flows could be compared to the observed extraction rates. Given the dynamic nature of the contained areas, the relative contributions from each source cannot be considered reliable quantitative estimates in and of themselves.

Given the anticipated continued declines in measured extraction rates if the PDP pumping were to have continued, the estimated combined design flows under the conditions observed during the PDP are consistent with the measured extraction rates that were required to maintain the water levels in both the former SV and former 8SS in 2016. This suggests that, on the whole, the SV and 8SS containment systems are operating as designed. Beyond the mitigative measures to reduce the contributions to flow from rainfall/stormwater infiltration within the former SV that are described below, these calculations suggest further repairs are not required to reduce infiltration.

Applying Darcy's Law to this scenario highlights the importance of gradient (i) and suggests a review of the target elevation (based on the low water datum) should be performed so that groundwater elevations within the PDP areas are not reduced to levels that are excessive and unnecessary to prevent the potential for outward migration. For example, a review of the hydrographs on Figure 3 indicates that during the second half of the 2016 PDP, the water levels within the former SV and former 8SS were approximately 3 and 4 feet below the measured river elevation, respectively. Theoretically, the potential for outward migration can be mitigated with only a fraction of these drawdowns. Optimizing drawdown levels will reduce the magnitude of the inward gradient and, in turn, reduce the quantity of groundwater extraction and treatment (and associated energy usage and waste generation) required to maintain compliance. An evaluation of a rolling target elevation based on measured river elevations will be completed as a separate submittal, as discussed in Section 5.4.

3.2 Measures Implemented to Date to Reduce Infiltration

During review of the groundwater elevation data collected during 2016 PDP activities, an apparent rise in groundwater elevations was observed in the monitoring wells near the former SV stormwater outfall (Outfall 6) following significant rainfall events. Based on a 2016 visual inspection of the area, it was concluded that infiltration may have been occurring along the base of the exposed SV remnant wall and at an apparent separated seam of the outfall piping.

In 2016, Tyco installed a "wedge" of asphalt along the exposed wall to direct water away from the remnant wall and sealed the area with asphaltic sealant material. In addition, the separated seam within the outfall pipe was sealed with asphaltic sealant material. It is important to note that infiltrated surface water was contained within the former SV containment structure likely contributing to groundwater recharge in the area. As part of a stormwater improvement plan implemented in 2017, Tyco abandoned the subsurface component of the former SV outfall and constructed a surface drainage system that directs stormwater offsite (to the Menominee River) via overland flow. The intent of the stormwater management improvement in this area is to minimize the potential for infiltration of stormwater into the groundwater system and prevent infiltration of groundwater into the stormwater conveyance system that may potentially be discharged offsite. During removal of a portion of the stormwater piping that penetrated the slurry wall, it was observed that a portion of the slurry wall near the ground surface had been removed to accommodate the conveyance piping. The slurry wall was repaired during reconstruction of the outfall area.

Tyco conducts regular visual inspections of the asphalt surface within the PDP area as required in the BWGMPU. Maintenance is conducted as necessary, including replacing damaged asphalt areas and sealing cracks and seams. The most recent inspection and repair activities were completed in the fall of

2017. These inspections indicated stormwater from the former SV (where puddling had been occurring) and surrounding areas is effectively being conveyed to the newly constructed Outfall 5/6, and the grading and cover in the former 8SS continue to be effective at diverting rainwater primarily to the adjacent Outfall 7 (overland flow to the river) and Wetlands Area.

In addition, a brief evaluation of groundwater elevation data collected during the interim shutdown period and historical slurry wall construction information suggested the potential for groundwater to be "overtopping" the SV slurry wall. During implementation of the stormwater improvement activities at the Outfall 5/6 area, Tyco elected to assess the area through limited excavation along the slurry wall alignment. As discussed below, five trenches were excavated perpendicular to the slurry wall alignment (two along the southern and three along the western slurry wall) to expose the top of the slurry wall and obtain visual and elevation information.

On September 13, 2017, two trenches were excavated along the western portion of the southern slurry wall alignment. At each location, the top of the slurry wall was exposed at a depth of 29 to 30 inches below surface grade and was observed to follow topography. Based on visual assessment during exposure of the slurry wall, groundwater was not encountered. Elevation data collected at the top of the slurry wall ranged from 584.91 to 583.72 feet amsl. The collected elevation data for the top of the slurry wall and groundwater indicates groundwater was not "overtopping" the slurry wall in the exposed area.

On September 26, 2017, three additional trenches were excavated along the western slurry wall alignment. The top of the slurry wall was encountered at depths ranging from 16 inches below grade at the southwestern corner of the slurry wall to 6 inches below grade at the other two trenches. Groundwater was not encountered during the slurry wall exposure. Top of the slurry wall elevations ranged from 586.57 feet amsl at the northernmost trench to 583.78 feet amsl at the southwestern corner of the slurry wall.

Based on the visual assessment and groundwater and top of slurry wall elevation data collected during the trenching, "overtopping" of the slurry wall is not likely to be occurring.

4.0 PDP Alternatives Evaluation

The goal of implementing the PDP is to eliminate the potential for outward migration of arsenic-containing groundwater to the Menominee River from the SV and 8SS contained areas in the event there was a compromised section of the barrier wall containing these areas. The AOR provides for maintaining groundwater levels at the target elevation. The target elevation is equivalent to the mean low water elevation for the river. For Tyco to maintain the target elevation long term, a permanent alternative to manage the extracted groundwater is required.

To meet the PDP objectives, an initial screening was completed by developing an inventory of technologies that are applicable based on professional experience, published sources, computer databases, and other available documentation. Tables 1a and 1b provide the initial list of potentially applicable alternatives involving the identified available technologies. The tables include a description of each alternative, the technology(s) involved, pros, cons, a summary of the preliminary assessment, and whether the alternative is being retained for further focused evaluation. Table 1a summarizes the water treatment/management alternatives, and Table 1b summarizes the conveyance system alternatives. Table 2 lists supplemental optimization options for reducing the quantity of PDP water to be managed. The options in Table 2 may not be central to the current evaluation, but could be implemented in the longer term to reduce flow and increase the effectiveness and sustainability of the remedy.

5.0 Work Plan Elements

The following subsections present the activities to be conducted during 2018 to achieve and maintain the target elevation within the PDP area.

5.1 Recharge Reduction Measures

As discussed during the December 20, 2017 project meeting and presented in the December 22, 2017 winter operation and optimization correspondence, Tyco is operating extraction wells EW-2 located in the former 8SS and EW-3 located in the former SV. These wells are connected to the existing GWCTS and each well pumps at approximately 0.5 gpm. These wells were not operated during the 2016-2017 interim shutdown period or during the aggressive pump down operations conducted in 2016 and 2017.

In addition to continuing the operation of EW-2 and EW-3, Tyco will conduct general maintenance to help enhance the hydraulic connection with the aquifer at all extraction wells in the PDP area. The maintenance activities will include:

- Removing the submersible pumps (only present in extraction wells EW-2 and EW-3)
- Conducting a down hole camera survey of each well to assess the degree of precipitate and biological accumulation on the well screens
- Surging and purging each well to remove fine-grained materials from the filter pack to improve communication with the aquifer
- Brush cleaning the well screen to remove precipitate and biological accumulation on the well screens
- Replacing the submersible pumps

The intent of the activities is to increase extraction rates to improve water level reduction capabilities. The maintenance activities are tentatively scheduled for mid-January 2018; however, winter weather conditions may affect completion of the general maintenance activities. Therefore, some maintenance activities (potentially for the extractions wells not being used during the winter operation period) may be delayed until weather conditions permit.

5.2 Aggressive Pumping Resumption and Target Elevation Achievement

Because it is unlikely that a permanent conveyance and groundwater management system can be designed and installed at the site before April 15, 2018, Tyco intends to re-install the temporary extraction and storage system within the PDP area for operation commencing on April 15, 2018[4]. The system layout will be consistent with operations conducted in 2016 and 2017. Groundwater will be aggressively pumped from the existing extraction wells and temporarily stored in tanks located adjacent to the pump down area. Recovered groundwater will be transported offsite and disposed via deep well injection at the Vickery facility.

The operation will be conducted until any of the following conditions occur:

- Permanent extraction and treatment system is installed and operational.
- Target elevation is reached, at which time the system will be operated as necessary to maintain the target elevation.
- Winter conditions require temporary shut down if a permanent system is not yet in place and operational.

It is estimated that extraction rates exceeding approximately 1.5 gpm are required in each area to reduce groundwater levels to below the target elevation. An extraction rate of less than 1.5 gpm in each area is likely to be necessary to sustain groundwater levels to maintain compliance with the target

[4] The schedule for commencing temporary aggressive pump down operations is dependent on weather conditions and the ability to install and operate the conveyance (including pumps) and temporary storage systems should cold weather conditions extend past the planned start date.

elevation. Based on past operations of the temporary extraction and storage system associated with the PDP, the target elevation should be achieved by May 31, 2017.

5.3 Focused Alternatives Evaluation

The following is a list of the top alternatives, included in bold font in Tables 1a, 1b, and 2, that will be considered further as part of a focused alternatives analysis that will be completed during winter 2018:

- Upgrades to the existing system by improving treatment efficiency
- Precipitation and ultrafiltration pre-treatment system
- Seasonal direct disposal
- Year-round direct disposal
- GWCTS partial direct disposal
- Conveyance system using an above ground, below ground, or combination of above and below ground piping system and using the existing extraction wells
- Installing a segregation wall in the former SV and former 8SS

The alternatives listed above will be evaluated using a qualitative comparison based on implementability, effectiveness, long-term management (including operations and maintenance), and cost. Careful consideration also will be given to the ability of the alternative to accommodate redundancies and other measures in a design that will minimize downtime and maximize the system's ability to meet discharge criteria. The alternatives identified in Tables 1a, 1b, and 2 are those offering theoretical applicability for remediation of the media of concern at the site. This list of options should be considered dynamic, flexible, and subject to revision based on design investigation findings, results of treatability and pilot studies, and technological developments.

5.4 Rolling Target Elevation

Concurrently, a separate evaluation will assess the effectiveness, implementability, and cost of using a rolling target elevation that is based on actual river elevation, as a potential substitute for the current fixed target elevation established in the AOR. The goal of this evaluation will be to assess whether the target elevation could be modified in a manner that would maintain an inward gradient and thereby achieve environmental protectiveness while potentially reducing overall extraction rates from the PDP area and thus improve environmental sustainability and reduce cost. If an implementable and effective approach is identified, Tyco will present the details of this approach to the agencies in a separate submittal.

5.5 Design and Implementation of Permanent Pumping System and Contingency Considerations

Design and implementation of a permanent alternative will commence after a final alternative is selected based on the focused alternatives evaluation and after any necessary pilot testing is conducted. The design also will include details on contingencies for alternative or emergency operation situations that could occur if the implemented alternative is temporarily unable to maintain the target elevation.

In addition, a plan for continuous performance evaluation of the GWCTS will be included as part of the design if the GWCTS is included as part of the future PDP activities. The plan may vary based on which alternative is selected.

5.6 Summary of Previous GWCTS Upgrades

The existing GWCTS was modified in fall 2016 to include an inclined plate separator and two additional reaction tanks capable of adding a ferric-based coagulant and lime slurry into the treatment process.

This was designed to reduce system fouling and thus also reduce maintenance downtime required in the microfiltration component of the system. The Vibratory Shear Enhanced Process unit also was added to the system as an alternative technology to the brine reverse osmosis designed to reduce the waste volume generated by the process.

6.0 Schedule

The following is a summary schedule of activities:

- Winter operations and optimization
  - Prepare and submit winter operation plan – Completed December 22, 2017
  - Implement winter operation plan – Ongoing
    - Cleanout of EW-2 and EW-3 – Planned to occur in January 2018[5]
  - Continue to operate EW-2 and EW-3 – Ongoing
- Submit work plan/root cause analysis to agency – January 12, 2018
- Submit focused alternatives evaluation to agency – January 31, 2018
- Meet with USEPA to review the focused alternatives evaluation – tentative February 14/15, 2018
- Mobilize and start setup of temporary pumping system – April 1, 2018[5]
- Resume aggressive pumping – April 15, 2018[5]
- Meet target elevation – May 31, 2018[5]
- Design and implementation of selected alternative – The goal is to complete the design and implementation of a permanent system by the end of 2018. However, the actual schedule may vary based on agency review times, pilot testing requirements, complexity of the design of the permanent system, availability of long-lead time equipment, and other unknowns, including possible subsurface obstructions in construction areas. The design and implementation schedule will be provided once a final alternative is selected.

[5] Schedule component could be delayed because of winter weather conditions or other circumstances beyond Tyco's reasonable control.

