FINAL REPORT

INFORMATION SUMMARY, CONCEPTUAL MODEL, AND GROUNDWATER MODELING REPORT:

BUTTE METRO SEWER TREATMENT PLANT DEWATERING

MONTANA POLE AND TREATING PLANT SITE
Butte, Montana

DEQ Contract No. 407026 -Task Order No. 68

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ACRONYMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
bgs	Below ground surface
BRW	Butte Reduction Works
BSB	Butte-Silver Bow
CDM	Camp Dresser & McKee
cm/sec	Centimeters per second
DEQ	Montana Department of Environmental Quality
EFF	Effluent water
EPA	U.S. Environmental Protection Agency
ft/day	Feet per day
ft^2/d	Square feet per day
ft^3/d	Cubic feet per day
GAC	Granular activated carbon
GIS	Geographic information system
gpd/ft	Gallon per day per foot
gpm	Gallons per minute
GPS	Global positioning system
GWIC	Ground-Water Information Center (GWIC) at the MBMG (http://mbmggwic.mtech.edu/).
HCC	Hydraulic Control Channel
HDPE	High density polyethylene
I-90	Interstate 90
K	Hydraulic conductivity
LAO	Lower Area One
LNAPL	Light nonaqueous phase liquid
LTU	Land treatment unit
MBMG	Montana Bureau of Mines and Geology
MDHES	Montana Department of Health and Environmental Services
MPTP	Montana Pole and Treating Plant
MSL	Mean seal level
NAD27	North American Datum of 1927
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCRT	Near Creek Recovery Trench
NGVD29	National Geodetic Vertical Datum of 1929
NHRT	Near Highway Recovery Trench
O&M	Operations and maintenance
OU	Operable Unit
PAH	Polycyclic aromatic hydrocarbons
PCP	Pentachlorophenol
ppb	Parts per billion
PRP	Potentially responsible party
PVC	Polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial investigation and feasibility study
RMS	Root mean squared
ROD	Record of decision
T	Transmissivity
µg/L	Micrograms per liter
WWTP	Wastewater treatment plant

1.0 INTRODUCTION

The Montana Department of Environmental Quality (DEQ) and Tetra Tech EM Inc. (Tetra Tech) entered into Task Order No. 68 under Contract No. 407026 on April 21, 2010 to develop an improved conceptual model, including a calibrated groundwater flow model, to assess potential contaminant migration and impacts at the Montana Pole and Treating Plant (MPTP) caused by construction dewatering at the Butte Metro Sewer Treatment Plant. Tetra Tech submitted a draft report to DEQ on September 7, 2010. Technical comments on the draft report were received from Andrew P. Schmidt, P.G., U.S. Environmental Protection Agency (EPA) Regional Superfund Hydrogeologist; Rick Larson, Butte Silver Bow Public Works Department; and Mr. Joe Griffin, DEQ. Tetra Tech subsequently revised the draft report based on the comments, new information received, and additional simulations. This final report has been prepared by Tetra Tech for DEQ to fulfill the requirements specified under Task 3, Task Order No. 68.

1.1 SITE LOCATION

MPTP is a former wood treating facility located in the Silver Bow Creek Basin, in the western portion of Butte, Montana. Groundwater at the MPTP site was contaminated by the former wood treating operations, and pentachlorophenol (PCP) is the primary contaminant of concern in groundwater. Figure 1-1 illustrates the following key features in the vicinity of MPTP:

- *Silver Bow Creek* – Located north of MPTP, the portion of the creek adjacent to MPTP was reconstructed in the late 1990s as part of the Lower Area One (LAO) Operable Unit (OU) remedy construction. LAO represents a portion of the larger Silver Bow Creek/Butte Area Superfund Site, which stretches for approximately 27 miles downstream of Butte, Montana. An upstream portion of Silver Bow Creek (east of Blacktail Creek, which is east of the MPTP site) is now referred to as the Metro Storm Drain (discussed in more detail in Section 2.1).

- *Old Silver Bow Creek* – The location of "Old Silver Bow Creek" (before the LAO construction) is illustrated with dashed lines on Figure 1-1. In addition, the western portion of the Hydraulic Control Channel is a portion of Old Silver Bow Creek (indicated on Figure 2-1a). Just north of the MPTP fence line, a remnant portion of "Old Silver Bow Creek" exists as a trench.

- *Butte Metro Sewer Treatment Plant ("Wastewater Treatment Plant" or "WWTP")* – This plant, which is located north of MPTP (on the opposite side of Silver Bow Creek) is operated by Butte-Silver Bow (BSB) County. Discharge of water from the WWTP is usually to Silver Bow Creek. However, water that was extracted for dewatering at the WWTP in late 2009 and early 2010, associated with construction of upgrades at the WWTP, was discharged to the Hydraulic Control Channel.

- *Hydraulic Control Channel (HCC)* – This channel is used to transmit water from a variety of sources, such as the Metro Storm Drain, the Butte Reduction Works "BRW-01W" pond (discussed below), the "West Camp" mine area dewatering (which is located approximately 1 mile north of the MPTP site), and recent WWTP dewatering. The HCC was also designed to collect groundwater. The HCC is part of the Superfund remedy for LAO, whereby the channel collects contaminated groundwater from the Butte Hill, in addition to the other sources mentioned above, and directs these waters to the Metals Treatment Lagoons for treatment before they are discharged to Silver Bow Creek. The eastern portion of the HCC (east, south, and southwest of the WWTP) was constructed as part of the LAO in the late 1990s that was described above. The portion of the HCC that is farther west of the WWTP (north of the Metals Treatment Lagoons) represents a portion of "Old Silver Bow Creek."

- Metals Treatment Lagoons – Located west of the WWTP, these lagoons are used to treat water in the HCC for metals before it is discharged to Silver Bow Creek. The Metals Treatment Lagoons are owned and operated by BP-ARCO as part of the Superfund remedy and are not the responsibility of BSB County government.

- Butte Reduction Works (BRW) Ponds – These ponds, located north of Silver Bow Creek and east of the WWTP, are an expression of the water table. Three of the ponds have names, as illustrated on Figure 1-1 (BRW-01W, BRW-01E, and BRW-00). The BRW-01W pond has historically discharged water to the HCC via a discharge pipe, and recently the BRW-01E pond was directly connected to the BRW-01W pond. There are plans to directly connect the BRW-00 pond to the BRW-01E pond in the near future. The BRW ponds are owned and operated by BP-ARCO as part of the Superfund remedy and are not the responsibility of BSB County government.

- Selected Remedy Components at MPTP – Features highlighted on Figure 1-1 associated with the remedy at MPTP include the following:

    - *Near Creek Recovery Trench (NCRT)* – Collects contaminated groundwater just south of Silver Bow Creek for treatment at the MPTP water treatment plant.

    - *Near Highway Recovery Trench (NHRT)* – Collects impacted groundwater just north of Interstate-90 (I-90) for treatment at the MPTP water treatment plant.

    - *MPTP Water Treatment Plant* – Location where extracted water from the MPTP is treated. The treated water is primarily discharged to Silver Bow Creek, though several other discharge options are available (discussed later).

      Land Treatment Unit (LTU) and Retention Pond – Located in the southeastern corner of the MPTP site, excavated soils from the MPTP site have been treated at the LTU using biological treatment. Water is re-circulated between the retention pond and the LTU. The retention pond and LTU are not in contact with the groundwater flow system.

Other features noted on Figure 1-1 include roads near MPTP, Blacktail Creek (a tributary of Silver Bow Creek), a wetlands area south of Blacktail Creek (east of MPTP), and a sediment pond for storm water located north of the BRW ponds.

1.2 PURPOSE OF THIS REPORT

MPTP staff[1] became concerned in November 2009 when groundwater levels at the MPTP site were observed to be at historical lows, despite generally high water levels in the spring and early summer of 2009 caused by injection of treated water at MPTP in February 2009 followed by high levels of spring and early summer precipitation. MPTP staff subsequently learned that significant dewatering was under way at the WWTP, located on the opposite (north) side of Silver Bow Creek, related to upgrades at the

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[1] In this document, the term "MPTP staff" refers to individuals at the DEQ who manage the remedy at MPTP, plus contractors to DEQ, including individuals at the Montana Bureau of Mines and Geology (MBMG) who have operated the active groundwater remedy under contract to DEQ. Operation of the MPTP plant was recently transferred from MBMG to Tetra Tech (subsequent to the draft report prepared for this study).

WWTP. The upgrades at the WWTP are required by an Administrative Order on Consent (AOC) issued by DEQ Enforcement to bring the treatment system into compliance with nitrate discharge regulations. Two recent periods of significant dewatering have occurred, referred to as the "Phase 1 Dewatering:"

- Period 1of the dewatering began on August 13, 2009, and ended on February 3, 2010. During this period, the daily extraction rate associated with the dewatering was generally between 200 and 300 gallons per minute (gpm), though infrequently the rate was slightly higher or lower.

- Period 2 of the dewatering began on March 28, 2010, and ended on April 21, 2010. During this period, the daily extraction rate associated with dewatering was generally between 250 and 300 gpm, though for the first 5 days the rate was slightly higher (initially on the order of 450 gpm averaged over the first 2 days).

Upon learning of the dewatering activities taking place, MPTP staff initiated collection of additional water level and water quality data, both north and south of Silver Bow Creek. The water level data clearly indicate that dewatering at the WWTP causes a water level response on both sides of Silver Bow Creek. The water quality data indicate that concentrations of PCP (the primary contaminant of concern at the MPTP) are above standards in groundwater samples collected north of Silver Bow Creek, including samples of the groundwater extracted by the WWTP dewatering pumps. In addition, the period of WWTP dewatering (and associated lower water levels) corresponded with a period of significantly reduced PCP concentrations extracted from the NHRT component of the MPTP groundwater remedy.

DEQ and EPA Region 8 have raised the following questions regarding dewatering events at the WWTP:

- Is it likely that the elevated PCP concentrations observed in groundwater north of Silver Bow Creek (during and after the Phase 1 WWTP dewatering) were the result of the dewatering activities pulling PCP-impacted groundwater from the MPTP site beneath Silver Bow Creek and the HCC?

- Does the drawdown at the MPTP site caused by dewatering at the WWTP cause negative impacts at the MPTP, including the following:

    - Does extended WWTP dewatering compromise the effectiveness of plume capture provided by the MPTP recovery trenches?

    - Does extended WWTP dewatering potentially reduce the amount of contaminant mass removed by the MPTP recovery trenches by lowering the water table below the most impacted zone of residual impacts for an extended period of time?

    - Does extended WWTP dewatering change the groundwater flow directions in a manner that leads to contamination of otherwise clean areas, and/or to changes in the observed shape of the PCP plume in a manner that compromises the ability to assess long-term performance of the MPTP groundwater remedy?

- What impacts may result if future dewatering is longer in duration and/or deeper than in late 2009 and early 2010?

- If dewatering at the WWTP removes water impacted by PCP (which appears to be the case), is there potential for subsequent degradation of surface water or groundwater from the discharge of that water to the HCC or Silver Bow Creek?

- If there are negative impacts caused by the WWTP dewatering, are there viable approaches to potentially mitigate those impacts.

DEQ has contracted Tetra Tech to attempt to address the questions listed above. The purpose of this report is to summarize information related to recent dewatering at the WWTP and to document an initial conceptual model on the impacts of dewatering at the WWTP at MPTP with respect to groundwater flow, contaminant transport, and remedy operations. This report also includes a summary of groundwater modeling performed as part of this effort. This report is not intended to present all historical information regarding the MPTP site and surrounding sites (which is extensive); rather, the intent of this report is to assemble and highlight information that is most pertinent to issues related to the WWTP dewatering and associated impacts.

1.3 KICK-OFF MEETING SUMMARY AND INFORMATION REVIEWED

A project kick-off meeting was held in Helena and Butte on May 19 and May 20, 2010. The following were present for the entire meeting:

- Lisa DeWitt, DEQ
- Roger Hoogerheide, EPA Region 8
- Rob Greenwald, GeoTrans Inc. (Tetra Tech)
- Dan Buffalo, Tetra Tech

On the morning of May 19, 2010, the following personnel were interviewed at the Tetra Tech office in Helena:

- Scott Murphy, Morrison and Maierle, Inc. (engineering consultant for BSB)
- Elizabeth Erickson, Water & Environmental Technologies (hydrogeology consultant for BSB)

On the afternoon of May 19, 2010, a site visit at the MPTP was conducted with:

- Tom Bowler, MBMG[2] (Montana Pole engineer and operations and maintenance (O&M) operator)

On the morning of May 20, 2010, discussions were conducted at Montana Tech in Butte with:

- John Metesh, MBMG (performed previous groundwater modeling)
- Tom Bowler, MBMG (Montana Pole engineer and O&M operator)

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[2] Mr. Bowler was with MBMG at the time of the meeting and during the vast majority of work performed for this study. Mr. Bowler continues to operate the MPTP plant, but currently is an employee of Tetra Tech. Mr. Bowler is referenced as an MBMG employee in this report for items where he provided information while he was working for MBMG.