Tables

Table 1a. PDP Water Treatment/Management Alternatives Evaluation

PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

Alternative Option	Description	Pros	Cons	Comments
Upgrade Existing System				
Improve Treatment Efficiency	**Replace the existing microfiltration (MF) unit and double pass reverse osmosis (RO) unit at the GWCTS with two (2) new Pall membrane microfiltration (MF) systems and two (2) new Pall triple pass RO systems. The additional flow capacity will result in lower loading rates to the membranes increasing treatment efficiency, as will the addition of triple pass RO units.** **Upgrade the control system to manage flow rates from individual wells to provide a consistent influent and add a new separate control system for new MF and RO units. The objective of the control systems is to manage the arsenic concentrations in the treatment system influent at an optimal concentration and allow 24 hour operation, 7 days a week (if desired).** **Verify existing GWCTS building size is sufficient to accommodate new MF and RO units, filter press(es) and associated instrumentation and control. Evaluate existing pretreatment system consisting of coagulation/flocculation equipment and clarifier to improve performance and reduce loading to MF membranes. This will ultimately improve the performance of the RO membranes in the groundwater treatment system.**	**· Proven treatment approach utilized during the sediment removal operations** **· Addition of Pall MF and RO units will increase treatment system capacity while reducing loading to MF and RO membranes** **· Allows for all water generated to be treated onsite** **· Eliminates need for separate pre-treatment system** **· Ability to easily control flow from high concentration wells at SV and 8SS** **· Treatment system efficiency to meet expected lower arsenic discharge limits** **· Volume of waste shipped offsite will be reduced and result in reduced disposal costs** **· Two parallel treatment trains allows for one system to operate while the second system undergoes cleaning or maintenance**	**· Reconfiguration of existing GWCTS is required** **· GWCTS would need to be shut down to complete the system upgrades** **· A trailer mounted temporary system would need to be brought in during the shut down, which would also require additional permitting requirements to operate the temporary system** **· Additional or new equipment and software may be required** **· May require additional pumping from non-PDP extraction wells, recirculate discharge water (makeup water from effluent) or could use water from the river**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Pre-treatment Alternatives				
GWCTS Mini Pretreatment	Install a pretreatment system with similar technology to the existing GWCTS on a smaller scale to provide initial arsenic reduction of groundwater from pump down area	· Provides the capability to meet and maintain the target elevation consistently · Would be more waste efficient than direct or partial disposal	· Would require additional building to house the system · Would result in estimated 250,000 gallons of additional hazardous waste leaving the site per year which poses over the road risk · Pretreatment system would be dependent on existing GWCTS to maintain operation	Eliminated, not as efficient as upgrading the existing system
Standard Evaporator	Pump and evaporate material from the SV and 8SS. Steam would be condensed and sent to GWCTS for polishing. Concentrate would be disposed offsite.	· Provides the capability to meet and maintain the target elevation consistently · Would be more waste efficient than direct or partial disposal	· Would require additional building to house the system · Would result in estimated 250,000 gallons of additional hazardous waste leaving the site per year which poses over the road risk · System would be highly subject to fouling resulting is substantial downtime · System condensate would need polishing at GWCTS and would likely upset system chemistry due to lack of minerals · System has very high energy demand · Bench or pilot testing required prior to implementation · Pretreatment system would be dependent on existing GWCTS to maintain operation	Eliminated, cons outweigh the pros and other technologies are more promising

Table 1a. PDP Water Management Alternatives Evaluation

PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

Alternative Option	Description	Pros	Cons	Comments
Vacuum Evaporator	Pump and evaporate material from the SV and 8SS. Steam would be condensed and sent to GWCTS for polishing. Concentrate would be disposed offsite.	· Provides the capability to meet and maintain the target elevation consistently · Would be more waste efficient than direct or partial disposal. Has less energy demand than standard evaporator	· Would require additional building to house the system · Would result in estimated 250,000 gallons of additional hazardous waste leaving the site per year which poses over the road risk · System would be highly subject to fouling resulting is substantial downtime · System condensate would need polishing at GWCTS and would likely upset system chemistry due to lack of minerals · Bench or pilot testing required prior to implementation · Pretreatment system would be dependent on existing GWCTS to maintain operation	Eliminated, cons outweigh the pros and other technologies are more promising
Precipitation and Ultrafiltration Pre-treatment System	**Install chemical precipitation and ultrafiltration-based pretreatment system.**	**· Provides the capability to meet and maintain the target elevation consistently** **· Would not generate Hazardous waste** **· Would have additional treatment capacity to catch up if any downtime threatened the target elevation**	**· Would require additional building to house system** **· Would use large amounts of ferric sulfate** **· Would generate large amounts of non-hazardous sludge** **· Bench or pilot testing required prior to implementation** **· Pretreatment system would be dependent on existing GWCTS to maintain operation**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Biogeochemical Reactor using Zero Valent Iron (ZVI) or ZVI+Organic Carbon	Divert PDP groundwater flows to a subgrade or above grade biogeochemical reactor containing ZVI or a mixture of ZVI and organic carbon that would be sized to provide sufficient hydraulic residence time given range of anticipated flow rates and treatment goal. PDP water would be introduced via a header pipe manifold and effluent either discharged to the existing groundwater treatment system (above grade) or out of the base (below the water table) of the reactor in the case of a subgrade reactor located within the Main Plant area. For ease of media change out a subgrade reactor could also be constructed as a concrete vault/vessel with an adjacent infiltration gallery instead of an unlined pit. If discharged back to the Main Plant groundwater using a subgrade target treatment goal would need to be less than concentrations in proposed area of discharge. If a separate infiltration gallery is used as part of a subgrade reactor setup, the design could accommodate diversion of effluent flow to existing system, provided a conveyance system is in place. Arsenic removal from water using ZVI is attributable to adsorption onto corrosion products of the ZVI, including iron hydroxides, oxyhydroxides, and mixed-valance iron Fe(II)-Fe(III) green rusts. In groundwater containing sulfate and a sufficient carbon source to promote sulfate reduction, arsenic can also be coprecipitated with metal sulfide minerals.	· O&M would be relative minimal compared to other treatment processes (pump and line maintenance/cleanouts, as well as reactive media changeouts). · Burial of reactor could avoid the need for significant new structures to house treatment works. · 2004 Pilot scale testing of ZVI and ZVI/compost mixtures ability to treat site groundwater with over 2,000 milligrams per liter (mg/L) showed 55 and 65% removal efficiencies, respectively. A review of these data suggests that ZVI +compost performed better than ZVI alone. · Sufficient sulfate concentrations are already present in groundwater precluding the need to add a sulfate source as part of the reactor media. · Opportunities for easily implementable pilot testing prior to, or during initial pump down would allow technology to be tested for PDP or future application. Considerations for pilot testing should at a minimum include an assessment of ZVI alone as well as ZVI plus organic carbon (compost), and an evaluation of residence times and the media's treatment capacity.	· Little information is available on the capacity of ZVI and ZVI/compost mixtures for treating organic forms of arsenic. Pilot scale testing of ZVI is required to determine feasibility as well as design specifications and to understand associated costs. · If it is assumed that the influent concentration is 310 mg/L (highest observed from SV alone during 2017 testing), then the 65% treatment efficiency observed during the 2004 testing would not be sufficient to reduce concentrations low enough to limit problems for the existing system. · If it is assumed that the 65% treatment efficiencies could be improved upon, the 2004 bench scale testing showed extended hydraulic residence times (10-20 days) were needed to achieve treatment this treatment. Given the anticipated PDP flows of 2-3 gallons per minute (gpm), this would require an impracticably large volume of reactive media to achieve. · Given the presence of organic forms of arsenic, the capacity of the media may be low relative to what is reported in the literature (~1 to 14 milligrams arsenic per grams ZVI [mg As/g ZVI] for ZVI only). With the high PDP arsenic concentrations, anticipated flows of 2 to 3 gpm, and assuming an arsenic treatment capacity of 2 mg As/g ZVI, the frequency of media changeouts would be impracticable and costly relative to other alternatives. · Discharge to groundwater in Main Plant area may pose a permitting challenge. · Pretreatment system would be dependent on existing GWCTS to maintain operation.	Eliminated. The combination of organic arsenic at such elevated concentrations and anticipated flows of 2-3 gpm, the reactor size and media changeout frequency would be impracticable.

Table 1a. PDP Water Management Alternatives Evaluation

PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

Alternative Option	Description	Pros	Cons	Comments
Offsite Disposal Alternatives				
Seasonal Direct Disposal	**Use temporary system to draw down the area seasonally for direct disposal.**	**· Temporary system components already available · 8SS water levels from 2016 to 2017 show that alternative could be maintained**	**· Inability to operate during winter could result in high risk of deviation from target elevation · Pumping down below target elevation would result in increased recharge rate in these cells which would result in inefficient additional pumping · System operation would rely on accessibility to disposal facility and transportation contractors, which provides additional risk to operation and maintenance of target elevation**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Year Round Direct Disposal	**Install permanent dewatering system for direct disposal year round, including conveyance piping and building to house storage tanks.**	**· Provides the capability to meet and maintain the target elevation consistently**	**· System operation would rely on accessibility to disposal facility and transportation contractors, which provides additional risk to operation and maintenance of the target elevation · Would result in estimated 1.6M gallons of additional hazardous waste leaving the site per year which poses over the road accident risk · System would require additional building**	**Further evaluation needed, not likely a long term solution, but will be included as part of focused alternatives evaluation as a potential contingency option**
GWCTS Partial Direct Disposal	**Install a bypass line for water conveyed from the SV and 8SS into the GWCTS to be all or partially diverted for direct disposal, non-diverted portion of groundwater would be treated through existing system.**	**· Provides the capability to meet and maintain the target elevation consistently · Would be more waste efficient than direct disposal.**	**· System operation would rely on accessibility to disposal facility and transportation contractors, which provides additional risk to operation and maintenance of the target elevation · Would result in estimated 1.1M gallons of additional hazardous waste leaving the site per year which poses over the road accident risk**	**Further evaluation needed, , not likely a long term solution, but will be included as part focused alternatives evaluation, but will be included as part of focused alternatives evaluation as a potential contingency option**

Note: Technologies that have been eliminated are in normal text. Technologies that are retained for the focused evaluation are**bolded**.

Table 1b. PDP Conveyance System Alternatives Evaluation

PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

Alternative Option	Description	Pros	Cons	Comments
Conveyance System Alternatives				
Piping - Below Ground	**New conveyance piping from the former Salt Vault (SV) and 8th Street Slip (8SS) wells installed below ground surface.** **Install below ground piping within a 6-inch carrier pipe and frequent cleanout locations to allow replacement and easier maintenance of plugged conveyance pipe.**	**· Piping is out of the way allowing unrestricted use of above ground surfaces** **· Heat tracing not expected to be required** **· Could utilize EW-2 and EW-3 lines to tie into for a portion of the water**	**· Can still have difficulty accessing pipes for cleaning, especially in winter** **· Excavation in contaminated soil requiring offsite disposal** **· Difficult to install piping all the way back to the GWCTS building** **· Likely to encounter subsurface structures in SV** **· Penetrations and repairs of existing barrier walls would likely be required**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Piping - Above Ground	**New conveyance piping from the SV and 8SS wells installed above ground surface.**	**· Easy access to pipes for maintenance** **· Minimal excavation in contaminated soil** **· Easier installation of piping to GWCTS building**	**· Pipes limit use of ground surface** **· Heat tracing and insulation required** **· May require larger pumps to account for head loss due to elevated piping over the emergency access road (depending on location of alternative treatment system, if needed)**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Piping - Combination: **Below ground in SV and 8SS Asphalt Areas** **Above ground to the GWCTS Building Starting at West End of SV**	**Install below ground piping within a 6-inch carrier pipe and frequent cleanout locations to allow replacement and easier maintenance of plugged conveyance pipe.** **Install above ground piping using existing pipe racks. Install new pipes racks as necessary.**	**Below** **· Piping is out of the way allowing unrestricted use of above ground surfaces at SV and 8SS areas** **· No heat tracing required** **Above** **· Easy access to pipes for maintenance** **· Minimal excavation in contaminated soil** **· Easier installation of piping to GWCTS building**	**Below** **· Can still have difficulty accessing pipes for cleaning, especially in winter** **· Excavation in contaminated soil requiring offsite disposal** **· Likely to encounter subsurface structures in SV** **· Penetrations and repairs of existing barrier walls would likely be required** **Above** **· Pipes limit use of ground surface** **· Heat tracing and insulation required**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Extraction - Existing Extraction Wells	**Use existing extraction wells to pump groundwater down to target elevation**	**· EWs are already installed and have shown they can meet the target elevation** **· Multiple wells in each area allow for operational contingency**	**· Conveyance piping required to each extraction well** **· Pumps needed for each extraction well**	**Further evaluation needed, will be included as part of focused alternatives evaluation**
Extraction - Horizontal Wells	Install below ground horizontal collection piping to pump groundwater down to target elevation	· Large screened area · May only need one pump for each area	· Subsurface structures likely to be encountered during installation · Not used at site before, would require hydrogeologic analysis to support design · Distance required to reach desired depth may make installation more difficult with the barrier walls	Eliminated, considering the EWs have already shown to work at meeting the target elevation

Note: Technologies that have been eliminated are in normal text. Technologies that are retained for the focused evaluation are **bolded**.