In addition to information gathered during these discussions, the information listed below was provided to Tetra Tech (or obtained by Tetra Tech) for this effort:

Reports

- Draft Tech Memo (7/6/10): Investigation of PCP Migration in the LAO and Evaluation of Mitigation Alternatives (MBMG) — Includes Well Logs for recently installed wells 10-16/17/18 and 10-19/20/21
- MPTP Draft Annual Report 2009 without Appendices (Tetra Tech) — Digital
- MPTP Annual Report 2008 (Tetra Tech) — PDF
- MPTP Annual Report 2007 (Tetra Tech) — Digital
- MPTP Second Five-Year Review 2006 (DEQ) — PDF
- Modeling Memorandum (7/19/04) from Ted Duaime — PDF
- Modeling section from 2001 MPTP Annual Report — PDF
- MPTP Record of Decision (ROD) 1993 — PDF
- MPTP Remedial Investigation (RI) Report 1993 (James M. Montgomery) — PDF
- Lower Area One (LAO) Construction Report, Volumes 1-6, 2002 (HKM Engineering and Anderson Engineering) — PDF, except many drawings not included
- Groundwater Modeling Report 1993 (Roy F. Weston) — Hardcopy
- Near Creek Trench Field Investigation, February 2007 (Camp Dresser & McKee [CDM]) — Hardcopy
- MPTP Phase 1 Construction Report 2001(CDM) — Hardcopy
- Montana Pole Cleanup Update, April 2010 (EPA and DEQ) — Hardcopy
- Wastewater Treatment Facility Geotechnical Investigation Report and Foundation Design Recommendations for Proposed Site Improvements, March 1995 (MSE, Inc.) — PDF
- SUPPLEMENT to Butte Silver Bow Wastewater Treatment Facility Geotechnical Investigation Report and Foundation Design Recommendations for Proposed Site Improvements, describing aquifer test at WWTP discharge well, June 1995 (MSE, Inc.) — PDF
- Thesis — Mobility of Pentachlorophenol at the Montana Pole NPL Site, May 1993 (Darrel M. Stordahl)

Other Electronic Files

- Transducer data files provided Andy Bobst (MBMG)
- CD with scanned copies of selected large maps (Figures 11-12 to 11-14 and Figures 13-1 to 13-3) from Lower Area One Construction Report
- Documents provided by Scott Murphy regarding layout of WWTP, water levels around WWTP, and pumping rates associated with dewatering in late 2009 and early 2010
- Topography map from 1897, provided by EPA, illustrating old streams

- Three DVDs provided by DEQ with CAD and geographic information system (GIS) type files, including AutoCAD drawings, ARC GIS files, and Excel spreadsheets with well coordinates
- Two CDs provided by Tom Bowler with information including water level and water quality data at MPTP and LAO, treatment plant data for MPTP, well coordinates, and various diagrams
- CD provided by Lisa DeWitt with lithology information
- Four images provided by EPA regarding LAO remedy concepts
- PDF map illustrating approximate location of recently installed wells 10-01 to 10-15 (pre-survey), plus global positioning system (GPS) coordinates (latitude-longitude in decimals) for recently installed wells 10-01 to 10-21, provided by Tom Bowler. Subsequently, Brad Hollamon of Pioneer Technical Services forwarded GPS coordinates for horizontal in North American Datum of 1983 (NAD83) FT (reportedly within 0.05-foot accuracy) and for vertical measuring point in North American Datum Vertical Datum of 1988 (NAVD 88) FT (reportedly within 0.10-foot accuracy) for 10-01 to 10-15 and 10-19 to 10-21. Dates for this survey were not provided, but it presumably took place during summer of 2010. Subsequent to that survey, the State performed surveying (in early August 2010) in the same coordinate systems, to an accuracy of within approximately 0.01 foot in the vertical. These data were provided by Lisa DeWitt.
- Informal regional water level contour map (PDF) by MBMG (date and values not available), provided by Tom Bowler
- E-mails from DEQ and Pioneer Technical Services containing information regarding the BRW Ponds
- E-mail from Tom Bowler regarding measuring points at MPTP monitoring wells over time
- Updated MPTP Water Levels through May 27, 2010, sent by DEQ
- Water quality data results from June 2010 sampling sent by Tom Bowler (MBMG)
- Sketch of location where "trench flooding" from MPTP treatment plant effluent is occurring, provided by Tom Bowler (MBMG)
- Tetra Tech obtained historical daily precipitation data for Butte, Montana, from Weather Underground (wunderground.com)
- Emails between Tetra Tech and Tom Bowler (MBMG) regarding measuring point elevation at well BMW-9A, August 24, 2010
- Various other e-mails

Other Hardcopy Files

- Large map with labels for selected well locations north and south of Silver Bow Creek provided by DEQ
- Large map illustrating previous MPTP groundwater recovery features (prior to current remedy) provided by Tom Bowler
- 11- by 17-inch map by with MPTP injection cells hand-labeled by Tom Bowler
- Well logs for recently installed monitoring wells near Silver Bow Creek (wells 10-01 to 10-15) – the well logs for 10-16/17/18 and 10-19/20/21 were provided electronically

- Four pages of current MPTP recovery system as-built diagrams provided by Tom Bowler

In addition, data including stratigraphy descriptions at wells, and well logs, are available from the Ground-Water Information Center (GWIC) at MBMG (http://mbmggwic.mtech.edu/).

1.4 PREVIOUS MODELING

Roy F. Weston performed simple groundwater modeling for the MPTP site in 1993 to evaluate remedial measures. This simplified analytical element modeling was conducted using the SLAEM code. Numerical modeling was also performed in 2001 and 2004 by John Metesh of MBMG to evaluate specific issues related to reinjection of treated water. Those simulations were performed with the MODFLOW code using Groundwater Vistas. However, Mr. Metesh advised that this modeling was not intended to be used for an area larger than the immediate MPTP site or for issues other than those which were being evaluated at the time. Neither of these modeling efforts provides a significant starting point for the modeling in this project.

1.5 STRUCTURE OF THIS REPORT

This draft report is organized as follows:

Section 2.0: Information Regarding Physical Features

- Silver Bow Creek (Current and Historical)
- Hydraulic Control Channel
- Metals Treatment Lagoons
- WWTP Structures
- BRW Ponds
- MPTP Remedy Features (Current)
- Power Poles (Potential Continuing Source for PCP)
- Coordinate Systems and Datums

Section 3.0: Summary of Hydrogeology
- Hydrostratigraphic Units
- Hydraulic Parameters
- Groundwater Flow Patterns
- Precipitation and Net Recharge

Section 4.0: Recent Dewatering and Related Actions
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- BRW Pond Activities
- Enhanced Recharge of Treated Water at MPTP
- Enhanced Monitoring of Water Levels and Water Quality

Section 5.0: Summary of Water Level Responses to Dewatering

Section 6.0: Summary of Water Quality Observations During/After Recent Dewatering

Section 7.0: Initial Conceptual Model Regarding Impacts of WWTP Recent Dewatering on MPTP Site

Section 8.0: Groundwater Modeling

- Modeling Objectives
- Software Used
- Model Extent, Grid, and Layering
- Boundary Conditions
- Numerical Solution
- Approach to Model Calibration
- Steady-State Calibration Results
- Transient Calibration Results
- Discussion of Model Calibration and Sensitivity Analysis
- Simulations For Potential Mitigation Strategies

Section 9.0: Recommendations

2.0 INFORMATION REGARDING PHYSICAL FEATURES

This section describes physical features that are potentially significant in terms of the impacts of the WWTP dewatering at MPTP. Figure 2-1a and Figure 2-1b illustrate monitoring locations in the vicinity of MPTP and the WWTP. These figures are at the same scale, but Figure 2-1a extends farther west and Figure 2-1b extends farther south. These figures illustrate groundwater monitoring wells and surface water monitoring locations. As noted on the figures, different well names are used for the same well in different portions of site data, and the well names on these figures in some cases reflect the "alias" well names for the wells included in Appendix B (which presents a listing of wells with coordinates and elevations).

2.1 SILVER BOW CREEK (CURRENT AND HISTORICAL)

Silver Bow Creek is located north of MPTP and south of the WWTP. Flow in the creek is from east to west. As mentioned earlier, the portion of the creek adjacent to MPTP was reconstructed as part of the LAO construction in the late 1990s. Figure 2-1a illustrates the locations of Silver Bow Creek and Old Silver Bow Creek. Figure 2-1a also illustrates elevations of the bottom of the reconstructed portion of Silver Bow Creek from LAO Phase 1 Construction Report. That report also refers to the reconstructed Silver Bow Creek as the "Low Flow Channel."

Figure 2-2 illustrates the location of three cross-sections presented in the Phase 1 LAO Construction report, and Figures 2-3 to 2-5 present annotated versions of those cross-sections to highlight the "new" stream channel versus the original stream channel. These sections also illustrate the extent to which the original ground was excavated and the elevation of the new stream channel versus the HCC. The LAO Phase 1 Construction Report states the following:

> *"Silver Bow Creek was reconstructed with specified materials from local borrow sources so the invert elevation of the channel is slightly above groundwater elevation. A Hydraulic Control Channel (HCC) was constructed on the north side of the reconstructed Silver Bow Creek flood channel to keep contaminated surface runoff and groundwater from the Butte Hill separated from the new channel."*

Based on the MPTP RI, Old Silver Bow Creek was in contact with groundwater before this reconstruction and was generally a gaining stream though the LAO before reconstruction. However, the new Silver Bow Creek was designed to generally be above groundwater to avoid discharge of contaminated surface runoff and groundwater into the creek. It was clarified during the kick-off meeting on May 19 and 20, 2010, that the concern addressed by this design was metals. The design allows for surface runoff and groundwater contaminated by metals to discharge to the HCC rather than Silver Bow Creek, and water in the HCC is then treated in the Metals Treatment Lagoons. It was also stated during the kickoff meeting of May 19 and 20, 2010, that the intent was for the reconstructed Silver Bow Creek channel to be relatively impermeable, such that not much leakage to groundwater would be expected under normal conditions, and not much groundwater would discharge to the creek when water tables were abnormally high. However, the degree of connection (potential for leakage) between the current Silver Bow Creek and groundwater near the MPTP site is not specifically detailed in the LAO Phase 1 Construction Report and is not well established.

The portion of Silver Bow Creek adjacent to the MPTP site receives inflow from upstream as it enters the vicinity of the site. This flow is now primarily from Blacktail Creek because the upstream water associated with the Metro Storm Drain is diverted into the HCC for metals treatment. During storms, Silver Bow Creek also receives water from the sediment pond (north of the BRW ponds) which is illustrated on Figure 2-6. Water from that sediment pond was deemed mostly clean such that it can be discharged directly to Silver Bow Creek rather than the HCC (it does not require treatment in the Metals Treatment Lagoons). Downstream of the MPTP site, Silver Bow Creek receives significant flow from the discharge of the WWTP (through a discharge pipe) and from the discharge from the HCC after the water passes through the Metals Treatment Lagoons (through a discharge pipe located near the eastern portion of the westernmost lagoon).

A remnant portion of Old Silver Bow Creek exists between the NCRT trench and Silver Bow Creek, in the form of a trench. Tom Bowler (MBMG) reported during the site visit on May 19 and 20, 2010, that beginning March 12, 2010, he dammed up the discharge location of the MPTP water treatment system so that this remnant portion of Old Silver Bow Creek would fill with water in an attempt to raise water levels that had been lowered by dewatering at the WWTP. There is believed to be a poor connection between the remnant portion of Old Silver Bow Creek and groundwater in this area based on the vegetation and detritus in the trench.

The stage of Silver Bow Creek is monitored at sampling location SS-06A adjacent to the MPTP (location illustrated on Figure 2-1a). Several locations on Silver Bow Creek are monitored for PCP, including SS-06A (adjacent to MPTP), SW-05 (downstream of MPTP), and SW-03/SS-07A (farther downstream, after the discharge from the Metals Treatment Lagoons and the WWTP to Silver Bow Creek).

2.2 HYDRAULIC CONTROL CHANNEL

The LAO Phase 1 Construction Report states the following:

> *"The Hydraulic Control Channel (HCC) runs east-west through LAO paralleling the floodplain and is located on the north side of the Flood Control Dike. The purpose of the HCC is to route surface water, ground water, and storm water around the [Low Flow Channel (i.e., Silver Bow Creek)]. Because the invert elevation of the HCC is lower than the Low Flow Channel, the HCC acts as a groundwater interceptor trench. Portions of the HCC are constructed and portions are made up of the original Silver Bow Creek Channel."*

As discussed earlier, the HCC is intended to route water requiring treatment for metals to the Metals Treatment Lagoons. Figure 2-6 illustrates locations where the eastern (upstream) portion of the HCC receives water, based on a sketch provided by Tom Bowler of MBMG. These locations include the Metro Storm Drain (the original upstream portion of Silver Bow Creek east of Blacktail Creek), pumped water from the "West Camp" mine area (which is located approximately 1 mile north of the MPTP site and includes the Travona Mine), and water from the BRW ponds. The HCC also received water from dewatering at the WWTP in late 2009 and early 2010. Based on HCC stage levels during the Phase 1 dewatering, it appears that a discharge point for WWTP dewatering into the HCC was between locations HCC-01B and HCC-02A.

Figure 2-1a illustrates the elevations of the bottom of the HCC in the constructed portions based on the Phase 1 LAO Construction Report and also indicates the portion of the HCC that is the Old Silver Bow Creek (north of the Metals Treatment Lagoons). By comparing the elevations of the bottom of the HCC versus the bottom of Silver Bow Creek on Figure 2-1a, it is apparent that the HCC is generally 1 to 2 feet lower than reconstructed Silver Bow Creek in the area adjacent to MPTP.

Water levels in the HCC are monitored at multiple points along the HCC, illustrated on Figure 2-1a (HCC-01 through HCC-07). Location HCC-07 is also referred to as SW-06. Several locations on the HCC are monitored for PCP, including HCC-01 (adjacent to MPTP) and HCC-07/SW06 (located at the western end of the HCC).

Based on information provided by Brad Hollamon of Pioneer Technical Services, the flow in the HCC is typically on the order of 800 to 1,000 gpm, and approximate flow rates for the sources of this combined flow are as follows:

- Approximately 500 to 600 gpm from the Metro Storm Drain
- Approximately 200 gpm from the "West Camp" Dewatering
- Approximately 100 to 200 gpm from the BRW ponds

The discharge rate of groundwater into the HCC has not been quantified. Recent dewatering at the WWTP in fall 2009 and spring 2010, which was generally on the order of 200 to 300 gpm, was also discharged to the HCC.

2.3 METALS TREATMENT LAGOONS

These lagoons are located north of Silver Bow Creek and west of the WWTP. The lagoons, operated by Pioneer Technical Services for ARCO, treat water that enters from the HCC for metals using lime. The metals precipitate and settle as water moves through the series of lagoons. The lagoons are not designed to treat PCP. Tetra Tech is not aware of the detailed operational procedures for these lagoons. However, there are a series of points where water levels in the lagoons are monitored, illustrated on Figure 2-1a (locations A1, A2, A3, B3, C3, D2, D3, D4), and periodic water levels from August 2007 through November 2009 were provided to Tetra Tech and are illustrated on Figure 2-7. Based on these data, it is apparent that the pond with the highest elevation is A-1, and the pond with the lowest elevation is D-4. The treated water is discharged to Silver Bow Creek through a discharge pipe from the eastern side of the westernmost lagoon (the lagoon with location D-4). It is believed that water is diverted into several different lagoons from various portions of the HCC. For instance, water that still remains in the HCC near the western end of the HCC (near monitoring location HCC-07/SW-06) may be diverted into the westernmost pond, which would suggest that some of the HCC water may pass through only one treatment lagoon before discharge to Silver Bow Creek.