Table 2. PDP Supplemental Optimization Options Evaluation

PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin

Option	Description	Pros	Cons	Comments
Tree Plot Install	Install trees to maintain the water levels through evapotranspiration.	· Low cost and low maintenance. · CO2 removal.	· May not grow in high salinity groundwater. · Would require penetrations to the SV and 8SS cover areas. · Would require 3-5 years for trees to mature enough to maintain target elevation and uncertain if trees alone could maintain target elevation · Pilot testing may be required prior to implementation	Eliminated, doesn't meet implementation schedule goals and uncertain if technology will work to maintain water levels to the target elevation
In-situ solidification/stabilization (ISS)	Stabilize the unconsolidated soils in place in the SV and 8SS areas using a pozzolan (e.g. portland cement) and other additives (e.g. ferrous sulfate) as necessary to fixate arsenic and reduce permeability. Stabilization of soils down to a depth of 30 feet (top of glacial till) would necessitate the used of deep augers for mixing.	· If successful, SV and 8SS soils would be transformed into low permeability monoliths, significantly reducing the overall flux of soluble arsenic from these areas. · Would eliminate the need for hydraulic control/pumping from the SV and 8SS areas.	· The mass of and mixture of additives (percent by weight of soil) required to achieve permeability and leachability reductions is unknown and extensive bench scale testing would be required. · Highly soluble and elevated arsenic concentrations as well brackish conditions pose a significant challenge for achieving permeability and leachability reductions. · Significant mass of pozzolanic materials and other arsenic fixation agents may be required which would result in a waste stream (water and soil) requiring off site disposal. · The resulting swell may jeopardize the integrity of the existing containment structure (slurry and sheet pile walls). Tie back structures would also pose a significant challenge that may result in incomplete stabilization in these areas. · Would require complete demolition of former SV and 8SS asphalt cover and construction debris present in the fill layers and SV concrete sub structure would likely need to be excavated/cleared prior to mixing. · Bench or pilot testing required prior to implementation.	Eliminated for the following reasons: · Uncertainty around the feasibility of finding an effective mix that can be applied across the entirety of these containment areas (including in the vicinity of tie back structures) · Potential for damage to the existing containment structures
Segregation Wall	**Install slurry wall or sheet pile wall to bisect the SV and 8SS, reducing the pump down area size near the river.**	**· Project could facilitate achievement and maintenance of an inward gradient.** **· Potential reduction in volume to be removed to maintain target elevation.**	**· Reduction of groundwater infiltration volume is dependent on source of influx; therefore, currently unknown source may not result in reduction of infiltration rate.**	**Further evaluation needed. Alternative not critical to current evaluation, could be considered in the future, if needed, to reduce volume of water pumped from the SV and 8SS.**
Rolling Target Elevation Based on River Elevation*	**This option is still being evaluated, however could include stilling wells with pressure transducers installed at select locations along the SV and 8SS to continuously monitor river water levels. Pressure transducers could also then be integrated into the GWCTS control system and provide elevation differential between river water levels and groundwater table elevation within the SV and 8SS areas.**	**· Would provide real-time data collected and recorded automatically to assist in determining when and how much water to pump from the SV and 8SS areas.** **· Rolling target elevation would still achieve and maintain an inward gradient, however, would have potential reduction in volume to be removed to maintain the target elevation.**	**· With this option the Instrumentation could be subject to field conditions which may result in false or inaccurate readings.** **· Instrumentation would require routine calibration and maintenance.**	**Further evaluation needed, will be evaluated separately as discussed in Section 5.4**

Note:

Technologies that have been eliminated are in normal text. Technologies that are retained for the further evaluation are**bolded**.

*The rolling target elevation will be kept as a separate evaluation, however, is included to show that it is a supplemental support system option that is being considered as discussed in Section 5.4

Figures

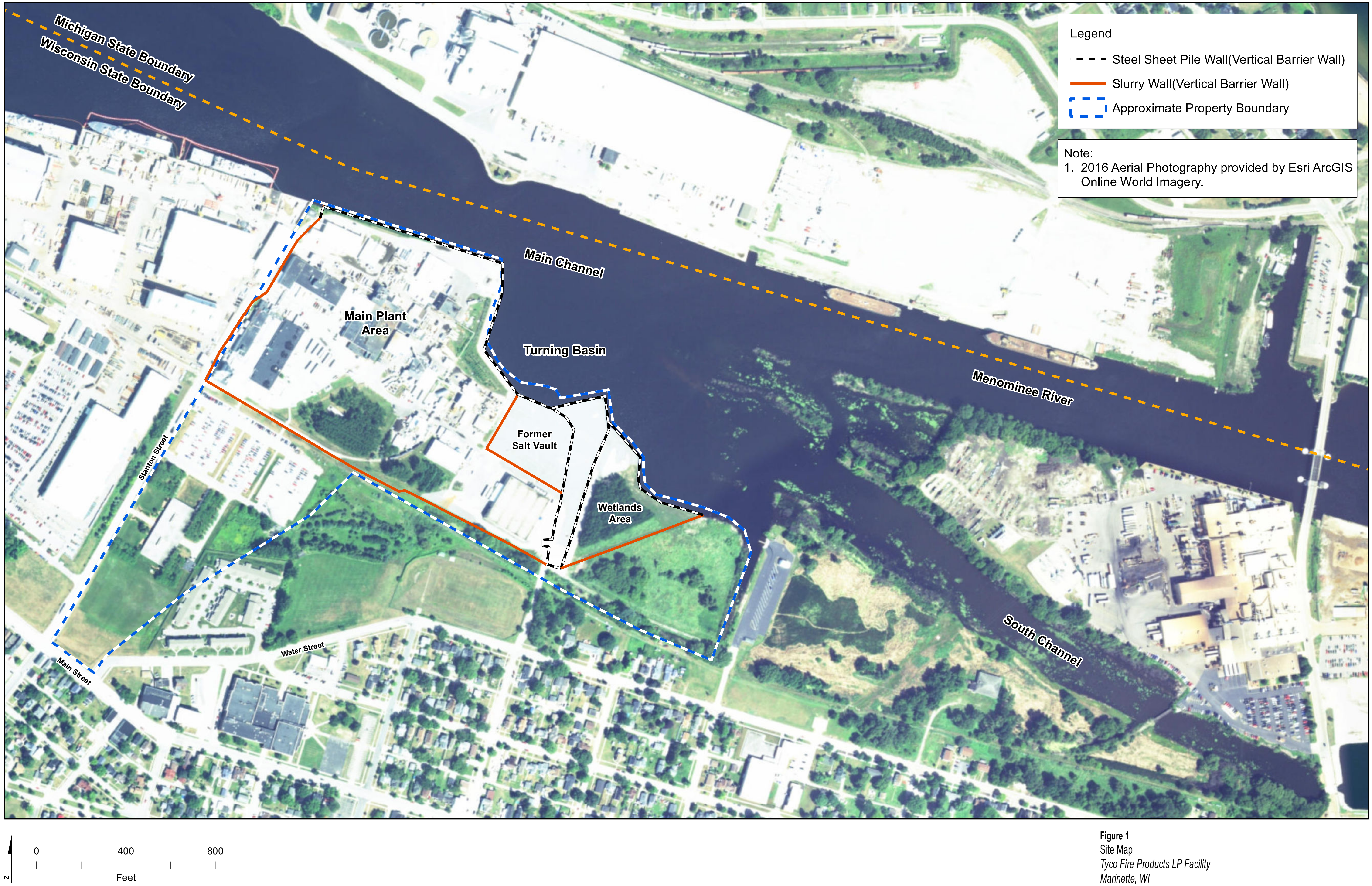


Figure 1
Site Map
Tyco Fire Products LP Facility
Marinette, WI

\\LAKEFRONT\PROJ\TYCO\MAPFILES\2017\FIGURE 1 - SITE MAP.MXD JHANSEN1 7/31/2017 2:27:51 PM

CH2MHILL

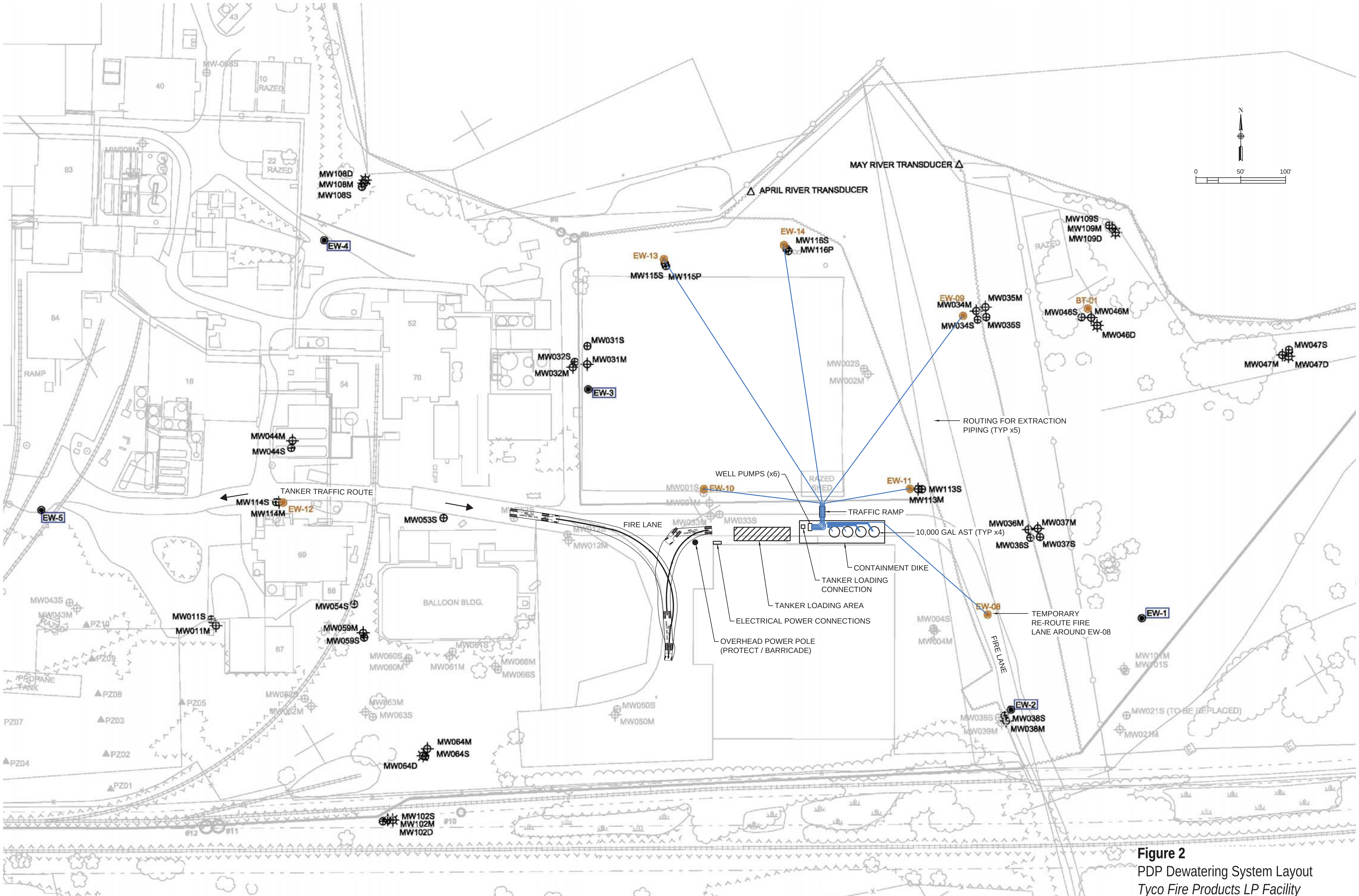


Figure 2
PDP Dewatering System Layout
Tyco Fire Products LP Facility
Marinette, WI

P:\Tyco - 415\001-Marinette Salt Vault & 8th St Slip\001-PDP\CAD\Record Drawings\SHT 1_415-001-001 Site Layout-Record Drawing.dwg

REV	DATE	
6	-	-
5	-	-
4	-	-
3	-	-
2	-	-
1	-	-
0	06/29/16	RECORD DRAWING

Endpoint Solutions
6871 S. LOVERS LANE
FRANKLIN, WI 53132
PHONE: (414) 427-1200

TYCO FIRE PROTECTION PRODUCTS
PUMP DOWN PROGRAM
DEWATERING SYSTEM LAYOUT
ONE STANTON STREET
MARINETTE, WISCONSIN 54143

DRAWN BY: NWD
CHECKED BY: WCW
APPROVED BY: WCW
DATE: 06/29/16
PROJECT NO. 415-001-001

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING; USE TO VERIFY FIGURE REPRODUCTION SCALE

SHEET NO.
1
SHEET 1 OF 4

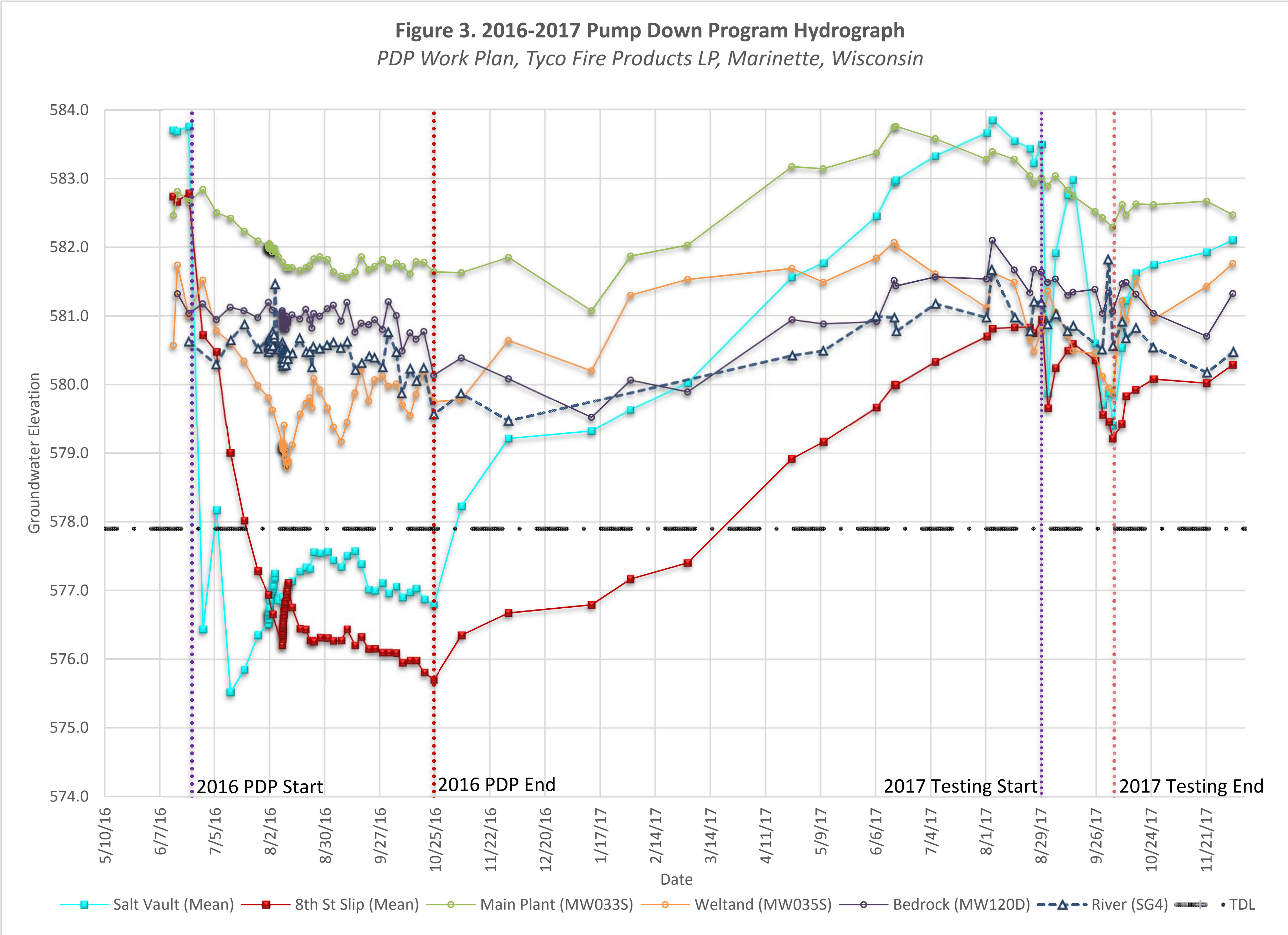


Figure 3. 2016-2017 Pump Down Program Hydrograph
PDP Work Plan, Tyco Fire Products LP, Marinette, Wisconsin
Groundwater Elevation
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
2016 PDP Start
2016 PDP End
2017 Testing Start
2017 Testing End
5/10/16
6/7/16
7/5/16
8/2/16
8/30/16
9/27/16
10/25/16
11/22/16
12/20/16
1/17/17
2/14/17
3/14/17
4/11/17
5/9/17
6/6/17
7/4/17
8/1/17
8/29/17
9/26/17
10/24/17
11/21/17
Date
Salt Vault (Mean)
8th St Slip (Mean)
Main Plant (MW033S)
Weltand (MW035S)
Bedrock (MW120D)
River (SG4)
TDL

Attachment 1

tyco
Fire Protection
Products

One Stanton Street
Marinette, WI 54143-2542

Tele: 715-735-7411

December 6, 2017

Mr. Conor Neal
Hydrogeologist
Land & Chemicals Division
US Environmental Protection Agency, Mail Code LU-9J
77 West Jackson Blvd
Chicago, IL 60604-3590

RE: 2017 Pump Down Program Summary Report
Tyco Fire Products LP Site
Marinette, WI

Dear Mr. Neal:

The information provided herein is a summary of activities conducted at the Tyco Fire Products LP (Tyco) site associated with the Pump Down Program (PDP) conducted in 2017. The PDP is required as part of the Administrative Order on Consent between Tyco and U.S. Environmental Protection Agency (USEPA). Specifically, this report provides a summary of the groundwater recovery and disposal, groundwater treatment system testing, and additional treatment approaches being evaluated for the management of the former Salt Vault and 8th Street Slip groundwater.

<u>Groundwater Recovery and Disposal</u>

The components of the temporary groundwater recovery system associated with the PDP were reinstalled after the interim shut period on June 15, 2017. However, commencement of system operation did not commence until August 29, 2017 for the following reasons:

- Tyco, USEPA, and WDNR participated in a conference call on May 23, 2017 at which time Tyco presented the status of the PDP and the proposed approach to collection and evaluation of technical information during 2017 for development of a permanent groundwater management system for the PDP area. Following the discussion, USEPA provided their response to the Tyco proposal in a correspondence dated June 26, 2017. Additional discussion regarding the proposed approach occurred on July 25, 2017 at which time Tyco provided further details regarding the proposed approach. USEPA provided a written response to the meeting presentation on August 10, 2017 that presented the USEPA position to conduct PDP activities in 2017.
- Groundwater treatment system testing was determined to be necessary to assess the ability of the existing permanent treatment system to successfully treat the groundwater generated as part of the PDP. An operation testing procedure was submitted to WDNR on June 20, 2017, which outlined the activities to be conducted as part of the system testing. The operation testing procedure was approved by the WDNR on June 26, 2017.

- PDP operations were subsequently scheduled to commence on August 7, 2017 with a portion of the recovered groundwater being transferred to the groundwater treatment plant for testing activities and the remaining recovered groundwater transported to Vickery for off-site disposal. On August 4, 2017, Tyco was notified that Vickery was unable to receive the groundwater from the PDP due to mechanical problems with an injection well and no capacity available at the other injection wells at the facility. The inability or limited ability of Vickery to receive and dispose of the recovered groundwater remained an issue throughout pump down operations until the interim shut down occurred on November 1, 2017.
- Temporary storage tanks were ordered for storing groundwater recovered from the PDP area for use in the groundwater treatment system. As proposed the tanks were to be placed near the exterior of the groundwater treatment plant and, for spill protection, be of double wall construction. Shortly after ordering the tanks, the impacts of the rainy weather in the southern United States resulted in a shortage of the tanks. Therefore, delivery and installation of the tanks was delayed until August 29, 2017 and groundwater treatment system testing was able to proceed.

Initial combined pumping rate in the former Salt Vault was 8.7 gallons per minute (gpm) from the four extraction wells (EW-10, EW-11, EW-13, and EW-14) used during the pump down operations. The initial combined pumping rate in the former 8th Street Slip was 6.9 gpm from the two extraction wells (EW-8 and EW-9) used during the pump down operation. Due to the limited access to the groundwater disposal facility (Vickery), limited onsite storage capacity, and the planned limited treatment capacity at the site groundwater treatment system during the system testing, groundwater recovery in the PDP area was consequently conducted sporadically (i.e., consistent active pumping was not viable).

Graphs of groundwater elevation data collected during the implementation of the PDP is attached. The graphs clearly illustrate the rise in groundwater elevations during the interim shut down period followed by subsequent drawdown and equilibration rebound during the sporadic operation of the extraction wells.

The extraction of groundwater from the PDP area ceased on October 9, 2017, primarily due to the sustained inability to dispose of water at Vickery. To insure that all existing extracted groundwater could be removed from the site, Tyco diverted some tanker trucks normally used for transportation of disposal of existing groundwater treatment system concentrate (reject water) to assist in management and disposal of the groundwater extracted during PDP operations. As a result, Tyco was able to remove and dispose of all collected groundwater by October 27, 2017.

The volume of groundwater recovered during the 2017 PDP operations was approximately 129,558 gallons with approximately 96,690 gallons disposed offsite. An additional 32,868 gallons was treated through the on-site groundwater treatment system as part of the system testing program. Details of the system testing program are provided herein.

Groundwater Treatment System Testing

On August 31, 2017, Tyco commenced the system testing program. The initial influent rate of groundwater recovered from each pump down area cell (former Sault Vault and 8th Street Slip) into the groundwater treatment system was approximately 0.25 gallons per minute (gpm). Periodically, and following effluent sampling and receipt of analytical testing results, the influent rate from each pump down area cell was incrementally increased to assess the ability of the system to effectively treat the groundwater contributed to the system from the pump down area. System testing ceased on October 6, 2017 following receipt of analytical testing results that documented a discharge criteria exceedence. The influent contribution rate from each pump down area cell at the time of system testing termination was approximately 2.5 gpm. The laboratory analytical results, influent feed rates, and approximate discharge quantities associated with the system testing are presented in the attached Table 1.

During the system testing period, it was observed that system fouling frequently occurred likely due to the increased chemistry needs (i.e., chemical addition) to effectively treat the groundwater. This resulted in more frequent system cleaning necessary to continue treatment system operations. The generation of system concentrate (reject water) also increased significantly during the system testing requiring additional off-site disposition of the water.

Based on the testing results, the existing groundwater treatment system appears capable of successfully treating groundwater with up to 1.5 gpm from each of the pump down area cells being combined into the total groundwater stream entering the treatment system. However, use of the existing groundwater treatment system for long-term management of the groundwater recovered from the pump down area does not appear viable at this time due to the following:

- The estimated recovery of groundwater necessary for maintenance of the target level within the pump down area is approximately 1.5 gpm from each area with pumping operations occurring the equivalent of 24 hours per day, seven days per week. Due to treatment system operational limitations and maintenance requirements, 24/7 operation of the existing system cannot be assumed. The ability to consistently and effectively treat groundwater with a contribution of approximately 2.25-2.5 gpm from the pump down area cells is more likely to be required to maintain the target elevation in each cell when taking into account the system limitations. The testing has demonstrated the successful treatment of a contribution of greater than approximately 2.0 gpm is not achievable.
- The arsenic concentrations in the groundwater contributed from the pump down area during the testing period appear to be relatively low when compared to historical sampling results from the monitoring wells in the area. As drawdown continues within the area to achieve the target elevation the arsenic concentrations will likely increase as more groundwater is contributed from the deeper portions of the aquifer. It is expected that as arsenic concentrations increase in the system influent, a reduction in the feed rate from the pump down area would likely need to occur to maintain compliance with the WDPES discharge criteria. A reduction in the feed rate introduces the likelihood that the target elevation may not be maintained long-term.
- The need for increased chemical addition to effectively remove the arsenic from the groundwater to achieve discharge criteria has been determined to severely “stress” the existing treatment system. Increased system maintenance, thereby, reducing system operational time, would be necessary due to the resulting system fouling (particularly in the reverse osmosis units).
- The increased chemical addition into the system has also resulted in the generation of significantly more reject water. The reject water is temporarily stored in an onsite tank

within the groundwater treatment building, which is offloaded into tanker trucks for off-site disposition as needed (currently approximately 5 times per week). The increase volume of reject water introduces the risk of limited availability of trucks for off-site disposition, which could further reduce system operational time necessary to allow maintenance of the target elevation.

Alternatives

Tyco continues to pursue options to effectively treat/manage the groundwater being removed from the pump down area. As has been previously presented, the following potential options remain to be evaluated:

- Design, installation, and operation of additional components to the existing groundwater treatment system to enhance the treatment capability of the system.
- Design, installation, and operation of a treatment system similar to the existing groundwater treatment system. The system would be used to only treat groundwater from the pump down area and likely provide an initial "knockdown" of the arsenic concentration in the groundwater followed by incorporation of the permeate into the existing treatment.
- Design, installation, and operation of a treatment system using alternative treatment technology (such as chemical precipitation or evaporation) to address arsenic concentrations in pump down area recovered water. Tyco has already initiated discussions, including on-going bench testing activities, with a treatment contractor to assess viability of these approaches.
- Incorporation of a portion of the recovered water into the existing groundwater treatment system coupled with a bypass to allow for direct transfer of the remaining recovered water into the reject water tank for off-site disposition.
- Groundwater recovery and off-site disposition of recovered water. This approach may be seasonal or permanent.

Following determination of the treatment/management approach for the recovered groundwater, a permanent collection and conveyance also will be designed and constructed, as necessary. The collection and conveyance system may include:

- Installation of permanent pumps in the existing extractions well coupled with underground conveyance to a centralized location.
- Installation of a horizontal well or well network coupled with pumps and associated underground conveyance to a centralized location.

Tyco continues to aggressively move forward on the PDP implementation. The alternatives described above are actively being evaluated with the goal of selection, implementation of the selected alternative(s), and compliance with the target elevation requirement by year end 2018.

Closing

I trust you will find the information provided herein informative and clearly documents Tyco's continued commitment to the project. If you have any questions regarding this report, please contact Jeff Danko at 262-951-6888 or jdanko@tycoint.com.