2.4 WWTP STRUCTURES

Information on the WWTP structures was provided by Scott Murphy of Morrison and Maierle, Inc. (engineering consultant for BSB). Key structures at the WWTP are labeled on Figure 2-8. The detailed drawings that were provided are included in Appendix D. Much of the WWTP infrastructure is constructed below ground, and dewatering is required for routine maintenance as well as for major construction. Three pumps are identified, and at least two of these pumps (Pump-1 and Pump-2) are used for dewatering via a network of underground piping constructed around the various site features. The locations of the three pumps are illustrated on Figure 2-8 and are summarized below:

- Pump-1 is located in a manhole-like structure in between the two clarifiers and is identified in other documents as "Pumping Well" and "Manhole." Pump-1 dewaters the two clarifiers and the Aeration Basins north of the clarifiers. The drain elevations are:
    - West clarifier: 5,417.55 feet mean sea level (MSL) NGVD29
    - East clarifier: 5,413.55 feet MSL NGVD29
    - Aeration basins: 5,416.30 feet MSL NGVD29

- Pump-2 is located in a manhole-like structure south of the clarifiers and is identified in other documents as “Meter No. 2” and “East Sump.” Pump-2 dewaters the aerobic digester and the previous chlorine contact basin #2 (now an ultraviolet structure). The drain elevations are:

    - Aerobic digester: 5,422.05 feet MSL NGVD29
    - Chlorine basin #2: 5,415.05 feet MSL NGVD29

- Pump-3 is located west of Pump-1 and is identified in other documents as “West Sump.” It was not reportedly pumped during dewatering in late 2009 and early 2010. No other information regarding this pump was provided.

Before the Phase 1 dewatering that started in August 2009, extracted water from any dewatering was directed to the effluent channel from the WWTP and was discharged directly to Silver Bow Creek along with plant effluent. However, extracted water was discharged to the HCC during the Phase 1 dewatering that occurred from August 2009 to April 2010.

Tetra Tech indicated during the site visit in May 2010 that there was presumably substantial dewatering that occurred when the WWTP was constructed, providing a potential for PCP from the MPTP to have been drawn toward the WWTP at that time. DEQ believes that the original Silver Bow Creek provided a substantial enough hydraulic barrier to flow to have prevented underflow of groundwater caused by dewatering at that time. At that time, Silver Bow Creek was the regional point of discharge for the alluvial aquifer, and it was likely in good hydraulic connection with the aquifer. Furthermore, the reported flow in Silver Bow Creek near MPTP reported in the RI was on the order of 10 cfs (approximately 4,500 gpm), which far exceeds the likely rate of extraction for dewatering. These items suggest that original Silver Bow Creek provided a substantial enough hydraulic barrier to flow to have prevented underflow of groundwater caused by dewatering at the time of construction, but there are no specific data available to state with certainty.

2.5 BRW PONDS

These ponds, which are located north of Silver Bow Creek and east of the WWTP, are operated by Pioneer Technical Services for ARCO. The BRW-01W pond has historically discharged water to the HCC via a discharge pipe (approximate location illustrated on Figure 2-6). These ponds represent a surface expression of the water table, and water level data for the three named ponds are indicated on Figure 2-9. These data include a period in late 2009 (coincident with the Phase 1 dewatering at the WWTP) when the BRW-01W pond was dewatered to allow construction of structures to connect the BRW-01E pond to the BRW-01W pond. Mr. Hollamon indicated the target elevation for the BRW-01W pond during this construction was 5,424.0 feet MSL NGVD29. This dewatering is also discussed in Section 4.2 of this report. After that connection was completed in late December 2009, the elevation of the BRW-01E pond became coincident with the elevation of the BRW-01W pond. Data from a transducer subsequently installed at location BRW-01W (included in Figure 2-9) suggests another period of pond dewatering occurred from approximately February 14 to February 24, 2010, and another period from April 28 to May 12, 2010. The elevation of the BRW-00 pond declined slightly in spring 2010 compared with prior conditions. According to Mr. Hollamon, there are plans to directly connect the BRW-00 pond to the BRW-01E pond in the near future.

2.6 MPTP REMEDY FEATURES (CURRENT)

This summary focuses on the physical features of the current groundwater remedy at MPTP. As mentioned earlier, the retention pond and LTU associated with the soil remedy are not believed to be in connection with groundwater.

Groundwater is collected at the NCRT and the NHRT and routed to the MPTP treatment plant (locations illustrated on Figure 1-1). Lisa DeWitt of DEQ provided hard-copy "as- built" figures for these trenches at the site meeting on 5/20/10. Observations include the following:

- *NHRT* – This trench is located just north of I-90. The collection pipe for the NHRT is indicated as 8-inch slotted high density polyethylene (HDPE) with no slope and an invert elevation of 5,418 feet MSL. A product recovery pipe at the NHRT is at a higher elevation (5,427 feet MSL) and is 24-inch slotted HDPE. The NHRT has 80-mil HDPE on north wall of trench intended to augment the collection of light nonaqeuous phase liquid (LNAPL) product and prevent migration of LNAPL beyond the NHRT. In August 2009, the eastern manhole for the NHRT was removed along with a cleanout in advance of construction on I-90.

- *NCRT* – This trench is located near the northern MPTP fence line. The collection pipe for the NCRT is indicated as 8-inch slotted HDPE with no slope and an invert elevation of 5,415 feet MSL.

Tom Bowler (MBMG) indicated during the site visit on May 19, 2010, that each trench is pumped from only the west end. In addition, both Mr. Bowler and John Metesh noted at the meeting on May 20, 2010, that water levels at the west end of the NCRT are lower than at the east end, suggesting there may be more extraction from the western portion or some collapse of the trench in the middle. Mr. Bowler also suggested that the NCRT was built near a trench from an earlier phase of the groundwater remedy at MPTP, which could have caused a partial trench collapse.

Mr. Bowler said at the site visit on May 19, 2010 that up until approximately 2009 the flow rates that had been reported for the NCRT and NHRT were being overestimated due to flow meter issues which have recently been resolved and corrected. Mr. Bowler indicated that the spreadsheet he provided to Tetra Tech for this current work contains corrected values that he feels are most reliable. However, he noted that flow rate values used in previous modeling by John Metesh and in the "Near Creek Trench Investigation" by CDM in 2007 were likely not correct, so reports on those efforts must be used with caution with regard to the trench flow rates. Based on values in the reports versus the corrected values, it appears that primarily the NHRT values were modified.

Extraction rates over time at the NCRT and NHRT are illustrated on Figure 2-10. This figure illustrates that the total extraction rate has increased in recent years to approximately 335 gpm, whereas before 2004 the total extraction rate was generally less than 250 gpm. During the recent periods of dewatering at the WWTP, the extraction rates at the MPTP trenches have been essentially constant, with extraction rates of approximately 210 gpm at the NCRT and 125 gpm at the NHRT.

Extracted PCP concentrations over time at the extraction trenches are illustrated on Figure 2-11. Extracted concentrations of PCP have always been lower at the NCRT versus the NHRT, and concentrations of PCP at both extraction trenches have been declining over time. A sharp decline in PCP concentrations at the NHRT occurred during Phase 1 dewatering. Concentrations dropped from 236 µg/L on August 10, 2009, shortly before dewatering began, to a low of 28.6 µg/L on January 27, 2010, near the end of dewatering, and then rebounded back to approximately 200 µg/L after the WWTP dewatering was terminated. The concentration of PCP extracted at the NCRT has been below 10 µg/L since early 2003 (versus a groundwater standard of 1 µg/L), but was generally less than 5 µg/L during the WWTP dewatering. There is an apparent correlation on these figures between the WWTP dewatering and lower influent concentrations at the NHRT and, to a lesser degree, the NCRT.

Water is treated at the MPTP water treatment plant using granular activated carbon (GAC) with no additional metals treatment and is generally discharged to Silver Bow Creek near the northwestern corner of the MPTP site. Treated water can also be used to replenish the retention pond adjacent to the LTU (though that has usually not been needed), and treated water can also be injected into a series of injection cells that were constructed on the MPTP property. There are nine injection cells on the MPTP property north of I-90 and eight injection cells on the MPTP property south of I-90. These injection cells consist of buried perforated pipes, and the precise configuration is poorly described in site documents. Mr. Bowler (MBMG) provided a sketch of the injection cell locations. There have been periods of time where some of the treated water has been recharged to one or more of these cells, but not during the time period that was the focus of this study.

2.7 POWER POLES (POTENTIAL CONTINUING SOURCE OF PCP)

Three power poles located north of the NCRT and MPTP fence are illustrated on Figure 2-1a. These power poles are potentially significant because soils beneath these power poles could not be excavated during the soil remedy at MPTP. Thus, there is a potential for there to be residual LNAPL beneath these power poles that might serve as a continuing source of dissolved PCP impacts in groundwater. Although all three power poles are south of the current Silver Bow Creek, only the southernmost of the three power poles (located northeast of well MW-87-3 and located just west of the ND-06 monitoring cluster) was located on the MPTP side of Old Silver Bow Creek . During the time of plant operations, free-phase oil that contained PCP was known to extend to Old Silver Bow Creek, so there is an enhanced possibility that soil beneath this southernmost power pole could be contaminated relative to the other two poles. The other poles could have been affected after Old Silver Bow Creek was reconstructed.

Figure 2-12 is based on a figure from CDM's 2007 "Near Creek Trench Investigation" with annotations added by Tetra Tech to illustrate the potential significance of the southernmost power pole. This figure includes PCP concentrations observed in shallow monitoring wells on both sides of the NCRT. Key observations include the following:

- On the north side of the recovery trench, there are extremely high concentrations of PCP (greater than 1,000 µg/L) at monitoring points located between the power pole described above and the NCRT (ND-06-S and NCTR-02-1)

- The concentrations entering the NCRT from the south side (the MPTP side) are lower than from the north side (the power pole side)

- The concentrations of PCP near the edges of the NCRT are low.

This pattern of PCP concentration strongly suggests the potential for a continuing source of dissolved PCP impacts beneath this power pole, with localized groundwater flow toward the NCRT (because of the extraction in the NCRT) resulting in the high concentrations of PCP observed at ND-06-S and NCTR-02-1. The fact that there are very low concentrations at the edges of the NCRT strongly suggests that these very high concentrations at ND-06-S and NCTR-02-1 are not a result of transport of PCP around the NCRT. Furthermore, the fact that extracted concentrations from the NCRT are generally below 10 µg/L suggests that these higher concentrations between the power pole and the NCRT are being diluted in the NCRT by water entering other portions of the trench (farther east and west, as well as from deeper horizons where PCP concentrations are still significant but lower). The Near Creek Trench Investigation indicated that “intermediate depth” wells near these poles contained PCP at concentrations greater than 200 µg/L (for example, PCP concentrations of 166 µg/L at MW-87-3 in November 2006 and 196 µg/L at N-D-06-1 in November 2006).

These power poles are located between MPTP and the WWTP, and it is possible that dewatering at the WWTP could cause groundwater contaminated by PCP from this area to be pulled toward the WWTP. This possibility is discussed further in later sections of this report.

2.8 COORDINATE SYSTEMS AND DATUMS

Horizontal Coordinate System

The following horizontal coordinate system is being used for this project:

Montana State Plane, North American Datum of 1983 (NAD 83) (feet)

Many of the data provided for the MPTP and WWTP sites are in this coordinate system. However, some data for the MPTP site and the surrounding sites are in Montana State Plane (Southern Zone), NAD 27 (feet). The difference between these coordinate systems for several wells is provided below:

Differences in horizontal coordinate systems for a few wells at MPTP

		MONTANA STATE PLANE (NAD83) (S.I. FEET)			MONTANA STATE PLANE SOUTH ZONE - 2503 (NAD27) (U.S. FEET)	
DEQ WELL ID		NORTHING	EASTING		NORTHING	EASTING
96-E		649843.46	1194632.77		740693.69	1226022.51
96-F		649365.71	1193672.36		740214.91	1225062.18
96-G		649618.47	1193254.93		740467.40	1224644.38
96-H		650026.32	1193198.07		740875.35	1224587.14
96-K		650890.17	1193257.50		741739.57	1224645.83

In some cases, coordinates are also provided in latitude-longitude (decimal degrees). When needed, software such as CORPSCON is used to convert coordinates to the desired system.

Vertical Coordinate System

The following vertical datum is being used for this project:

National Geodetic Vertical Datum of 1929 (NGVD 29) (feet)

Many of the data provided for the MPTP are based on this datum. However, some data for MPTP use the NAVD 88 (feet) datum rather than NGVD 29 (feet). There is a 4.22 foot difference between these vertical coordinate systems. The difference between these coordinate systems for several wells is provided below:

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Differences in vertical coordinate systems for a few wells at MPTP:

DEQ WELL ID	NAVD88 (U.S. FEET) TOP PVC ELEVATION FROM LEVELS	NAVD88 (U.S. FEET) TOP CASING ELEVATION FROM GPS	NAVD88 (U.S. FEET) GROUND ELEVATION FROM GPS	NGVD29 (U.S. FEET) TOP PVC ELEVATION FROM LEVELS	NGVD29 (U.S. FEET) TOP CASING ELEVATION FROM GPS	NGVD29 (U.S. FEET) GROUND ELEVATION FROM GPS
96-E	5458.66	5459.18	5457.33	5454.44	5454.96	5453.11
96-F	5469.86	5470.47	5470.39	5465.64	5466.25	5466.17
96-G	5480.15	5480.54	5479.24	5475.93	5476.32	5475.02
96-H	5462.80	5463.35	5461.13	5458.58	5459.13	5456.91
96-K	5439.72	5440.36	5437.65	5435.50	5436.14	5433.43

In addition, many of the data for the WWTP are based on a plant datum. Based on information provided by Scott Murphy of Morrison and Maierle, Inc. (engineering consultant for BSB), these values can be converted to the NGVD 29 (feet) datum by adding 5,344.55 to the elevations shown on the plans. This conversion was provided on a site plan for the WWTP from 1977, and Mr. Murphy assumes it is a conversion to NGVD 29 (feet) since the map precedes the potential use of the 1988 datum.

Notes about Measurement Points for Water Levels at MPTP

Review of MPTP water level data indicates that different measurement points are used over time for individual wells, based on different survey data over time. Mr. Bowler (MBMG) indicated that there are different survey data over the years for a number of reasons. The most frequent reason is that wells are damaged or extended during construction and a new survey is needed. For instance, if a well is extended, a new survey is done and provides the new measuring point elevation from that point forward. Thus, the water level elevations for that well are computed using different measuring point elevations for different time periods.

Tetra Tech noted that the measurement points for MPTP wells used for calculation of water levels by MBMG differed consistently (by approximately 0.2 feet) from "top of PVC" elevations provided by the State (which are the top of PVC elevations included in Appendix B). The values provided by the State appear to be from a more recent survey. Tetra Tech is using the water level data provided by MBMG as provided, with the following exceptions:

- BMW-9A – Tetra Tech concluded that the water levels at BMW-9A seemed to be too low, and questioned if the measurement point used by MBMG is accurate. MBMG confirmed that the surveyed measuring point is most likely about 1.2 feet higher than the actual measuring point. This well has heaved such that the PVC extends above the casing, and could have caused the discrepancy. As a result, the measuring point elevation for calculating water levels was adjusted from 5,432.38 feet MSL (previously used by MBMG) to 5,433.58 feet MSL to account for this discrepancy, and water levels at this point were adjusted accordingly.

- There were several other points where the "top of PVC" provided by the State differed significantly from the measurement point used by MBMG (above and beyond the consistent 0.2-foot difference). For these points, the more recent state data were used, with a 0.2-foot correction applied so water levels would be consistent with those provided by MBMG. These locations are summarized below.

Well Name	State’s 2009 Survey Top of PVC Elevation (NGVD 29 ft)	Measuring Point Elevation Used by MBMG for Water Levels (NGVD 29 ft)	Difference (ft)	Add this Amount to MBMG Water Levels to Account For Consistent 0.2 ft Difference in Surveys (ft)
GS-18R	5432.37	5431.85	0.52	0.32
MW-D-95	5485.47	5485.57	-0.10	-0.30
MW-I-01	5433.64	5433.27	0.37	0.17
MW-L-96	5434.04	5433.02	1.02	0.82
MW-M-96	5434.18	5433.79	0.39	0.19
NCRTPZ-03	5438.24	5437.75	0.49	0.29
PZ-S6-02	5451.93	5453.75	-1.82	-2.02

For wells monitored by others (for example, at the WWTP), there is some variability in the measuring points in different sets of data provided, presumably as a result of the different surveys over time. In addition, some inconsistencies are likely since different wells were surveyed at different times by different surveyors, perhaps using different methods. These items cause some uncertainty in water levels. There is also the possibility that measurement points at some locations may be based on the NAVD 88 coordinate system rather than NGVD 29 coordinate system, which would introduce approximately 4.22 feet of error at these locations.

3.0 SUMMARY OF HYDROGEOLOGY

This section describes aspects of hydrogeology that are potentially significant with respect to the impacts of the WWTP dewatering at MPTP.

3.1 HYDROSTRATIGRAPHIC UNITS

Most site reports refer to the following stratigraphic units, from bottom to top:

- Bedrock
- Weathered Bedrock
- Alluvium

The bedrock is usually described as "granite" or "quartz monzonite." The MPTP and WWTP sites are located in a valley that dropped (via faulting), and the valley is filled with sediment (alluvium) derived from erosion of the surrounding hills.

During the meeting on May 19, 2010, Elizabeth Erickson (hydrogeology consultant to BSB) indicated that she considers the major hydrostratigraphic units (units where groundwater flow is significant) in the valley to be the "upper alluvium" and the combined "lower alluvium/weathered bedrock." There is often material of lower hydraulically conductivity consisting of silty clay or peat between the upper and lower alluvium (an aquitard). Consistent with other reports, Ms. Erickson indicated the weathered bedrock and lower portion of the alluvium are hard to differentiate. For instance, the WWTP Geotechnical Report by MSE states the following: "Depth to quartz monzonite bedrock is variable in the area and due to the highly weathered surface it is difficult to distinguish [from] the alluvium material overlying it. The contact between residual soil and bedrock often cannot be identified during exploratory drilling due to the gradual transition that commonly occurs." Different site documents sometimes refer to "bedrock" as the weathered bedrock and sometimes refer to "bedrock" as the "competent bedrock" which complicates the matter.

For this effort, Tetra Tech has attempted to develop information regarding the elevation of the top of competent bedrock to serve as a base for the subsequent numerical modeling. There is some groundwater flow in the fractured competent bedrock, but as per Ms. Erickson, the primary regional flow is expected to be within the overlying alluvium and weathered bedrock. Figure 3-1 presents the approximate elevation for "top of competent bedrock, ft MSL NGVD29" for locations where "competent bedrock" was clearly indicated in well logs or report descriptions:

- Depth to competent bedrock for M-1A-87, M-4A-87, and Well 17 (W-17) are provided in the MPTP RI Report, from which top of competent bedrock elevation could be calculated.

- Depth to bedrock is noted in the well log for new well 10-01, from which top of competent bedrock elevation could be estimated.

- In all other cases, lithologic information was gathered from well logs provided by the GWIC database (http://mbmggwic.mtech.edu/).

These locations are summarized on Table 3-1. Many of the records from the GWIC database clearly indicate "weathered bedrock" and "competent bedrock." Terms such as "granitic bedrock," "hard bedrock," "hard granite," and other variations were interpreted as competent bedrock. Fractured bedrock was also considered competent bedrock. Descriptions such as “decomposed bedrock,” “decomposed granite,” “weathered granite,” or similar descriptions were interpreted as weathered bedrock.

Several sources were used to determine the locations for the various wells where depth to competent bedrock was identified, as follows:

- In some cases, state plane coordinates in NAD 83 were available in other site-related documents. If state plane coordinates were available but in NAD 27, then they were converted to NAD 83 using the CORPSCON software.

- If state plane coordinates were not available, latitudes and longitude values on the “one page reports” for each well provided by the GWIC database were used, some of which were in NAD 83 while others were in NAD 27. Latitudes and longitudes given in NAD 27 were converted to latitude and longitude in NAD 83. Subsequently, all latitudes and longitudes were later converted to state plane coordinates in NAD 83.

The depth to bedrock was subtracted from approximate ground surface elevation to estimate the approximate elevation for the top of competent bedrock. The approach for assigning the ground surface elevation was as follows:

- If a surveyed ground surface was available, it was used

- If not, and a surveyed “measuring point elevation” was available, the ground surface was assumed to be 2 feet lower than the measuring point

- If surveyed measuring points were unavailable, and “altitude” was provided in the GWIC database “one page report,” it was used. It was assumed that these altitudes refer to the ground surface elevation at each well.

- If the altitude was not recorded in the “one page report,” then the NAD 83 latitudes and longitudes were used to find the location of the well on Google Earth and the elevation in Google Earth for that location was used as the ground surface elevation. Tetra Tech believes these elevations to be accurate only to within ±20 feet.

Inspection of the values for elevation of the top of competent bedrock illustrated on Figure 3-1 yields the following observations:

- As would be expected, the top of bedrock elevation is higher south and the north of the MPTP and WWTP sites and lower in the center of the valley near Silver Bow Creek. Near Silver Bow Creek, the top of competent bedrock is typically close to 5,400 feet MSL. Farther north are values such as about 5,460 feet MSL at 96-01S/D and 5,511 feet MSL at AMW-17. Farther south are values such as 5,445 feet MSL at Well 17 and 5,527 feet MSL at Worley Shane.

- Far to the east, at location GS-50, the bedrock is at a much lower elevation (5,208 feet MSL). This lower elevation is consistent with a description of the geology in the WWTP Geotechnical Investigation by MSE (see Figure 3-2, which is a generalized east-west cross-section reproduced from Figure 4 of that report).

- There are some cases where adjacent numbers are vastly different. For instance, the value at GS-25D of 5,322 feet MSL is much lower than nearby points, and the value at BMW-2D of 5341 feet MSL is much lower than nearby points.

The thickness of weathered bedrock is highly variable. As indicated in Table 3-1 no weathered bedrock is identified in the well logs in some locations, and 50 feet or more of weathered bedrock is indicated at other locations. During the RI at the MPTP site, the thickness of weathered bedrock was generally observed to be less than 10 feet. Again, since the weathered bedrock is difficult to differentiate from the alluvium, these thicknesses are likely influenced by interpretations of the different geologists.

The unconsolidated alluvium is highly variable and consists of discontinuous layers and lenses of sandy clay, clayey silty sand, sand, and gravel. The shallow subsurface has been highly disturbed in the area on and around MPTP by mining operations, excavation associated with the LAO remedy, and excavation associated with the MPTP remedy. An example of an east-west cross section near Silver Bow Creek from the MPTP RI (before excavation associated with the MPTP and LAO Remedies) is presented in Figure 3-3. This figure illustrates the relative complexity of the alluvium caused by the discontinuous nature of the deposits. The WWTP Geotechnical Investigation states that “logs can be correlated only for short distances because of the discontinuous nature of the alluvial layers (Botz, M.K., 1969).” A peat layer is located in the vicinity of Old Silver Bow Creek noted on the RI cross-section presented as Figure 3-3, as well as on some well logs for recently drilled wells 10-01 to 10-15 (such as at well 10-01 from 8 to 11.5 feet bgs, at well 10-08 from 9 to 16 feet bgs, and at well 10-13 from 7 to 10 feet bgs).

Ground surface in the northern part of the MPTP site, and at the WWTP, is at an elevation of approximately 5,430 to 5,440 feet MSL NGVD 29. The top of competent bedrock is at an elevation of approximately 5,400 feet MSL NGVD 29. Therefore, the combined thickness of the alluvium and weathered bedrock in that immediate area is approximately 30 to 40 feet, with the saturated thickness on the order of 25 to 30 feet. Tetra Tech also notes that some of the monitoring points at the WWTP that show clear response to the dewatering (such as BMW-13B) are reported to be “bedrock” wells, with elevations that appear to be lower than the top of competent bedrock. Well BMW-13B has also been affected by PCP (discussed later). The fact that wells identified as “bedrock” wells respond to pumping stresses in the alluvium and are impacted by PCP further illustrates the difficulty in clearly establishing the base of the aquifer system.

3.2 HYDRAULIC PARAMETERS

Transmissivity and Hydraulic Conductivity

There are several instances where previous reports provide values for transmissivity or hydraulic conductivity (or both), including the following:

- The MPTP Geotechnical Investigation Report states that “Aquifer tests performed in the LAO indicate the hydraulic conductivities of both the alluvium and the bedrock are in the range of 22.3 to 290 ft/d” (Hydrometrics 1990).

- The 1993 “Hydrogeology and Groundwater Modeling Report” for MPTP by Roy F. Weston states that “A pumping test was conducted by REAC personnel using recovery well EPA-2 as the pumping well on October 8, 1992….Based on the analysis, the approximate aquifer transmissivity is 3.56 ft^2/min [~5,100 f^2/d]…the saturated thickness is 30 ft…the hydraulic conductivity was calculated to be 171 ft/d.

- The MPTP RI report describes an aquifer test at well GW-15. Table 3-6 of the RI suggests that transmissivity (from the observation wells, which are likely more reliable than the pumping well) ranged from 16,500 to 22,000 gallon per day per foot (gpd/ft) (2,205 to 2,941 square feet per day [ft^2/d]). A saturated thickness of ~25 feet would suggest a hydraulic conductivity of 80 to 120 feet per day (ft/day).

- Slug tests performed during the MPTP RI exhibited a wide range of values, with calculated hydraulic conductivity from 3.8×10^{-5} to 4.2×10^{-2} centimeters per second (cm/sec) (from 0.1 to 119 ft/day). Slug testing is prone to wide variation of results, and is considered less reliable than pump testing.

It appears that a representative value for hydraulic conductivity is on the order of 100 ft/day, but conditions are expected to be highly variable because of the heterogeneity of the subsurface.

Transducers installed at many locations after January 1, 2010 (data illustrated in Appendix A), provide a robust set of data for analysis of hydraulic properties with the numerical model (see Section 8), since the time period monitored by these transducers includes many different stresses (dewatering at the WWTP and associated recovery, dewatering at the BRW ponds, and flooding of the trench just north of the NCRT).

Storage

For confined aquifers, storage is referred to as storage coefficient (typical values are 0.001 to 0.00001), and for unconfined aquifers, storage is referred to as specific yield (typical values are 0.1 to 0.2). It is considered likely at this site the storage values will indicate semi-confined conditions, with intermediate storage coefficient values of 0.001 to 0.1.

The 1993 “Hydrogeology and Groundwater Modeling Report” for MPTP (Roy F. Weston) presented results for a pump test from which an average storage coefficient of 0.024 was estimated, with a minimum of 0.0045 and a maximum of 0.064. These values are consistent with the expectations of semi-confined conditions.

The storage coefficient determines the curvature of the drawdown and recovery in response to pumping. The lower the storage coefficient, the faster the drawdown or recovery approaches its final steady-state value. Transducers installed at many locations after January 1, 2010 (data illustrated in Appendix A), provide a robust set of data for analysis of hydraulic properties with the numerical model (see Section 8), since the time period monitored by these transducers includes many different stresses (dewatering at the WWTP and associated recovery, dewatering at the BRW ponds, and flooding of the trench just north of the NCRT).

3.3 GROUNDWATER FLOW PATTERNS

Regionally, groundwater flows from the hills (primarily bedrock) into the valley (alluvium and bedrock), with groundwater flow in the valley from east to west (in the flow direction of Silver Bow Creek). Before reconstruction of Silver Bow Creek, groundwater discharged to Old Silver Bow Creek from both sides. South of Silver Bow Creek, the flow was generally to the northwest, and north of Old Silver Bow Creek, flow was generally to the southwest. Reconstruction of Silver Bow Creek and implementation of the HCC changed the flow system. The reconstructed portion of Silver Bow Creek is designed to be above groundwater, and the HCC is designed to intercept groundwater. Therefore, it is expected that groundwater will flow to the northwest toward the HCC from south of the HCC, and that groundwater will flow to the southwest toward the HCC from north of the HCC. Groundwater that does not discharge to the HCC would generally be expected to converge on an east-west axis and flow beneath the HCC or Silver Bow Creek to the west, though the exact location of such a “convergence zone” is subject to uncertainty.

Flow patterns at the MPTP site are influenced by extraction at the NCRT and NHRT. Of particular interest is the NCRT, which would be expected to form a capture zone extending some distance to the north of the NCRT. In other words, it would be expected that flow would be to the south toward the NCRT for some distance north of the NCRT, but flow would be north/northwest toward the HCC beyond that capture zone. The 2007 “Near Creek Trench Investigation” confirmed that the NCRT capture zone extends some distance to the north (based on flow direction from north to south in the area north of the NCRT), but the exact distance to the “stagnation point” was still hard to define because of the slight head difference between monitoring points.