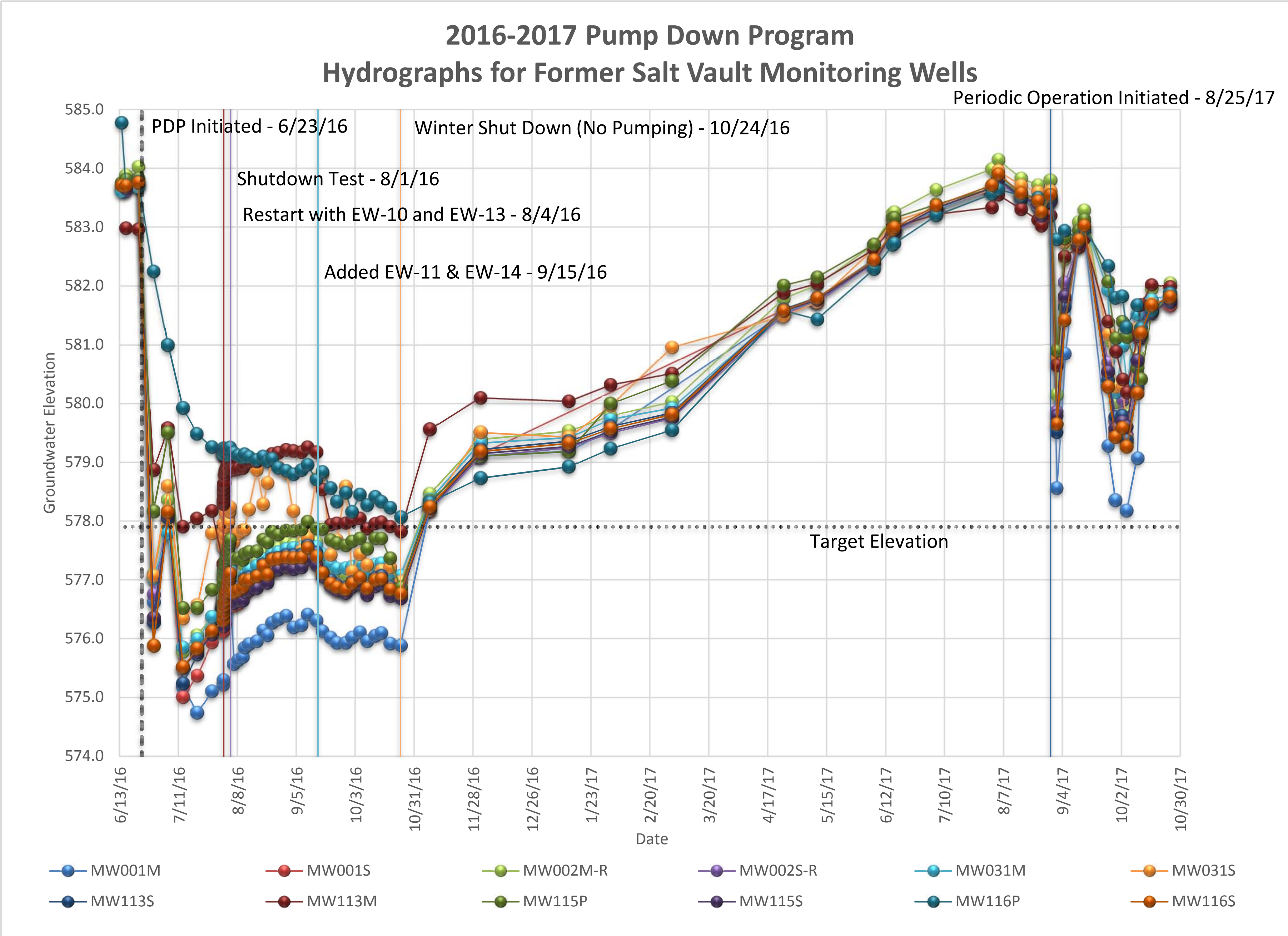
Sincerely,

Jeff Danko
Environmental Project Geologist

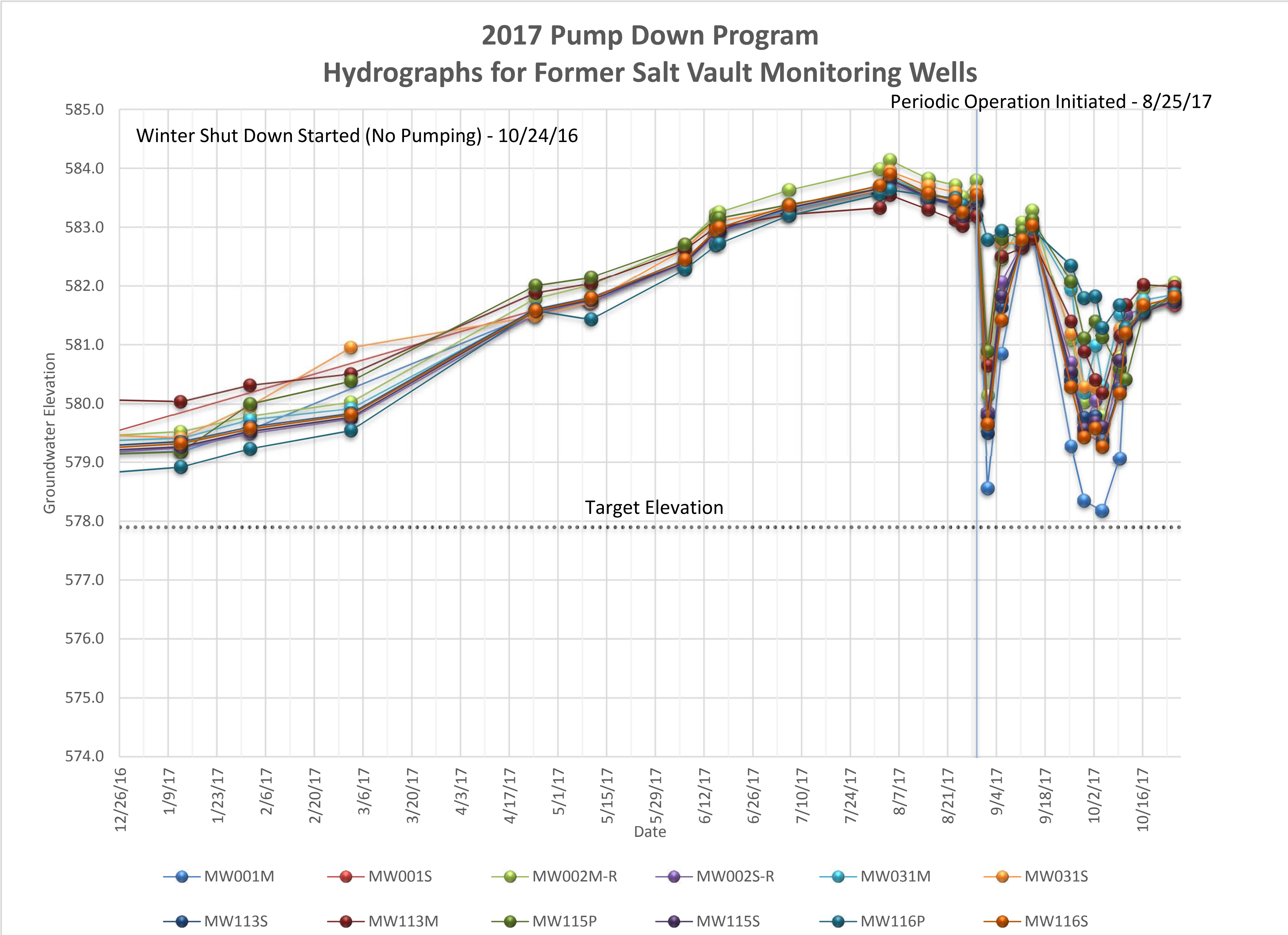
Attachments:

2016 and 2017 Pump Down Program Groundwater Elevation Monitoring Graphs
Table 1 – Groundwater Treatment System Testing – Pump Down Program

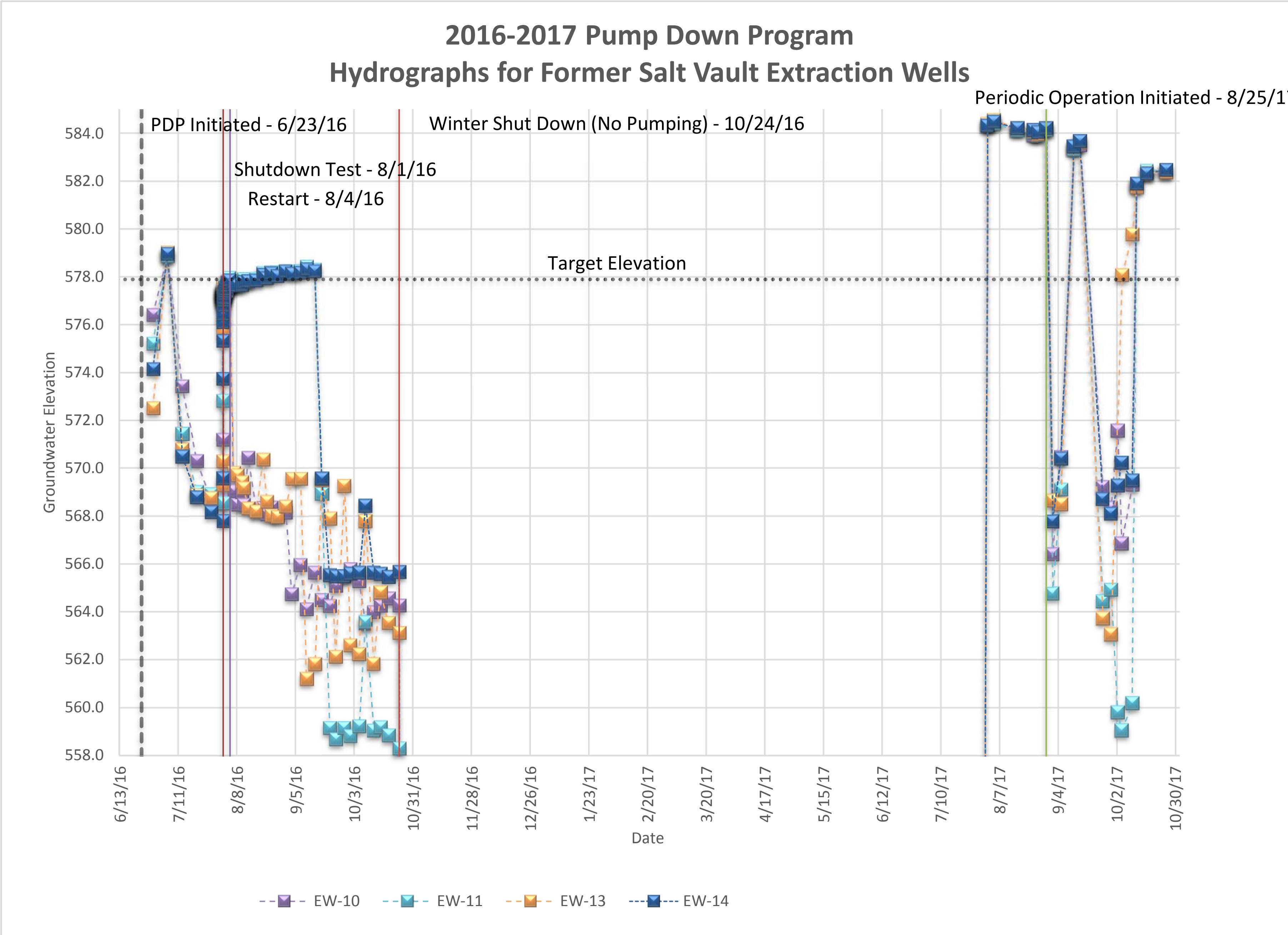
cc: Kristin DuFresne – WDNR
Mark Stanek - WDNR
Joseph Janeczek – Johnson Controls
Richard Mator – Johnson Controls
Ryan Suennen – Tyco Fire Protection Products