Surface water sampling from the HCC suggests that, under typical operating conditions (without dewatering at the WWTP) there is some PCP discharging to the HCC. The PCP presumably originates from the south where the MPTP site is located, given that the groundwater at the MPTP site south of the HCC is known to be contaminated by PCP from previous operations at that site, and the HCC is designed to intercept groundwater. At sampling location HCC-7/SW-06 (at the far west end of the HCC), samples have been collected for analysis of PCP monthly for many years. Between 2006 and 2009, the results generally indicate PCP concentrations between 0.5 and 2.0 µg/L (versus groundwater standard of 1.0 µg/L). These results suggest that some groundwater contaminated by PCP is discharging to the HCC, where it is diluted by water in the HCC from other sources (the Metro Storm Drain, the West Camp water, and the BRW-01W water). Section 2.7 discussed a potential source of dissolved PCP beneath a power pole near MW-87-3 and ND-06-D and other power poles north of that pole. If the capture zone of the NCRT does not extend to this power pole (or other power poles) all of the time, then it is possible that groundwater contaminated by PCP could periodically flow north or northwest toward the HCC.

An interesting aspect of the WWTP dewatering is the potential for that dewatering to cause water levels to be drawn down below the HCC, allowing water from the south side of the HCC that might otherwise discharge to the HCC to instead be transported under the HCC and to the north of the HCC. This potential is discussed in more detail in Sections 5 and 6 of this report.

3.4 PRECIPITATION AND NET RECHARGE

Net Recharge

The MPTP RI indicates that “The climate within Butte and the surrounding vicinity is characterized by short, cool, dry summers and cold winters. Total annual precipitation measured at the Butte airport averages 11.7 inches. Records dating back to 1905 indicate that annual precipitation varies between 6.4 and 20.6 inches. May and June are generally the wettest months, during which approximately 35 percent of the total annual precipitation occurs. During an average year, over two-thirds of the precipitation falls between April and September. The net annual evaporation is estimated at 26 inches per-year (NOAA, 1939-1987).” Based on this information, it is expected that net recharge to groundwater from precipitation in the immediate vicinity of MPTP is generally small or negligible, particularly in the period being modeled (August 2009 to April 2010).

Tetra Tech obtained historical precipitation data for Butte, Montana, from Weather Underground (www.wunderground.com). The total amount of precipitation for each month was calculated from the daily precipitation levels. Daily precipitation amounts were superimposed on transducer data, as illustrated for selected wells in Figure 3-4 (GS-34S) and Figure 3-5 (BMW-13B). The following observations are made from these figures:

- Precipitation levels were relatively low for the period between January 1, 2010 (prior to transducer installation), and May 17, 2010. During this time, precipitation did not have a notable impact on water levels.
- Higher rainfall concentrations were observed beginning on May 18, 2010, and continued through the end of June. During this period of increased precipitation, a visible impact was observed with respect to the groundwater elevation.
- Rainfall was particularly heavy on June 15 and 16, 2010, and this event was concurrent with a sharp increase in water levels on those days and in the days to follow.

These observations suggest that the rainfall appears to have some effect on groundwater elevations during periods of higher precipitation, but precipitation did not seem to significantly impact water levels from the time these transducers were installed through the end of April 2010 (before later high precipitation events).

4.0 RECENT DEWATERING ACTIVITIES AND RELATED ACTIONS

4.1 WWTP DEWATERING ACTIVITIES

Two recent periods of significant dewatering have occurred at the WWTP, referred to as the "Phase 1 Dewatering:"

- Period 1 of the dewatering began on August 13, 2009, and ended on February 3, 2010. During this period, the daily extraction rate associated with the dewatering was generally between 200 and 300 gpm, though infrequently the rate was slightly higher or lower.

- Period 2 of the dewatering began on March 28, 2010, and ended on April 21, 2010. During this period, the daily extraction rate associated with the dewatering was generally between 250 and 300 gpm, though for the first 5 days the rate was slightly higher (closer to 375 gpm).

Dewatering was accomplished by extraction of water at Pump-1 and Pump-2 at the WWTP. The extraction rates are summarized on Figure 4-1. Observations from Figure 4-1 include the following:

- Pumping from August 13, 2009 to September 15, 2009 was only from Pump-1. Extraction was added at Pump-2 on September 15, 2009.

- Between September 15, 2009 and February 3, 2010 there was much more extraction from Pump-2 (approximately 175 gpm) than from Pump-1 (approximately 75 gpm).

- There was no dewatering between February 3, 2010 and March 28, 2010.

- For the second period of dewatering, between March 28, 2010 and April 21, 2010, there was much more extraction from Pump-1 (approximately 160 to 250 gpm) than from Pump-2 (approximately 100 to 150 gpm).

According to Scott Murphy of Morrison and Maierle, Inc., during the Phase 1 project the groundwater pumps were operated on level control some of the time and at other times they were operated on a timer. It is not certain exactly how the pumps were operated during any given period during the Phase 1 dewatering because specific records were not kept on the mode of operation. The information provided by Mr. Murphy indicated that dewatering was not operated in manner that led to dewatering down to the total depth of the sump, so the pumps are best represented in a numerical model based on pumping rates that were provided using the well package, rather than as drains.

Mr. Murphy noted there were several other dewatering events in September and October 2008, though each lasted only several days. Mr. Murphy indicated at the meeting on May 19, 2010, that there were also previous short-term dewatering events for routine maintenance which would also generally have been of short duration. In previous events, the extracted water was discharged to Silver Bow Creek, but the extracted water was discharged to the HCC for the Phase 1 dewatering.

4.2 BRW POND ACTIVITIES

In late 2009, construction was performed to connect the BRW-01E pond to the BRW-01W pond. According to Brad Hollamon of Pioneer Technical Services, a 4-inch trash pump or other submersible pump was placed into the southwestern corner of the BRW-01W pond and the water was pumped through a hose over the dike into the HCC (where it goes through the water treatment system for metals) to accomplish dewatering for this construction. Figure 2-9, which presents water levels in these ponds, clearly illustrates this dewatering period. The significant dewatering appears to have started sometime in September 2009, and a second pump was added on November 4, 2009, which lowered the stage of the BRW-01W pond below the staff gage. Mr. Hollamon indicated the target elevation for the BRW-01W pond during this construction was 5,424.0 feet MSL. It appears the construction work was completed on approximately December 23, 2009, and after that construction the elevation of the BRW-01W pond was generally at approximately 5,427.0 feet MSL (except during subsequent periods of pond dewatering). Data from a transducer subsequently installed at location BRW-01W (included in Figure 2-9) suggest another period of pond dewatering occurred from approximately February 14 to February 24, 2010, when the pond was reportedly dewatered to an elevation of 5,425.3 feet MSL, and another period from April 28 to May 12, 2010, when the pond was dewatered to an elevation of approximately 5,423.2 feet MSL.

For the BRW-01E pond, the elevation was approximately 5,432 feet MSL before construction of the pond connection in later 2009, and assumed to be similar to the BRW-01W pond after construction. The elevation of the BRW-00 pond declined slightly in spring 2010 relative to prior conditions. Initially, the elevation was approximately 5,434.5 feet MSL, but by late April 2010 the elevation was closer to 5,433.75 feet MSL. According to Mr. Hollamon, there are plans to directly connect the BRW-00 pond to the BRW-01E pond in the near future.

4.3 ENHANCED RECHARGE OF TREATED WATER AT MPTP

A remnant portion of Old Silver Bow Creek exists between the NCRT trench and Silver Bow Creek, in the form of a trench. Mr. Bowler (MBMG) reported in personal communications that beginning March 12, 2010, at the request of MPTP staff, he dammed up the discharge location of the MPTP water treatment system so that this remnant portion of Old Silver Bow Creek would fill with water. The approximate location where the trench flooding has occurred is illustrated on Figures 5-1 and 6-1. This trench flooding has continued to the present time, and the intent is to augment recharge to the shallow aquifer to counter-balance drawdown caused by dewatering at the WWTP. The dam keeps the water at constant elevation similar to, but slightly higher than, the elevation of the discharge pipe for the MPTP water treatment plant. The discharge pipe elevation is 5,428.23 feet NGVD 29. There appears to be a poor connection between the remnant portion of Old Silver Bow Creek and groundwater in this area based on the vegetation and detritus in the trench. The benefits of this trench flooding are currently being evaluated, and the numerical modeling can be used to help with that evaluation.

4.4 ENHANCED MONITORING OF WATER LEVELS AND WATER QUALITY

MPTP noticed declining water levels in November 2009 (several months after the MPTP dewatering began) and learned at that time that the dewatering was under way. Enhanced monitoring activities were subsequently implemented, including the following:

- A drilling program was initiated for wells 10-01 to 10-21 (see Figure 2-1a). These clustered monitoring wells are located on both sides of Silver Bow Creek and the HCC, and are located between MPTP and the WWTP.

- Transducers (“level loggers”) were installed at numerous locations on both sides of Silver Bow Creek beginning in January 2010 (locations illustrated on Figure 4-2). Results from these transducers indicated a clear water level responses on both sides of Silver Bow Creek to the extraction at the WWTP. These transducer results are discussed in Section 5.0.

- Water quality samples were collected and analyzed for PCP at locations on both sides of Silver Bow Creek, including new wells 10-01 to 10-21. These samples are significant because there are no recent PCP data for groundwater monitoring wells north of Silver Bow Creek, between MPTP and the WWTP extraction pumps, before these sampling events. There have been very minor detections of PCP that are well below the groundwater standard of 1 µg/L at one residential well located just northeast of the WWTP[3]. These recent results indicated that PCP concentrations above groundwater standards were observed in monitoring wells north of Silver Bow Creek and north of the HCC, as well as in the WWTP extraction wells, after WWTP dewatering was initiated. These results are discussed in Section 6.0.

- Increased frequency of water quality sampling at selected surface water locations.

Tetra Tech was provided with the raw data for the transducers by Andy Bobst of MBMG.

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[3] Based on information provided to Tetra Tech, no PCP data are available from monitoring wells north of Silver Bow Creek between the time of the MPTP RI (in 1993) until the recent data collected after the recent WWTP dewatering began (sampling locations and dates illustrated on Figure 6-1). Sampling for PCP was conducted during the RI at a few locations north of Old Silver Bow Creek (see Figure 4-12 of the RI). The results of sampling were ambiguous, because a screening method referred to in the RI as the “Keystone 589 Method” indicated some detections of PCP (such as 21 µg/L at GS-25 and 14.2 µg/L at GS-18), but when those wells were re-sampled with EPA Method 8040 for PCP they were non-detect. Tetra Tech interprets this to be “non-detect,” since the screening method is considered less reliable. Residential sampling north of Old Silver Bow Creek during the RI indicated non-detect for PCP. There has been recent sampling at one residential well north of Silver Bow Creek (the Bowler residence), and this well is located just northeast of the WWTP. Based on the MPTP Draft Annual Report 2009, this residential well is sampled for analysis of PCP annually, and there have typically been non-detect values for PCP between 2001 and 2009, although there have been a few detections of PCP at very low levels that are below the groundwater standard of 1.0 µg/L (such as 0.12 µg/L in 2001, 0.47 µg/L in 2007, and 0.08 µg/L in 2008). These PCP concentrations at the Bowler residence are much lower than the PCP concentrations detected north of Silver Bow Creek between MPTP and the WWTP after the WWTP dewatering began, and these low PCP concentrations at the Bowler residence could be caused by cross-contamination of equipment in the field or in the laboratory.

5.0 SUMMARY OF WATER LEVEL RESPONSES TO RECENT DEWATERING

The best illustration of the water level responses to WWTP dewatering is provided by the transducers that were installed at a large number of monitoring locations on both sides of Silver Bow Creek beginning in January 2010. Plots of water levels versus time at these transducers provided by MBMG are included in Appendix A. These plots refer to “detrended calculated DTW” and, according to Andy Bobst of MBMG, that terminology reflects the approach where the transducer values have been adjusted to match hand-measured values to remove any drift. They are adjusted by applying an adjustment factor to each measurement (weighted by time) based on the hand-measured values. Most of the transducers were installed before the first period of dewatering ended on February 3, 2010. Water levels are fairly steady just prior to February 3, indicating that a near steady-state was reached in response to the extraction that began August 13, 2009 (and in response related to the BRW-01W pond dewatering that ended December 23, 2009). Once dewatering was terminated on February 3, 2010, water levels rose sharply at many wells, with the largest responses at locations closest to the WWTP. Responses to the second phase of WWTP plant dewatering (March 28 to April 21, 2010), and to two subsequent BRW-01W pond dewatering events (February 2010 and May 2010), are also represented on the plots of transducer data.

Figure 5-1 summarizes the approximate water level changes that occurred from the time dewatering stopped on February 3, 2010 to the time dewatering was started again on March 28, 2010. Figure 5-1 differentiates relative depths of the monitoring points according to layer assigned in the numerical model (discussed in Section 8.3). Observations from Figure 5-1 include the following:

- The greatest response is at the two WWTP extraction pump locations (Pump-1 and Pump-2), with approximately 6 feet of water level change observed.

- The water level response to the termination of dewatering was observed on both sides of the HCC and both sides of Silver Bow Creek. Initially it might be expected that the HCC would provide a complete hydraulic barrier to drawdown since it is a potential source of water to the extraction pumps. However, further evaluation of water levels (discussed below) indicates that, during the dewatering, groundwater levels were lowered below the bottom of the HCC. More water flows in the HCC than was dewatered, suggesting that the HCC is imperfectly connected to groundwater. It is expected that Silver Bow Creek is also imperfectly connected to groundwater (by design), and that during dewatering the elevations of groundwater are likely below the bottom of Silver Bow Creek. As a result, Silver Bow Creek also does not provide a complete hydraulic barrier with respect to drawdown.

- There are some monitoring well clusters where the water level response appears to be muted at shallower depths. For example, the water level response is greater at deeper well BMW-9B (1.6 feet) than shallower well BMW-9A (1.0 foot). Similarly, the water level response is greater at deeper well GS-25C (2.5 feet) than shallower well GS-25 (1.1 feet). This difference is likely a result of the vertical anisotropy associated with subsurface heterogeneity. It is noted that both those well clusters are located near surface water (one near the HCC and once near Silver Bow Creek). Leakage of water from those features during dewatering, in conjunction with vertical anisotropy, could also lead to lower drawdown in the shallow wells. This issue implies that multiple model layers are appropriate for the numerical modeling.

- The new wells (10-01 to 10-15) cannot be used for Figure 5-1 because the transducers for those wells were installed after February 3, 2010.

- For wells near the enhanced recharge of treated water at MPTP that began on March 12, 2010 (in a trench that is a remnant of Old Silver Bow Creek), the effects of that recharge were not included in the estimates of recovery illustrated on Figure 5-1. The amount of recovery from prior to that trench recharge were projected forward visually to estimate the values posted on Figure 5-1. The fact that there is less recovery noted on Figure 5-1 at HCA-21 than at GS-18R and GS-14R is therefore not specifically related to the trench recharge; rather, it appears to occur because HCA-21 is a slightly shallower monitoring well that has a lower response to extraction changes at the WWTP than adjacent deeper monitoring wells (as discussed above for other shallow and deeper monitoring wells).

- Water level response to the WWTP dewatering occurred as far as nearly 1,500 feet from the WWTP extraction locations. This response provides insight regarding the needed horizontal extent of the numerical model grid so model edge boundaries do not impact simulation results.

Additional observations based on the figures in Appendix A include the following:

- At locations closest to the extraction, the recovery reaches a near-steady-state within approximately 1 month after dewatering is stopped, whereas at greater distances the recovery is still increasing after 1 month. This type of response pattern is helpful for calibrating storage coefficient in the numerical model.

- Transducers for the 15 of the new wells (10-01 to 10-15) were installed after February 3, 2010, so these points are not included on Figure 5-1. However, the response to the next period of dewatering that started on March 28, 2010, and ended on April 2, 2010, is apparent at many of the new wells (in addition to the other wells), and these responses can be assessed with the numerical model. Again, there are clusters of new wells where the response to pumping is muted at shallow depths. For example, deeper well 10-03 (screened 11.6 to 16.6 feet bgs) has a significant drawdown response, but shallower well 10-04 (screened 5.2 to 8.2 feet bgs) does not.

- The recovery curves are clearly interrupted in mid-February 2010 at locations closest to the BRW-01W pond (for example, GS-17DR and GS-16). This interruption corresponds to a clear change in the water level at the BRW-01W pond that appears to begin on approximately February 14, 2010, and appears to end on approximately February 23, 2010. A water level response to this change in the BRW-01W pond elevation is also observed in other wells, but it decreases with distance away from the BRW-01W pond. The same general responses were observed for another BRW-01W pond dewatering event that occurred in May 2010. These types of data provide some indication of the magnitude of water level responses to changes in pond elevation at the BRW-01W pond, and how that magnitude changes with distance from the pond. This information is useful for the numerical modeling.

- There is also a clear water level change at some wells in response to the flooding of the trench north of the NCRT (a remnant of Old Silver Bow Creek) that MBMG implemented on March 12, 2010. As expected, the response is greatest near the enhanced recharge at a shallow well (HCA-21). The response to trench flooding is generally limited to the shallow wells and diminishes with distance from location of the enhanced recharge. This information is useful for the numerical modeling.

A significant observation associated with the WWTP dewatering is that it causes groundwater levels to be lowered below the bottom of the HCC as is illustrated for the vicinity of BMW-13B in Figure 5-2, and for the vicinity of GS-34S in Figure 5-3. These are the only two monitoring locations between MPTP and the

WWTP that are located close to the HCC and north of the HCC with measured water level data. Observations from Figures 5-2 and 5-3 include the following:

- *Figure 5-2*. Before the Phase 1 dewatering, it is clear that flow at BMW-13 is to the south toward the HCC, since the water level at BMW-13B was higher than the stage in the HCC (based on HCC monitoring locations upstream and downstream). However, the water level at BMW-13B fell below the stage of the HCC soon after dewatering began and also fell below the bottom of the HCC. This drop in water level below the bottom of the HCC suggests that the dewatering creates the potential to pull water under the HCC from south to north. In addition, the stage at HCC-02a, which is located downstream of BMW-13B, increased nearly 1 foot when the dewatering began. However, the stage at HCC-01B, which is located upstream of BMW-13B, barely changed. This difference in response suggests a discharge point for the WWTP dewatering was likely between these two locations.

- *Figure 5-3*. Before the Phase 1 dewatering, flow at GS-34S was presumably to the south toward the HCC, since the water level at GS-34S was higher than the assumed stage in the HCC (based on HCC monitoring locations upstream and downstream, which unfortunately are each some distance away from GS-34S). However, the water level at BMW-13B fell below the stage of the HCC soon after the dewatering began, and also fell below the bottom of the HCC. This drop in water level below the bottom of the HCC suggests that the dewatering creates the potential to pull water under the HCC from south to north.

Figure 5-4 is a similar figure for groundwater elevation at BMW-9A versus the bottom elevation of adjacent Silver Bow Creek. Note that the water levels at BWM-9A have been corrected (increased by 1.2 feet) from the water level data originally provided by MBMG, based on an improved estimate of the current measuring point elevation of the well, which has heaved (as per discussions with MBMG). On Figure 5-4, the stage of Silver Bow Creek has been estimated as at least 1.0 foot above the constructed bottom elevation of the channel. This figure illustrates that the groundwater level at BMW-9a is generally below the stage of Silver Bow Creek (as per the design for the reconstructed Silver Bow Creek), such that flow would be from the creek to the aquifer, and the dewatering lowers the groundwater elevation below the bottom elevation of Silver Bow Creek.

6.0 SUMMARY OF WATER QUALITY OBSERVATIONS DURING/AFTER RECENT DEWATERING

Figure 6-1 presents the results of PCP sampling at wells located north of Silver Bow Creek and at new wells 10-01 to 10-21, conducted after the Phase 1 dewatering at the WWTP was initiated. Screened intervals are included on the figure. These results represent the only recent samples for PCP north of Silver Bow Creek between MPTP and the WWTP extraction pumps (see Section 4-4). Observations from Figure 6-1 include the following:

- PCP is detected in groundwater north of Silver Bow Creek and north of the HCC. It cannot be conclusively stated that PCP was not present in groundwater north of the HCC prior to the Phase 1 dewatering because no recent PCP results are available north of Silver Bow Creek between MPTP and the WWTP extraction pumps prior to the dewatering. However, groundwater typically flows north to south towards the HCC in that area (as discussed in Section 5.0), and the presence of PCP in groundwater north of the HCC after the dewatering began is consistent with the fact that groundwater levels were lowered below the bottom of the HCC during the Phase 1 dewatering, allowing for contaminant transport below the HCC from south to north.

- The highest PCP concentrations on Figure 6-1 are observed at new well 10-02, which is the shallowest well in the cluster located nearest to the power poles discussed in Section 2.7. Of the remaining results on Figure 6-1, the results with the highest concentrations are all located in a general path between the power poles and the WWTP extraction pumps. Coupled with the figure presented on Figure 2-12 (which showed very high PCP concentrations in groundwater north of the NCRT near the southernmost power pole), these data strongly suggest that a continuing source of PCP exists under one or more of the power poles.

- Where wells are clustered, the higher PCP concentrations are generally found in the shallower wells:
  - 10-02 is shallower than 10-15 and has higher concentrations of PCP
  - 10-15 is shallower than 10-01 and has higher concentrations of PCP
  - GS-34S is shallower than GS-34D and has higher concentrations of PCP
  - GS-25 is shallower than GS-25C and has higher concentrations of PCP (note that GS-25C is screened in bedrock, but it responds hydraulically to the WWTP dewatering and has some detections of PCP, similar to well BMW-13B, which is also screened in bedrock [slightly higher elevation than GS-25C], also responds hydraulically to WWTP dewatering, and has higher PCP concentrations than GS-25C)

  These data also suggest a nearby shallow source of PCP such as the power poles.

The sharp decline in PCP concentrations at the NHRT that occurred during Phase 1 dewatering (shown in figure 2-11) may indicate that Phase 1 dewatering caused the water table to drop below the zone of highest contaminant concentration, and that as a result capture of contaminant mass at this trench was less effective during this time.

The fact that concentrations of PCP have typically been found in sampling at HCC location HCC-7/SW-06 prior to the dewatering (discussed in Section 3.3) suggests the possibility that PCP may generally discharge to the HCC even when dewatering is not occurring at the WWTP (i.e., PCP from beneath one or more of the power poles may not be fully within the capture zone of the NCRT some or all of the time). However, the dewatering at the WWTP would be expected to reduce the capture zone of the

NCRT, increasing the potential for such migration of PCP impacted water to the north. This will be evaluated with the numerical modeling.

Surface water sampling performed during the Phase 1 dewatering indicated the following:

- At HCC-7/SW-06, at the western end of the HCC, PCP concentrations increased slightly after the Phase 1 dewatering began, to as high as approximately 2.75 µg/L (versus PCP concentrations of approximately 0.5 to 1.0 µg/L just prior to the Phase 1 dewatering). This increase may reflect that concentrations of PCP extracted by the WWTP extraction wells during the dewatering may be somewhat higher than the PCP concentrations that typically discharge from groundwater to the HCC under normal conditions. These concentrations are still just slightly above the groundwater standard of 1.0 µg/L.

- At HCC-1 (see Figure 6-1), no PCP was detected in the three samples collected during active dewatering (December 30, 2009, January 27, 2010, and April 12, 2010) but low levels of PCP were detected when dewatering was not occurring (March 8, 2010). This finding is consistent with the possibility that low levels of PCP in groundwater in that vicinity discharge to the HCC when dewatering does not occur, but flow under the HCC when dewatering does occur. This location was not sampled for PCP before the Phase 1 dewatering.

- Low levels of PCP (up to 1.7 µg/L) were detected where the Metals Treatment Lagoons discharge to Silver Bow Creek during the Phase 1 dewatering.

- PCP was not detected in the BRW-01W pond in the two samples collected during dewatering. This location was not sampled for PCP prior to the Phase 1 dewatering.

- PCP concentrations are typically detected at low concentrations (generally less than 1 µg/L) in surface water sampling at SDS-07/SW-03, which is located in Silver Bow Creek downstream of where the Metals Treatment Lagoons discharge to Silver Bow Creek and also downstream of the discharge location of the WWTP to Silver Bow Creek. Similar concentrations were observed during the Phase 1 dewatering.

- At SW-05, located on Silver Bow Creek between MPTP adjacent to the Metals Treatment Lagoons, low concentrations of PCP (generally less than 0.5 µg/L) are sometimes detected. These low concentrations may suggest that groundwater contaminated by PCP may discharge to Silver Bow Creek in some locations at some times (despite the design for Silver Bow Creek to generally be above groundwater). However, the PCP concentration at SW-05 was always non-detect during the Phase 1 dewatering, consistent with lower groundwater levels caused by the dewatering that would eliminate any discharge from groundwater to Silver Bow Creek that might otherwise occur in some locations.

7.0 INITIAL CONCEPTUAL MODEL (PRIOR TO GROUNDWATER MODELING) REGARDING IMPACTS OF WWTP PLANT DEWATERING ON MPTP SITE – KEY ITEMS

The initial conceptual model has been presented in the preceding sections of this report, and no attempt is made here to replicate all of that information. However, some key items are highlighted below.

- The dewatering at the WWTP causes a clear water level response north and south of the HCC and north and south of Silver Bow Creek.

    - The water level response to WWTP dewatering has a generally radial pattern (see Figure 5-1), particularly in the deeper portion of the alluvium and bedrock represented by layer 3 in the numerical model (discussed in Section 8.3). There is some uncertainty in the pattern of drawdown north of the WWTP since there were no observation points for drawdown in that direction.

    - The WWTP dewatering causes groundwater levels to be lowered below the bottom of the HCC, which creates the potential for groundwater contaminated by PCP to flow beneath the HCC from south to north.

    - There are some monitoring well clusters where the water level response appears to be muted at shallower depths. For example, the water level response is greater at deeper well BMW-9B (1.6 feet) than at shallower well BMW-9A (1.0 ft). Similarly, the water level response is greater at deeper well GS-25C (2.5 feet) than at shallower well GS-25 (1.1 feet). This muted response is likely caused by vertical anisotropy associated with subsurface heterogeneity. It is noted that both those well clusters are located near surface water (one near the HCC and once near Silver Bow Creek). Leakage of water from these features during dewatering, in conjunction with vertical anisotropy, could also lead to lower drawdown in the shallow wells. This variation in drawdown response can be evaluated with the numerical model, and this issue implies that more than one model layer is appropriate for the numerical modeling.

    - Water level response to the WWTP dewatering occurred as far as nearly 1,500 feet from the WWTP extraction locations. This distance provides insight regarding needed horizontal extent of the numerical model grid (at least 5,000 feet in all directions from area of primary interest) so that boundaries do not impact the simulation results.

- PCP is detected north of Silver Bow Creek and north of the HCC. It cannot be conclusively stated that PCP was not present in groundwater north of the HCC prior to the Phase 1dewatering because no recent PCP results are available north of Silver Bow Creek between MPTP and the WWTP extraction pumps before the dewatering (see Section 4.4). However, groundwater typically flows north to south toward the HCC in that area (as discussed in Section 5.0), and the presence of PCP in groundwater north of the HCC after dewatering began is consistent with the fact that groundwater levels were lowered below the bottom of the HCC during the Phase 1 dewatering, allowing for contaminant transport below the HCC from south to north.

- Dewatering at the BRW-01W pond also affects water levels, but the effects are smaller in magnitude than the WWTP plant dewatering and are more localized to the vicinity of these ponds. However, the numerical modeling can be used to illustrate how lowering the elevation of the BRW-01W pond affects water levels, flow directions, and the capture zone of the NCRT.

- Similarly, the enhanced recharge from the MPTP plant to the remnant portion of Old Silver Bow Creek affects water levels locally (and generally only in the shallow portion of the aquifer), and the numerical model can be used to illustrate how this activity alters flow directions and the capture zone of the NCRT.

- The transducer data presented in Appendix A incorporate the effects of all of these stresses, and calibration of the numerical model should attempt to reasonably match these responses. Once the model is calibrated, the flow model can be used to predict impacts to flow directions and capture zones resulting from specific stresses to the system.

- The data highly suggest that the southernmost power pole is a continuing source for dissolved PCP impacts in groundwater (for example, see Figure 2-12 and Figure 6-1). The numerical modeling (and further data analysis) can be used to evaluate the following items:

    - Is the southernmost power pole within the capture zone of the NCRT under typical conditions?

    - To what extent does dewatering at the WWTP alter the capture zone of the NCRT with respect to the location of this pole (and the other poles)?