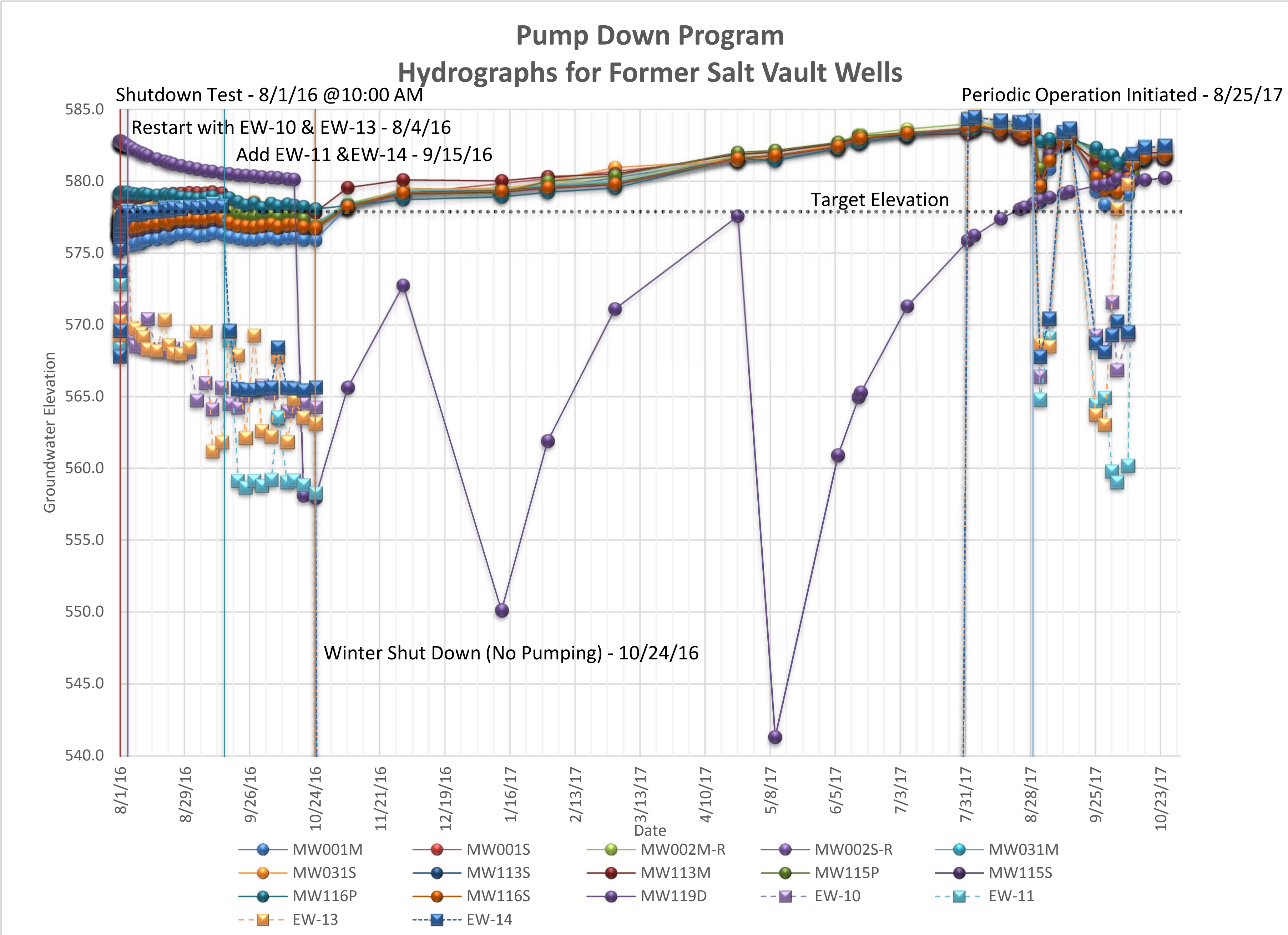


2016-2017 Pump Down Program
Hydrographs for Former Salt Vault Monitoring Wells
Periodic Operation Initiated - 8/25/17
PDP Initiated - 6/23/16
Winter Shut Down (No Pumping) - 10/24/16
Shutdown Test - 8/1/16
Restart with EW-10 and EW-13 - 8/4/16
Added EW-11 & EW-14 - 9/15/16
Target Elevation
Groundwater Elevation
585.0
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
6/13/16
7/11/16
8/8/16
9/5/16
10/3/16
10/31/16
11/28/16
12/26/16
1/23/17
2/20/17
3/20/17
4/17/17
5/15/17
6/12/17
7/10/17
8/7/17
9/4/17
10/2/17
10/30/17
Date
MW001M
MW001S
MW002M-R
MW002S-R
MW031M
MW031S
MW113S
MW113M
MW115P
MW115S
MW116P
MW116S

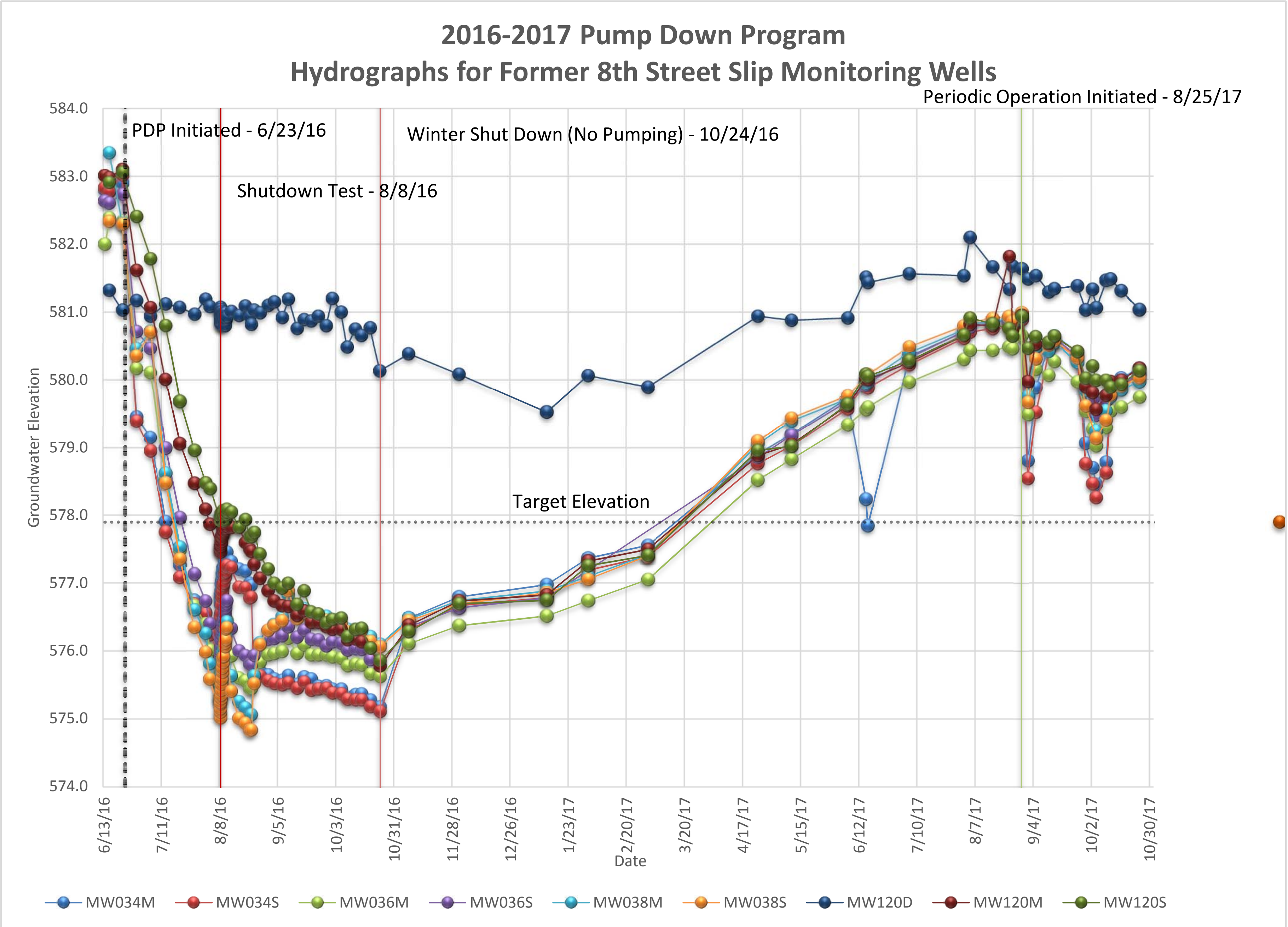


2017 Pump Down Program
Hydrographs for Former Salt Vault Monitoring Wells
Periodic Operation Initiated - 8/25/17
Winter Shut Down Started (No Pumping) - 10/24/16
Target Elevation
Groundwater Elevation
585.0
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
12/26/16
1/9/17
1/23/17
2/6/17
2/20/17
3/6/17
3/20/17
4/3/17
4/17/17
5/1/17
5/15/17
5/29/17
6/12/17
6/26/17
7/10/17
7/24/17
8/7/17
8/21/17
9/4/17
9/18/17
10/2/17
10/16/17
Date
MW001M
MW001S
MW002M-R
MW002S-R
MW031M
MW031S
MW113S
MW113M
MW115P
MW115S
MW116P
MW116S

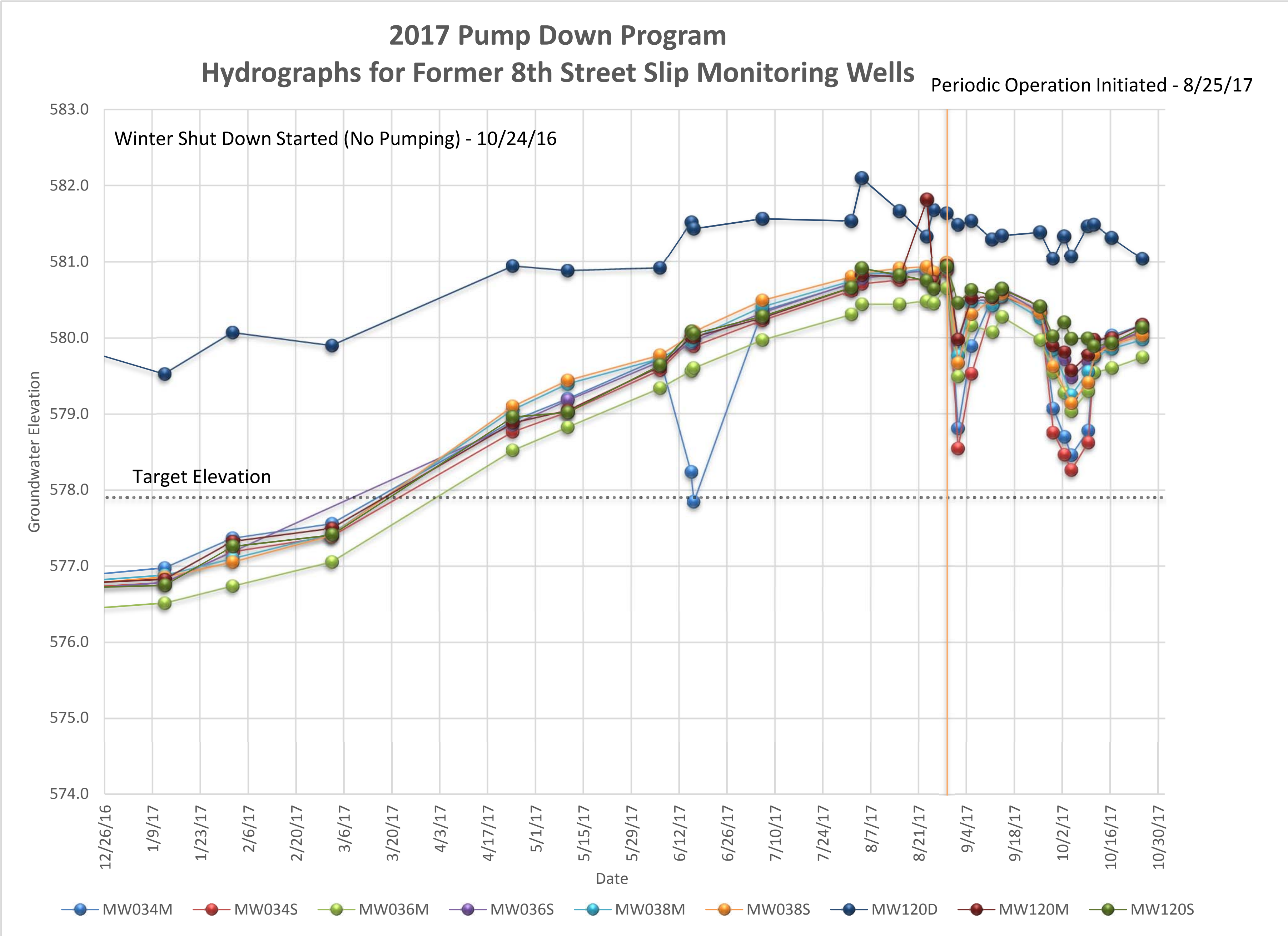

2016-2017 Pump Down Program
Hydrographs for Former Salt Vault Extraction Wells
Periodic Operation Initiated - 8/25/17
PDP Initiated - 6/23/16
Winter Shut Down (No Pumping) - 10/24/16
Shutdown Test - 8/1/16
Restart - 8/4/16
Target Elevation
Groundwater Elevation
584.0
582.0
580.0
578.0
576.0
574.0
572.0
570.0
568.0
566.0
564.0
562.0
560.0
558.0
6/13/16
7/11/16
8/8/16
9/5/16
10/3/16
10/31/16
11/28/16
12/26/16
1/23/17
2/20/17
3/20/17
4/17/17
5/15/17
6/12/17
7/10/17
8/7/17
9/4/17
10/2/17
10/30/17
Date
EW-10
EW-11
EW-13
EW-14