    - To what extent does the enhanced recharge of treated water from the MPTP plant into the remnant Old Silver Bow Creek augment the capture zone of the NCRT and prevent water beneath this pole from migrating to the north? Does this enhanced recharge raise water levels high enough to cause discharge of groundwater to Silver Bow Creek? If there is also a continuing source of PCP beneath the other two power poles (north of this enhanced recharge), is it possible that the enhanced recharge augments the transport of these impacts to the north?

During the WWTP dewatering, the extracted water that contained PCP was discharged directly to the HCC. However, the data suggest it is likely that groundwater containing PCP discharges to the HCC under typical conditions as well (via groundwater discharge rather than pumping discharge). There may be a net change in impact to water quality in the HCC (and subsequently the Metals Treatment Lagoons and Silver Bow Creek) with respect to PCP, but any such change to date appears to be relatively minor.

8.0 GROUNDWATER MODELING

The groundwater modeling construction, calibration, and predictions are presented in the following sections:

- Section 8.1 – Modeling Objectives
- Section 8.2 – Software Used
- Section 8.3 – Model Extent, Grid, and Layering
- Section 8.4 – Boundary Conditions
- Section 8.5 – Numerical Solution
- Section 8.6 – Approach to Model Calibration
- Section 8.7 – Steady-State Calibration Results
- Section 8.8 – Transient Calibration Results
- Section 8.9 – Discussion of Model Calibration and Sensitivity Analysis
- Section 8.10 – Simulations for Potential Mitigation Strategies

8.1 MODELING OBJECTIVES

The objectives of this groundwater modeling effort include the following:

- Calibrate a numerical groundwater flow model that incorporates items expected to alter the flow system in the vicinity of MPTP and the WWTP and reasonably represents the groundwater flow system and responses to various stresses that occurred in late 2009 and early 2010 (WWTP dewatering and changes in water elevation at the BRW ponds).

- Use the numerical model to confirm or refute elements of the site conceptual model presented in previous sections of this report.

- Evaluate the capture zone of the NCRT under typical conditions and during dewatering at the WWTP.

- Evaluate the degree that dewatering at the BRW ponds altered the flow system and capture zone of the NCRT.

- Evaluate the amount of drawdown that occurs near the NHRT as a result of dewatering at the WWTP and as a result of dewatering at the BRW ponds.

- Evaluate the impacts of the trench flooding north of the NCRT that began in March 2010 and determine if it provides a benefit that merits continuing these efforts.

- Determine if there are other actions that can be implemented to mitigate any negative impacts associated with WWTP dewatering.

The model domain covers a larger area than the immediate vicinity of MPTP, and a simplified definition of features such as the hills north and south of the valley, Blacktail Creek, and the Metro Storm Drain is included to provide a basic representation of the regional flow system. However, no attempt is made to rigorously represent the flow system far away from the MPTP site.

8.2 SOFTWARE USED

The groundwater flow simulations were performed using the *MODFLOW-2000 code*, which simulates three-dimensional groundwater flow through a porous medium by using a finite-difference method. *Groundwater Vistas (Version 5.33 Build 21)* was the user interface software that was used to manage model input and output.

8.3 MODEL EXTENT, GRID, AND LAYERING

Areal Extent and Horizontal Grid Spacing

The model is oriented north-south (in other words, with no rotation), and the lower left-hand corner of the model grid is (1185200, 643000) in Montana State Plane Coordinates, NAD 83 (feet). The model has 211 rows and 262 columns. The grid has variable spacing, with minimum grid cell size of 10 feet by 10 feet near the NCRT, 25 feet by 25 feet near the WWTP, and maximum grid cell size of 200 feet by 200 feet. Variable grid spacing allows for more accurate matching of observed drawdown near the WWTP and the NCRT. The extent of the model grid is illustrated on Figure 8-1. The grid spacing in the immediate vicinity of the NCRT and the WWTP is illustrated in Figure 8-2.

Vertical Layering (Including Discussion of Approach for Simulating Regional Flow)

The stratigraphy in the vicinity of the MPTP site is complex, and a series of simplifications was made to perform the modeling. The model consists of three model layers:

Layer 1:	Shallow Portion of Alluvium
Layer 2:	Aquitard (where present)
Layer 3:	Deep Portion of the Alluvium plus Weathered Bedrock

As discussed earlier, the base of the aquifer is difficult to clearly define. Furthermore, not much is known about aquifer parameters and stratigraphic configuration in the regions north and south of the area of primary interest (north and south of the alluvial valley that contains Silver Bow Creek). A simplified approach was used to construct the model layering so that regional flow is reasonably represented, and so that the difference in responses to stresses between the shallow and deeper portions of the alluvium (near the MPTP site) are also reasonably represented. The assigned bottom elevations for each model layer are illustrated on Figure 8-3, and the overall approach used for representing the regional flow system is summarized below:

- In the alluvial valley, the bottom of layer 3 was established at elevation 5,400 feet MSL near the MPTP site and to the east, which is generally consistent with the top of competent bedrock presented on Figure 3-1. However, the bottom elevation was lowered west of the site, consistent with the topography (and lower elevation of Silver Bow Creek).

- In the alluvial valley, layer 2 is assigned generically as an aquitard that is 2 feet thick. The elevation of this 2-foot aquitard near the MPTP site is 5,418 to 5,420 feet MSL, and this elevation decreases toward the west. The exact elevation and thickness are not material, since the uncertainty in thickness is small relative to the uncertainty in vertical hydraulic conductivity. Layer 1 is then assigned as an unconfined aquifer (LAYCON = 1 in MODFLOW) above this aquitard.

- In the regions north and south of the alluvial valley, a simplified representation is used that combines the layering, boundary conditions, and aquifer parameters.

    - First, a relatively low bottom elevation is assigned to all three model layers (5,399 feet MSL, 5,402 feet MSL, and 5,404 feet MSL). Although these elevations do not represent the true bottom of the aquifer north and south of the alluvial valley (which is likely at higher elevation), these elevations were assigned to prevent dry cells from occurring, which makes the model unstable.

    - In this region, uniform hydraulic conductivity values are assigned in model layers 1 to 3, with no vertical anisotropy, so the combined unit north and south of the alluvial valley (which is primarily bedrock) effectively acts as one large unconfined layer (see Figure 8-5).

    - Next, a specified head boundary is used at the northern and southern edges of the model in all three layers (illustrated on Figure 8-4). The purpose of this boundary is to provide water into the aquifer that ultimately recharges the alluvial valley. The amount of water is determined by the value of specified head that is assigned and the transmissivity assigned to the aquifer at those boundaries (which in turn is controlled by the value of hydraulic conductivity which is treated as a calibration parameter).

    - Between the northern and southern edge of the model and the alluvial valley, uniform values for hydraulic conductivity are assigned in layers 1 to 3 for hydraulic conductivity, with no vertical anisotropy, so the unit (primarily bedrock) effectively acts as one large unconfined layer (see Figure 8-5). The transmissivity of this zone is controlled by the value of hydraulic conductivity assigned in the model. The value of hydraulic conductivity assigned is not intended to be a true representation of the hydraulic conductivity in these areas north and south of the alluvial valley (which are not known with any certainty); rather, combined with the bottom elevation assigned (which is intentionally set low to avoid dry cells and improve model stability), the hydraulic conductivity controls the hydraulic gradient between the specified head boundaries (at the northern and southern edge of the model) and the alluvial valley.

This approach recognizes that no attempt is being made to simulate the geometry or flow conditions in the hills (predominantly bedrock) in any detail. Rather, the approach allows water to be provided into the alluvium in the valley from the bedrock in the hills. This simplified approach has the following advantages:

- In the area of greatest interest (within the alluvial valley), it allows for differentiation of the shallow and deep portions of the alluvial aquifer, which show different responses to stresses such as dewatering at the WWTP and trench flooding north of the NCRT.

- In the areas north and south of the valley, where there is tremendous uncertainty regarding aquifer configuration and parameter values, this approach allows the amount of water entering the alluvium in the area of interest as a result of regional flow to be easily controlled, by adjusting the value of specified head at the northern and southern model boundaries or by adjusting the hydraulic conductivity value north and south of the alluvial valley.

This simplified approach provides a representation of the subsurface that is appropriate for this level of modeling. The tops and bottoms of the layers are approximations over space and are not meant to precisely represent actual stratigraphy outside the MPTP area. However, attempting a more precise specification is not necessary given the substantial heterogeneity that exists and the objectives of this modeling. Sensitivity analysis was performed to assess the extent this simplification alters the simulation results.

Layers 2 and 3 are assigned LAYCON = 3 in MODFLOW (convertible), which means that when these layers are fully saturated, the transmissivity is constant (hydraulic conductivity multiplied by aquifer thickness) and the specific storage (Ss) entered into Groundwater Vistas is multiplied by aquifer thickness to yield storage coefficient. However, the transmissivity in locations where the water table falls below the top of the layer is calculated based on the saturated thickness of the layer (water level minus bottom elevation), and the storage coefficient is based on the specific yield (Sy) entered into Groundwater Vistas.

8.4 BOUNDARY CONDITIONS

The locations of boundary conditions are summarized on Figure 8-4 and are described below.

Specified Head

Specified head boundaries were placed along portions of the northern and southern model edge to provide groundwater into the flow system (discussed in detail in Section 8.3). A head value of 5,625 feet MSL was assigned at the northern model edge, and a head value of 5,552 feet MSL was assigned at the southern model edge. These heads were selected to be generally realistic given the topography and approximate water levels observed at locations included in the GWIC on-line database, but there was no attempt to rigorously define these values based on observations. The actual values assigned were varied somewhat during steady-state model calibration to improve the overall match (raising or lowering these values has a corresponding effect throughout the model domain), which explains why a “not-so-round” value of 5,552 feet MSL was assigned in the final model rather than a “round” value such as 5,550 feet MSL. The actual amount of water supplied to the model from these boundaries is a function of the hydraulic conductivity assigned at the constant head cells.

River Package

The river package was used for the following features:

- Silver Bow Creek and HCC – These features were broken into several reaches. The stage was assigned as approximately 1 foot above the bottom elevation in portions where the features were constructed (see Figures 2-1a and 2-1b). These values were assigned using interpolation functions within Groundwater Vistas to be generally consistent with the constructed bottom elevations. The assignment of elevation was slightly refined during model calibration in some locations to improve the match with observed water level, but these adjustments were minor such that values remained reasonable with respect to the constructed values. Approximate elevations were assigned for portions of Silver Bow Creek and the HCC that were not constructed to be generally consistent with measured stages or adjacent water levels or topography. The stages for Silver Bow Creek and the HCC were assigned as constant values over time. The conductance of each reach was treated as a calibration parameter.

- Blacktail Creek and Metro Storm Drain – In both cases, stage was assigned to be generally consistent with adjacent water levels or topography. Conductance was set to a reasonably high value since these features are believed to be in good connection with groundwater. The bottom was set 1 foot below the stage.

- BRW Ponds – The stages were assigned based on values provided by Brad Hollamon of Pioneer Technical Services, and these stages varied over time (see Table 8-1). The conductance was treated as a calibration parameter. The bottom elevation was set approximately 10 feet below the typical stage.

- Trench Flooded Just North of NCRT – The conductance for periods prior to the trench flooding was set to a value very close to zero, such that the feature would have no impact on the simulation. The stage for periods where trench flooding was occurring was assigned to achieve a reasonable match with nearby well HCA-21. During model calibration, it appeared that the trench flooding caused the stage of the feature to slowly increase over time, rather than one specific stage, and that the ultimate stage was somewhat higher than the elevation of the discharge pipe, which is 5,428.23 feet MSL. The conductance of this trench was treated as a calibration parameter.

The Metals Treatment Lagoons were not represented as boundary conditions in the model. Tetra Tech compared water levels over time near these lagoons with stages of the lagoons, and there appeared to be no clear relationship, suggesting these lagoons are not well connected with groundwater.

Well Package

The well package was used for the following features:

- NCRT and NHRT – Initially, an attempt was made to model these features with the drain package. However, the drain package cannot effectively represent these features since the extraction rate is controlled with pumping. During the period that was modeled, the reported extraction rates at these features were 210 gpm (40,428 cubic feet per day [ft^3/d]) at the NCRT and 125 gpm (24,064 ft^3/d) at the NHRT. If a drain boundary is used, then flow to the drain decreases as the WWTP dewatering lowers the aquifer water levels, such that the actual extraction rates would not be accurately represented. In actuality, the drain extraction rates were kept constant using a pump. Therefore, the only way to accurately represent the constant pumping rate at the NCRT and NHRT was to use a series of extraction wells, with the total extraction rate for each trench divided evenly between the cells representing that trench. The trenches were implemented by assigning the pumping wells in layer 3 (consistent with the bottom elevation of each trench), but assigning a high vertical hydraulic conductivity in those locations (the cells with the wells in layer 3, and the same cells in layers 1 and 2) so the wells would pull water effectively from both the shallow and deep portions of the alluvial aquifer consistent with measured water levels. With respect to the NCRT, it was noted in Section 2.6 that based on the observed patterns in water level, which show lower heads near the western part of the trench, the site operator indicated that it was possible that there was preferential extraction from the western part of the trench. However, the model suggests that the observed pattern of heads occurs with pumping distributed evenly along the trench. The equal distribution of extraction was assigned since there is no other basis for assuming an unequal pattern of extraction along the trench.

- WWTP Dewatering – The same issue regarding the use of drains also pertains to these features. In addition, the information provided by Scott Murphy of Morrison and Maierle, Inc. indicated that dewatering was not operated in manner that led to dewatering down to the total depth of the sumps. As a result, the pumps are best represented in a numerical model based on pumping rates that were provided using the well package, rather than as drains. Therefore, each of the two pumps (Pump-1 and Pump-2) was represented with a series of wells in the regions where each pump is connected to drains, with the total pumping rate for each region divided evenly between the wells and assigned in layer 3. A lower resistance to vertical flow was applied in model layer 2 for the region where WWTP structures exist relative to the adjacent area, allowing for dewatering to affect both the shallow and deep portions of the aquifer (consistent with observations that there is response to pumping in both shallow and deep portions of the aquifer, though there is less response in shallow portions of the aquifer). The overall extraction rates for Pump-1 and Pump-2 were previously summarized on Figure 4-1, and the assignment of rates by stress period for the transient calibration is presented in Table 8-1.