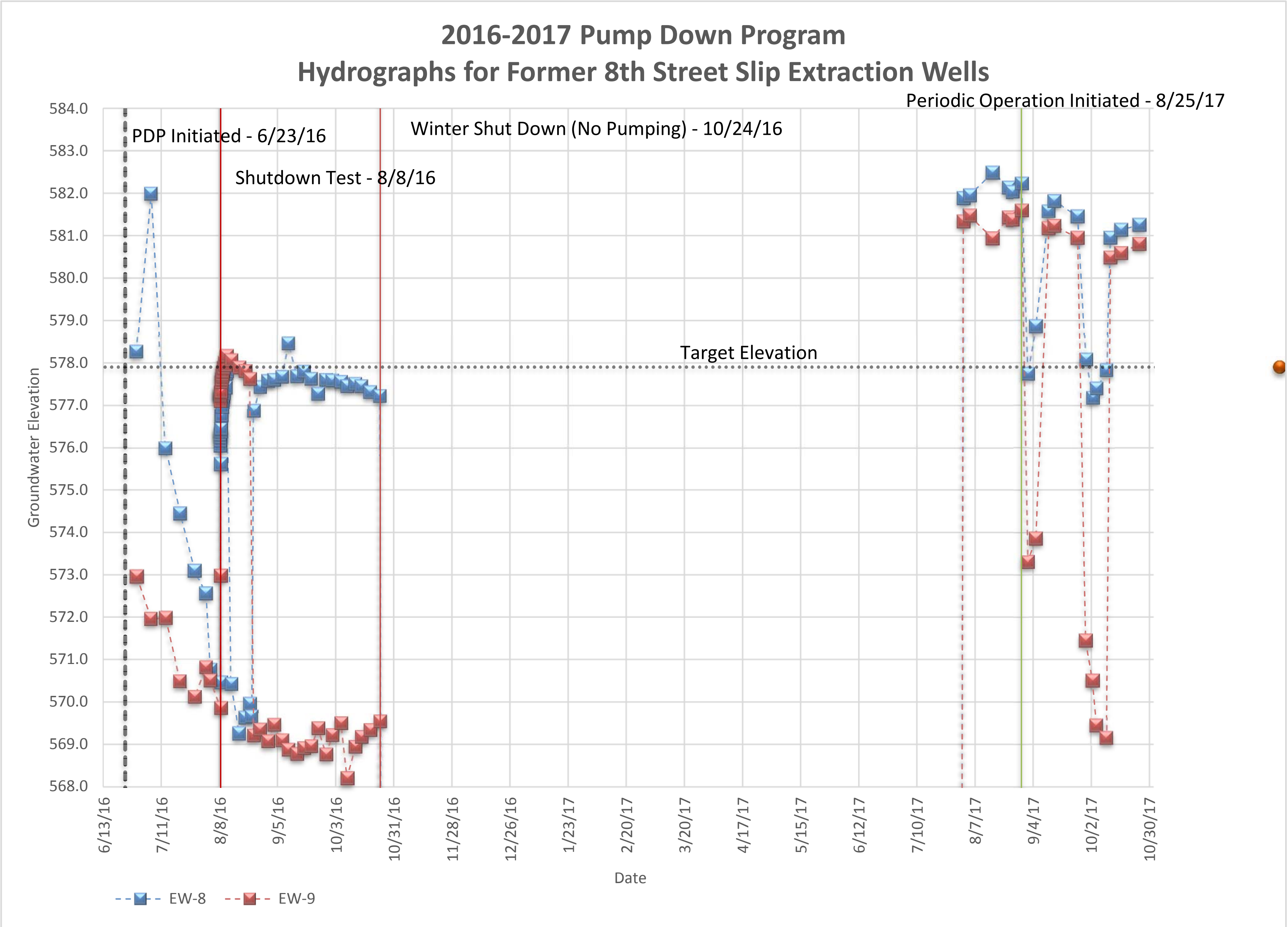
Pump Down Program
Hydrographs for Former Salt Vault Wells
Shutdown Test - 8/1/16 @10:00 AM
Periodic Operation Initiated - 8/25/17
Restart with EW-10 & EW-13 - 8/4/16
Add EW-11 &EW-14 - 9/15/16
Target Elevation
Winter Shut Down (No Pumping) - 10/24/16
Groundwater Elevation
585.0
580.0
575.0
570.0
565.0
560.0
555.0
550.0
545.0
540.0
Date
8/1/16
8/29/16
9/26/16
10/24/16
11/21/16
12/19/16
1/16/17
2/13/17
3/13/17
4/10/17
5/8/17
6/5/17
7/3/17
7/31/17
8/28/17
9/25/17
10/23/17
MW001M
MW001S
MW002M-R
MW002S-R
MW031M
MW031S
MW113S
MW113M
MW115P
MW115S
MW116P
MW116S
MW119D
EW-10
EW-11
EW-13
EW-14



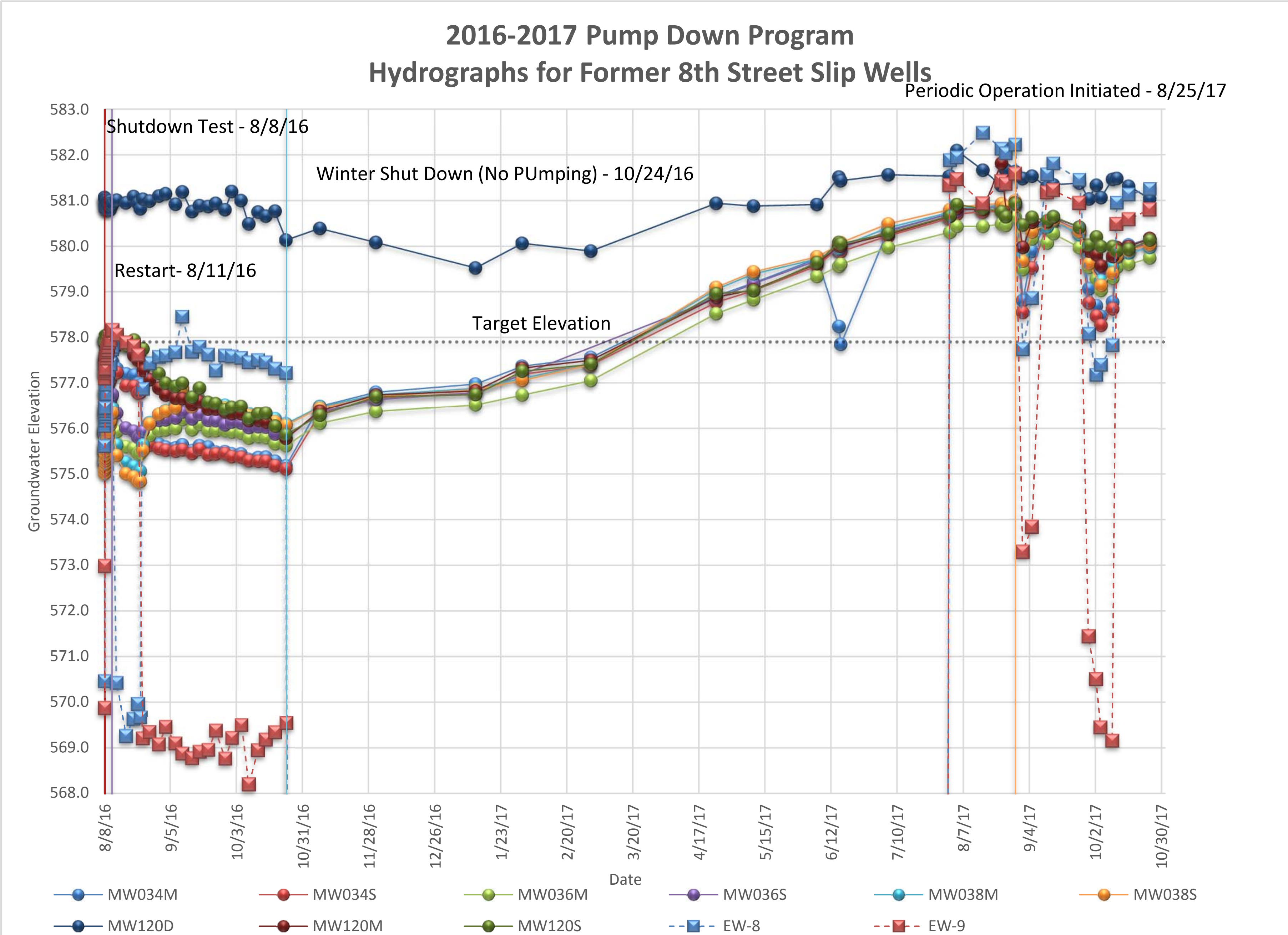
2016-2017 Pump Down Program
Hydrographs for Former 8th Street Slip Monitoring Wells
Periodic Operation Initiated - 8/25/17
PDP Initiated - 6/23/16
Winter Shut Down (No Pumping) - 10/24/16
Shutdown Test - 8/8/16
Target Elevation
Groundwater Elevation
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
6/13/16
7/11/16
8/8/16
9/5/16
10/3/16
10/31/16
11/28/16
12/26/16
1/23/17
2/20/17
3/20/17
4/17/17
5/15/17
6/12/17
7/10/17
8/7/17
9/4/17
10/2/17
10/30/17
Date
MW034M
MW034S
MW036M
MW036S
MW038M
MW038S
MW120D
MW120M
MW120S



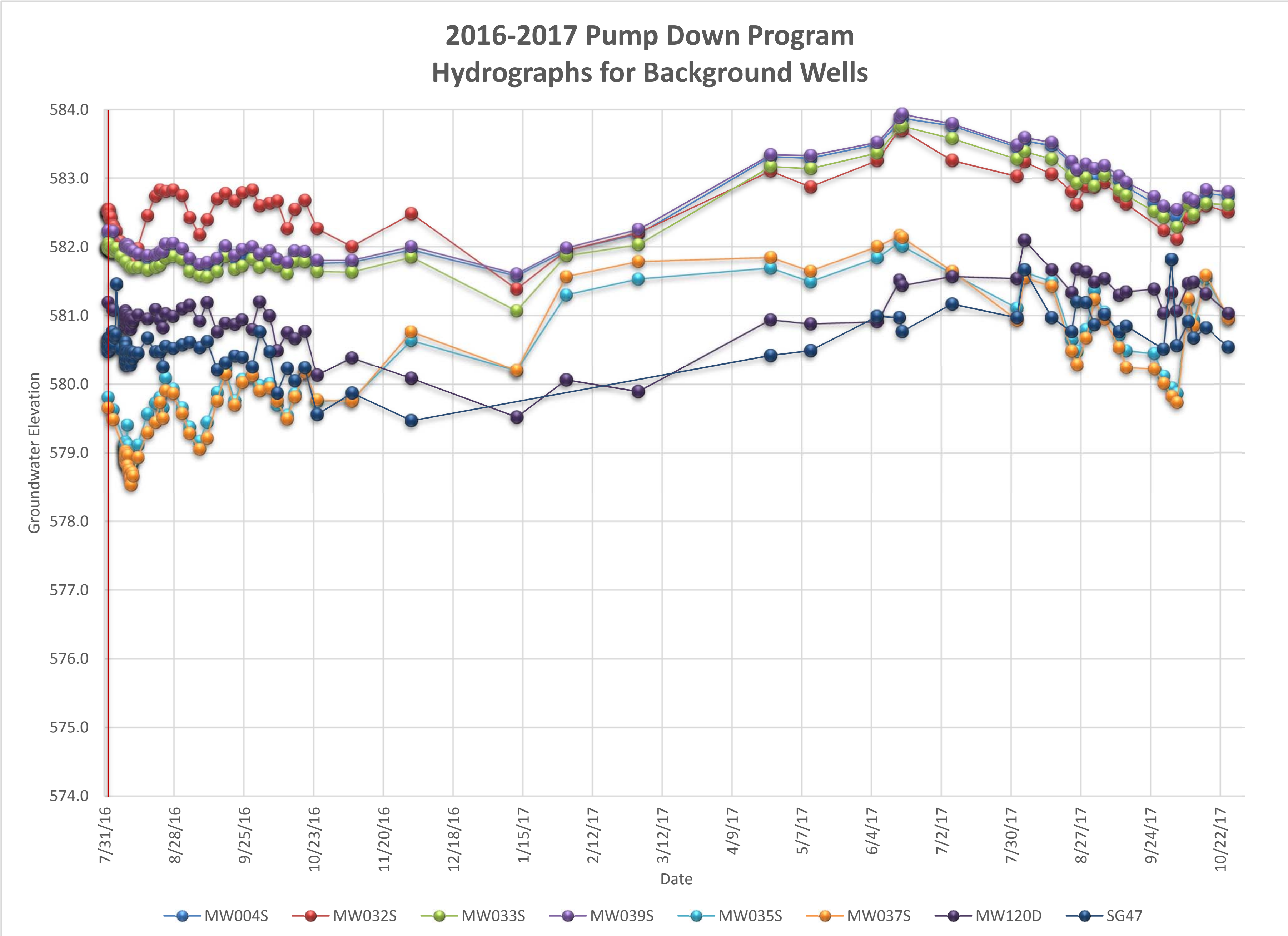
2017 Pump Down Program
Hydrographs for Former 8th Street Slip Monitoring Wells
Periodic Operation Initiated - 8/25/17
Winter Shut Down Started (No Pumping) - 10/24/16
Target Elevation
Groundwater Elevation
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
12/26/16
1/9/17
1/23/17
2/6/17
2/20/17
3/6/17
3/20/17
4/3/17
4/17/17
5/1/17
5/15/17
5/29/17
6/12/17
6/26/17
7/10/17
7/24/17
8/7/17
8/21/17
9/4/17
9/18/17
10/2/17
10/16/17
10/30/17
Date
MW034M
MW034S
MW036M
MW036S
MW038M
MW038S
MW120D
MW120M
MW120S



2016-2017 Pump Down Program
Hydrographs for Former 8th Street Slip Extraction Wells
Periodic Operation Initiated - 8/25/17
PDP Initiated - 6/23/16
Winter Shut Down (No Pumping) - 10/24/16
Shutdown Test - 8/8/16
Target Elevation
Groundwater Elevation
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
573.0
572.0
571.0
570.0
569.0
568.0
6/13/16
7/11/16
8/8/16
9/5/16
10/3/16
10/31/16
11/28/16
12/26/16
1/23/17
2/20/17
3/20/17
4/17/17
5/15/17
6/12/17
7/10/17
8/7/17
9/4/17
10/2/17
10/30/17
Date
EW-8
EW-9



2016-2017 Pump Down Program
Hydrographs for Former 8th Street Slip Wells
Periodic Operation Initiated - 8/25/17
Shutdown Test - 8/8/16
Winter Shut Down (No PUmping) - 10/24/16
Restart- 8/11/16
Target Elevation
Groundwater Elevation
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
573.0
572.0
571.0
570.0
569.0
568.0
8/8/16
9/5/16
10/3/16
10/31/16
11/28/16
12/26/16
1/23/17
2/20/17
3/20/17
4/17/17
5/15/17
6/12/17
7/10/17
8/7/17
9/4/17
10/2/17
10/30/17
Date
MW034M
MW034S
MW036M
MW036S
MW038M
MW038S
MW120D
MW120M
MW120S
EW-8
EW-9



2016-2017 Pump Down Program
Hydrographs for Background Wells
584.0
583.0
582.0
581.0
580.0
579.0
578.0
577.0
576.0
575.0
574.0
Groundwater Elevation
7/31/16
8/28/16
9/25/16
10/23/16
11/20/16
12/18/16
1/15/17
2/12/17
3/12/17
4/9/17
5/7/17
6/4/17
7/2/17
7/30/17
8/27/17
9/24/17
10/22/17
Date
MW004S
MW032S
MW033S
MW039S
MW035S
MW037S
MW120D
SG47

Table 1
Groundwater Treatment System Testing - Pump Down Program
Total Arsenic Concentrations
Tyco Fire Products LP Site
Marinette, WI

Date	Sample ID	Salt Vault Influent Concentration	Sample ID	Slip Influent Concentration	Sample ID	Composite Influent Concentration	Sample ID	Effluent Concentration	Onsite Lab Effluent Concentration	System Test Rate* (gpm)	Volume Discharged (gallons)**
8/31/2017	20170831-SV-INF	280	20170831-SL-INF	86	20170831-COM-INF	29					
9/1/2017	20170901-SV-INF	280	20170901-SL-INF	84	20170901-COM-INF	31	20170901-EFF	2.1		0.25	13207
9/5/2017	20170905-SV-INF	290	20170905-SL-INF	84	20170905-COM-INF	16	20170905-EFF	1.6		0.25	9593
9/15/2017	20170915-SV-INF	230	20170915-SL-INF	72	20170915-COM-INF	50	20170915-EFF	0.086	0.169	0.5	51191
9/18/2017	20170918-SV-INF	270	20170918-SL-INF	68	20170918-COM-INF	110	20170918-EFF	0.1	0.153	0.5	0
9/19/2017	20170919-SV-INF	270	20170919-SL-INF	69	20170919-COM-INF	33	20170919-EFF	0.1	0.11	1	12001
9/20/2017	20170920-SV-INF	260	20170920-SL-INF	67	20170920-COM-INF	47	20170920-EFF	0.2	0.229	1	0
9/21/2017	Vault	270	Slip	70	Com Inf	22	Effluent Comp	0.32	0.352	1.5	20367
9/22/2017	Vault	270	Slip	60	Com Inf	14	Effluent	0.2	0.313	1.5	10402
9/25/2017	SV	260	Slip	59	Com Inf	30	Effluent	0.13	0.238	1.5	0
9/27/2017	20170927-SV-INF	270	20170927-SL-IINF	59	20170927-COM-INF	29	20170927-EFF	0.27	0.369	1.5	7321
9/29/2017	20170929-SV-INF	280	20170929-SL-INF	57	20170929-COM-INF	45	20170929-EFF	0.63		2	8956
10/3/2017	20171003-SV-INF	290	20171003-SL-INF	57	20171003-COM-INF	43	20171003-EFF	3		2	4050
10/4/2017	20171004-SV-INF	280	20171004-SL-INF	55	20171004-COM-INF	40	20171004-EFF	3		2	4130
10/5/2017	20171005-SV-INF	310	20171005-SL-INF	61	20171005-COM-INF	46	20171005-EFF	16		2	9292
10/6/2017							20171006-EFF	2.4		2.5	

Results expressed in milligrams per liter
* - approximate influent rate contributed to groundwater treatment system from each cell at time of effluent sample collection
** - volume discharge since prior sampling event
gpm - gallons per minute
ID - identification

Composite Influent represents concentration of influent resulting from incorporation of water from Extraction Wells 1, 4, 5, 6, and 7, former Slip water and and former Salt Vault water.
[yellow highlight] - effluent concentration exceeds WPDES discharge criteria (.68 mg/l)

Attachment 2

Attachment 2

Estimates of Design Flows to Former Salt Vault and Former 8th Street Slip under 2016 Pump Down Program Conditions

Tyco Fire Products LP, Marinette, Wisconsin

Wall Section Specifications and Hydraulic Conditions

Containment Area	Wall Section	Wall Type	Wall Section ID	Bordering Area	Length of Wall Section (ft)	Approximate Elev. of Top of Glacial Till (ft amsl)	Approx. Elevation of Bottom of Wall (ft amsl)	Approx. GW Elevation within Containment Area during 2016 PDP (ft amsl)	Approx. GW Elevation in Bordering Area during 2016 PDP (ft amsl)	Head Drop Across Wall (ΔH = elev outside-elev inside) (ft)	Thickness of Slurry Wall Sections (ft)	Saturated Height of Wall Section (ft)	Notes
Former SV	North	Steel Sheet Pile	SV-SP-N	River	200	554	545	576.8	580.5	3.7	NA	36	Groundwater elevation outside wall = Avg of river staff gauge (SG-4) manual measurements 6/2016 thru 10/2017
	East	Steel Sheet Pile	SV-SP-E	8th St. Slip	440	554	544	576.8	575.7	-1.1	NA	32	Groundwater elevation outside wall = Avg elevation within 8SS at end of 2016 PDP
	South	Slurry	SV-SW-S	Main Plant	402	554	546	576.8	582.4	5.6	0.33	36	Groundwater elevation outside wall = Avg of manual measurements in main plant area shallow wells 6/2016 thru 10/2017
	West	Slurry	SV-SW-W	Main Plant	304	554	546.5	576.8	582.4	5.6	0.33	36	Groundwater elevation outside wall = Avg of manual measurements in main plant area shallow wells 6/2016 thru 10/2017
Former 8SS	North	Steel Sheet Pile	8SS-SP-N	River	360	554	545	575.7	580.5	4.8	NA	36	Groundwater elevation outside wall = Avg of river staff gauge (SG-4) manual measurements 6/2016 thru 10/2017
	East	Steel Sheet Pile	8SS-SP-E	Wetland	658	554	545	575.7	579.6	3.9	NA	35	Groundwater elevation outside wall = Avg of manual measurements in wetland area shallow wells 6/2016 thru 10/2016
	South	Steel Sheet Pile	8SS-SP-S	Upgradient	62	554	547	575.7	583.5	7.8	NA	37	Groundwater elevation outside wall estimated using recent measurements from upgradient wells MW102S and M021S-R (not monitored during PDP)
	West1	Steel Sheet Pile	8SS-SP-W1	Salt Vault	440	554	547.5	575.7	576.8	1.1	NA	29	Groundwater elevation outside wall = Avg elevation within SV at end of 2016 PDP
	West2	Steel Sheet Pile	8SS-SP-W2	Main Plant	351	554	546.5	575.7	582.4	6.7	NA	36	Groundwater elevation outside wall = Avg of manual measurements in background main plant area shallow wells 6/2016 thru 10/2017

Slurry Wall Sections - Estimates of Recharge (Q_{SW})

Q_{SW} = gradient induced flow across slurry wall section

$Q_{SW} = K \cdot i \cdot A$

			Slurry Wall Sections SV-SW-S	SV-SW-W	Units	
where:	K=		1.E-08	1.E-08	cm/s	mean of measured hydraulic conductivities during installation (Dames & Moore, 1999)[1]
		or	4.E-05	4.E-05	ft/day	
	i=		17.0	17.0	ft/ft	ΔH (ft) ÷ wall thickness (ft) (see above)
	A=		14644	10903	ft^2	Saturated surface area of wall section (outside)
	Q_{SW}=		0.05	0.04	gpm	gradient induced flow across slurry wall sections

Sheet Pile Wall Sections - Estimates of Recharge (Q_{SP})

Q_1= gradient induced flow across single sheet pile wall joint

$Q_1 = p \cdot \Delta H \cdot (\Delta H/2 + h)$

Sheet Pile Wall Sections

			Former Salt Vault SV-SP-N	SV-SP-E	Former 8th Street Slip 8SS-SP-N	8SS-SP-E	8SS-SP-S	8SS-SP-W1	8SS-SP-W2	Units	
where:	p =		3.E-10	3.E-10	3.E-10	3.E-10	3.E-10	3.E-10	3.E-10	m/s	
		or	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	ft/min	inverse joint resistance for interlocking steel sheet pile using water-swelling sealant (Adeka P210 (Roxan)) as specified through testing (Seijeimeir et al, 1995) [2] (Arcelor, 2006)[3]
	ΔH =		3.7	-1.1	4.8	3.9	7.8	1.1	6.7	ft	head difference between inside and outside wall (ΔH)
	h =		9	10	9	9	7	6.5	7.5	ft	distance from the top of the impervious bottom layer (glacial till) to the water level within the contained area
	Q_1 =		2.E-06	-6.E-07	3.E-06	3.E-06	5.E-06	5.E-07	4.E-06	ft^3/min	flow per joint
		or	1.8E-05	-4.6E-06	2.4E-05	1.9E-05	3.8E-05	3.4E-06	3.2E-05	gpm	

Q_{SP} = gradient enduced flow across length of sheet pile wall section

$Q_{SP} = Q1 \cdot n$

where:	n= L/b								number of joints/interlocks
	L=	200	440	360	658	62	440	351 ft	length of individual sheet pile wall section (see specs for Skyline Steel AZ26-700 sheet pile)
	b=	2.3	2.3	2.3	2.3	2.3	2.3	2.3 ft	system width of AZ26 sheet pile (27.56 in)
	n=	87	192	157	287	27	192	154	number of joints/interlocks
	Q_{SP}=	0.002	-0.001	0.004	0.005	0.001	0.001	0.005 gpm	flow across length of sheet pile wall section

Base of Containment Areas - Estimates of Recharge (Q_b)

Q_B = gradient induced flow across base of contained area

$Q_B = K_v \cdot i \cdot A$

			Salt Vault	8SS	Units	
where:	K_v=		2.E-06	2.E-06	cm/s	
		or	0.006	0.006	ft/day	vertical hydraulic conductivity (Kv); assumed ratio of horizontal K (K_h) to K_v in model at 50:1 (consistent with prior estimates in model); where K_h = 0.03 ft/day and K_v = 0.006 ft/day
	i=		0.12	0.17	ft/ft	vertical gradient measured in 8SS between MW-120M and D, vertical gradient in SV estimated using average M well elevations and bedrock as measured at MW-120D
	A=		104950	90350	ft^2	Area of SV and 8SS
	Q_B=		0.4	0.5	gpm	gradient induced flow across slurry wall sections

Attachment 2

Estimates of Design Flows to Former Salt Vault and Former 8th Street Slip under 2016 Pump Down Program Conditions

Tyco Fire Products LP, Marinette, Wisconsin

Rainfall Infiltration- Estimates of Recharge (Q_{rain})

Q_{rain} = contribution to flow from rainfall

$Q_{rain} = R_{rain} \cdot A$

	Salt Vault	8SS	Units	
Precipitation=	10.5	10.5	inches	Precipitation observed; 10.5 inches of rainfall recorded between June 26, 2016 and PDP pilot shutdown on October 24, 2016 (90 days preceding shutdown)
Percent infiltration=	5.0	2.5	%	percent rainfall infiltration; assumed infiltration at cracks/seams prior during PDP (prior to outfall work); assumed higher in SV due to observed ponding and drainage issues identified and addressed in 2016-2017
R_{rain}=	0.006	0.003	in/day	rainfall infiltration rate to SV and 8SS; note 0.003 in/day (1.1 in/yr) used for SV and 8SS as assumption in prior modeling work (CH2M Hill, 2014) [4]
A=	104,950	90,350	ft^2	area of SV and 8SS
Q_{rain}=	51	22	ft^3/day	rainfall recharge rate to SV and 8SS
or	0.3	0.1	gpm	

Summary of Estimated Design Flows

		Salt Vault	8SS	Units	
Gradient Induced Flow Thru Barrier Walls (Q_{SW} and Q_{SP})	Q_{SW} =	0.002	0.02	gpm	from slurry wall sections; see calculations and assumptions
	Q_{SP} =	0.09	NA	gpm	from sheet pile sections; see calculations and assumptions
	$Q_{SW} + Q_{SP}$ =	0.1	0.02	gpm	combined slurry wall and sheet pile sections
Gradient Induced Flow Thru Base (Q_B)	Q_B =	0.4	0.5	gpm	
Contribution to Flow from Rainfall (Q_{rain})	Q_{rain}=	0.3	0.1	gpm	
Combined Design Flows ($Q_{combined}$)		0.8	0.6	gpm	

Notes:

1.) Dames & Moore, 1999. Interim Barrier Construction Report, Ansul Facility, Marinette, WI.

2.) J. B. Sellmeijer, J.B., Cools, J. P. A. E., Decker, J., Post W. J. 1995. Hydraulic Resistance of Steel Sheet Pile Joints. Journal of Geotechnical Engineering, Volume 121 Issue 2. February

3.) Arcelor. 2006. Steel Sheet Piling, the Impervious Steel Sheet Pile Wall, Part 1: Design. (accessed online Dec. 6, 2017)
https://jsteeluat-public.sharepoint.com/Documents/WhitePaper/ArcelorMittal_The%20Impervious%20Steel%20Sheet%20Pile%20wall.pdf

4.) CH2M Hill, 2014. Technical Memorandum, Aquifer Testing Field Activities and Results: April and May 2014. July.