General Head Boundary Package

A small line of general head boundary cells was placed in each model layer along the far western boundary of the model (see Figure 8-4), perpendicular to where Silver Bow Creek exits the model (for a distance of approximately 500 to 1,000 feet on either side of Silver Bow Creek). The purpose of these boundary cells is to allow some water to exit the western model edge, rather than forcing all water to discharge to Silver Bow Creek. This representation is more realistic. These boundary cells were assigned relatively high values of conductance, so they act much like specified head boundaries.

8.5 NUMERICAL SOLUTION

The PCG2 solution package in MODFLOW-2000 was used to iteratively solve the finite difference equations for flow. Because it is a nonlinear (unconfined) solution, both inner iterations (maximum of 50) and outer iterations (maximum of 100) were used. MODFLOW updates the transmissivity of the unconfined layer at the beginning of each of the outer iterations based on the calculated saturated thickness. A convergence criterion of 0.0005 feet and a residual criterion of 10 ft^3/d were used, and the resulting mass balance error reported by MODFLOW was sufficiently small. The achieved mass balance error was generally 0.01 percent to 0.15 percent or less in each stress period, and generally less than 0.01 percent cumulative for the simulation.

8.6 CALIBRATION APPROACH

Calibration of a groundwater flow model is the process of adjusting model calibration parameters within reasonable ranges to obtain an acceptable match between observed and simulated heads, flow directions, or other calibration targets. The model parameters considered to be varied during the calibration were:

- Hydraulic conductivity (horizontal)
- Vertical anisotropy
- Specific yield (S_y) for model layer 1
- Specific storage (S_s) for other layers - note that storage coefficient (S) is the specific storage multiplied by the aquifer thickness
- Net recharge initially assigned as zero, but some assignment of net recharge was considered during the calibration process as part of the sensitivity analysis
- Conductance of the HCC
- Conductance of Silver Bow Creek

- Conductance of the trench flooded just north of the NCRT (and to some extent, the boundary head)

- Boundary head at northern and southern edges of the model.

The approach was to generally avoid the assignment of zones for parameter values, unless they seemed appropriate conceptually or significantly improved the fit between simulated and observed values. The final parameter zone assignments in the calibrated model are indicated on Table 8-2 and are illustrated on Figures 8-5 to 8-8.

Two types of calibration were performed:

- Steady-state calibration was performed based on conditions that occurred prior to the beginning of the Phase 1 dewatering on August 13, 2009 (water levels from late July and early August were used as targets). This calibration was represented by "stress period 1" indicated on Table 8-1, and it was identified as "steady-state" within MODFLOW (no change with respect to time, so the length of time for this stress period is not material).

- Transient calibration was performed for the period from August 13, 2009 through April 25, 2010. The transient calibration consisted of stress periods 2 to 20 on Table 8-1. This period covered two periods of dewatering at the WWTP, changes to the BRW pond elevations, and flooding of the trench north of the NCRT that began in March 2010 (see Table 8-1). This transient calibration compared observed changes in water levels during that period of time versus simulated values. The final water levels from the steady-state calibration serve as the initial heads (drawdown reference) for the transient calibration.

Goals for the steady-state calibration included the following:

- The mean of the residuals (observed minus simulated values) should be close to zero to indicate that there is not much bias for simulating values too low or too high.

- The absolute residual mean (which is the mean of the absolute value of each residual) divided by the range of observed values at the targets should be at most between 5 percent and 10 percent, and ideally less than 5 percent.

- A plot of simulated versus observed values should generally follow a 45-degree line, with little bias toward simulating values too high or too low.

The steady-state simulation should also yield flow patterns consistent with expectations. The goal for the transient simulation is to match observed changes in water level over time as well as possible. This calibration exercise required an iterative approach, in that modifications made for matching the transient responses needed to also be reasonable for the steady-state calibration, and vice-versa.

8.7 STEADY-STATE CALIBRATION RESULTS

A comparison of simulated versus observed water levels for all of the steady-state targets, and the values for key calibration statistics, is presented on Table 8-3. The "calibration statistics" tool within Groundwater Vistas was used to calculate the calibration statistics and prepare a "45-degree line plot" for the steady-state calibration. These results are presented on Figure 8-9. Observations from Table 8-3 and Figure 8-9 include the following:

- The mean of the residuals ("residual mean") is 0.03 feet, which is very close to the target of zero and indicates that there is not much bias for simulating values too low or too high.

- The absolute residual mean (which is the mean of the absolute value of each residual) is 0.84 feet, and the absolute residual mean divided by the range of observations (42.35 feet) is 1.99 percent, which is significantly below the 5 percent to 10 percent range, which is a commonly used target for this type of comparison.

- The root mean squared (RMS) error is also presented on Table 8-3 (calculated by squaring each residual, summing to yield the sum of squares, dividing by the number of observations, and then taking the square root). The RMS error, which will always be greater than the absolute residual mean, is 1.27 feet, and the RMS divided by the range of observations (42.35 feet) is 3.00 percent.

- The plot of simulated versus observed values generally follows a 45-degree line as desired, with little bias toward simulating values too high or too low.

Both the statistics and the 45-degree line plots presented on Figure 8-9 indicate the match between simulated and observed values is very good (R^2= 0.9783, where 1.0 is a perfect fit). Several potential targets were excluded from the steady-state calibration, for the following reasons:

- Three monitoring wells at the southwestern corner of the MPTP site (MW-H-96, MW-G-96, and MW-F-96) were not used in the calibration. (These wells are also referred to as 96-H, 96-G, and 96-F.) The observed water levels at these wells are much higher than at other wells on the site, and the screened intervals are also higher. It is possible that these wells monitor perched conditions that are disconnected from the aquifer system that is represented by the model. For instance, the measured water level at MW-G-96 is greater than 5,450 feet MSL, which is on the order of 20 feet higher than most of the on-site monitoring wells. This concept of perched conditions in the southwestern corner of the MPTP site is consistent with the transducer results at MW-96-H, which show no response to the WWTP dewatering. The model suggests that some response to the WWTP dewatering would be expected at that location (see plot in Appendix C for MW-H-96), and the fact that no response was actually observed is consistent with the idea that MW-96-H monitors perched water that is disconnected from the aquifer being modeled.

- One monitoring well (RLP-W), located just west of the Metals Treatment Lagoons, was eliminated because it has a much higher water level (by 6 to 7 feet) than several nearby water levels. The target was eliminated given the consistent water levels at the other wells and the proximity to surface water that suggests the water level at RLP-W is unrealistically high.

Some of the targets for the steady-state calibration were far east of the MPTP site, between Blacktail Creek and the Metro Storm Drain. These targets were included to ensure that the model was reasonably representing the regional flow condition. Water levels in that portion of the model did not match quite as well because no attempt was made to rigorously calibrate model parameters in that area, but water levels were generally reproduced with approximately 2 feet in that area, with reasonable flow patterns toward Blacktail Creek and the Metro Storm Drain.

Simulated water levels near the NCRT and WWTP for the steady-state calibration (before Phase 1 dewatering) are illustrated on the following figures:

Figure 8-10:	Layer 1
Figure 8-11:	Layer 2
Figure 8-12:	Layer 3

These figures also include model residuals in that area (observed minus simulated). Observations from these figures include the following:

- The residuals near the NCRT are low in all three model layers.

- Groundwater discharges to the HCC in layer 1, consistent with the conceptual model, illustrated by the "V" pattern pointing upstream. Adjacent to the MPTP site, Silver Bow Creek provides water to the aquifer, also consistent with the conceptual model.

- The NCRT and NHRT have higher water levels at the eastern ends rather than the western ends, consistent with field observations. Note that these levels are not caused by increased extraction at the western end of the trench. Based on the observed water level patterns, which show lower heads near the western part of the trench, the site operator indicated that it was possible that there was preferential extraction from the western part of the trench (discussed in Section 2.6). However, the model suggests that the observed pattern of heads occurs with pumping distributed evenly along the trench. Since there is no other basis for assuming an unequal pattern of extraction along the trench, the equal distribution of extraction was assigned.

- The NCRT captures water from wells to the north in model layer 3, but the flow divide in model layer 1 appears to correspond to the location of Silver Bow Creek.

- There is generally a downward hydraulic gradient from layer 1 to layer 3, though near the HCC the hydraulic gradient is upward, consistent with the conceptual model.

- There is some clustering of residuals (groups of adjacent locations simulated too high or too low), which is likely a result of heterogeneity in aquitard properties or aquifer properties beyond that represented in this model.

Regional flow patterns represented in the model are illustrated in Figure 8-13. Key features are higher water levels north and south of the alluvial valley, flatter hydraulic gradients in the alluvial valley, and groundwater flow generally from east to west, with discharge to surface water bodies such as Blacktail Creek, the Metro Storm Drain, the HCC, and Silver Bow Creek west of the Metals Treatment Lagoons. Although no attempt is made to match the exact regional flow pattern (which is not well documented), this representation matches the overall conceptual model and provides a reasonable regional flow representation for this level of modeling.

Velocity vectors (that illustrate flow directions) between the NCRT and WWTP are presented for this steady-state simulation on Figure 8-14 (layer 1) and Figure 8-15 (layer 3). Observations on the simulated flow patterns prior to dewatering at the WWTP and the BRW ponds include the following:

- Figure 8-14 (model layer 1): Silver Bow Creek (which provides water to the aquifer) acts as a flow divide, such that groundwater flow in layer 1 north of Silver Bow Creek is to the HCC, and groundwater flow in layer 1 south of Silver Bow Creek is toward the NCRT. Groundwater in layer 1 discharges to the HCC from both the south and the north, consistent with the site conceptual model.

- Figure 8-15 (model layer 3): Groundwater in layer 3 east of the WWTP generally flows toward the NCRT and groundwater adjacent to (and immediately south of) the WWTP flows to the west.

There is also an upward hydraulic gradient from layer 3 to layer 1 near the HCC that is not clearly indicated on Figures 8-14 and 8-15.

8.8 TRANSIENT CALIBRATION RESULTS

The water levels from this steady-state calibration are used as the initial conditions for the transient calibration. The stress periods used for the transient calibration, and stresses applied in each period (e.g., the WWTP dewatering extraction rates, the BRW pond elevations, and the trench flooding elevations) are summarized on Table 8-1. Some simplification was required because it is not practical to assign a unique stress period for every time the dewatering extraction rates changed (which was essentially every day) or every time the pond elevations changed. The WWTP dewatering extraction rates were assigned as "representative values" for each of the model stress periods, based on visual inspection of the daily rates. These simplifications obviously cause some deviation between simulated and observed drawdown patterns.

Hydrographs illustrating the transient match between simulated and observed conditions are presented in Appendix C. The observed values on these plots are a combination of hand-measured water levels from before the transducers were installed, plus the subsequent transducer readings. For wells 10-01 to 10-15, which were installed after the transient modeling period began, the drawdown at the beginning of the transducer measurements was estimated so the remainder of the modeled period could be evaluated.

Storage coefficient, which affects how fast drawdown approaches a steady-state value (the curvature of the drawdown curve), was assigned by model layers, with no further refinement by zone. In some cases where the drawdown reaches a reasonable value after some period of time, but occurs too quickly, the storage coefficient may be too low. However, the storage coefficients assigned provide a reasonable "curvature" match to the vast majority of observations. The calibrated values of storage coefficient assigned in the model are as follows:

- Model layer 1:	S_s = N/A	S_y = 0.05
- Model layer 2:	S_s = 0.0015	S_y = 0.05
Model layer 3:	S_s = 0.0015	S_y = 0.05

The simulated drawdown patterns match the observed patterns very closely for many of the hydrographs in Appendix C, while others do not match as closely. Some observations from the figures in Appendix C include the following:

- The match is quite good at monitoring locations closest to the WWTP (such as BWM-13B, GS-34S, and GS-25C), where drawdown caused by WWTP pumping is greatest.

- There is also a reasonable representation of higher drawdown in deeper monitoring wells (such as BMW-9B and GS-25C) versus lower drawdown in shallower monitoring wells (for example, BWM-9A and GS-25).

- Although observed data are not available for newly installed wells 10-01 to 10-15 for the entire transient calibration period, the hydrographs for these wells illustrate that the model reasonably differentiates a strong response to WWTP extraction in deeper monitoring wells (such as 10-01, 10-03, 10-06, 10-08, and 10-09) and little or no response in shallower monitoring wells that are screened above a clay/peat layer (for example, 10-02, 10-04, and 10-11). Intermediate responses at locations 10-12 and 10-14 are also reasonably simulated.

- At location HCA-21, the total drawdown caused by the WWTP and BRW dewatering reaches the appropriate level but occurs too fast, indicating that the uniform value of the storage coefficients assigned in the model may be too low for this area. However, the impact of the trench flooding in the latter part of the simulation is well matched at HCA-21.

- As discussed earlier, location MW-H-96 was eliminated as a target for the steady-state calibration (along with several other nearby locations) because it has higher water levels than other on-site wells and may represent perched conditions. The plot for location MW-H-96 in Appendix C is consistent with this concept because the model predicts a drawdown response would occur at that location, which is not reflected in the observed conditions. The lack of drawdown response in the observed values suggests the zone monitored by that well is not in good connection with the aquifer material represented by layer 1 in the model (it may be perched).

- Some of the hydrographs at locations south of the HCC and Silver Bow Creek match well (for example, BMW-9A/9B, GW-14R-98, GS-18R, and GW-13), but at others there is either too much simulated drawdown response (early portions of GW-06R and HCA-21, latter portions of BMW-01A and GW-12) or too little drawdown (early portions of GW-10, GS-22, and MW-9). Some of this variation may be explained by heterogeneity that is not fully represented in the model (regarding the aquifers, aquitard, and the conductance of surface water boundary conditions, including the HCC and Silver Bow Creek). However, some variation could also be a result of response to other unknown transient conditions. For example, while the early portions of the hydrographs for some monitoring locations at the MPTP site do not match very well (such as GW-10, GS-22, and GW-9), the drawdown patterns in the latter portions seem to match well. The poor match in the early portion of the calibration period suggests there may have been some changes in water levels occurring at the MPTP site early in the transient calibration period caused by unknown stresses above and beyond the transient stresses represented in the model.

- Near the BRW ponds, shallow monitoring location GS-16 matches the overall change in water level (which is primarily caused by adjustments in the BRW pond elevation) quite well, though the simulated values change quicker than the observed values. This quicker response in the simulated response may be caused by the storage coefficient being too low, but may also be a result of the pond elevation changing more gradually in real life than is represented in the model.

Deeper monitoring location GS-17-DR, also located near the BRW ponds, also matches quite well.

Overall, given the complexity of this site, the transient match is quite reasonable, though some improvements are possible with additional modeling effort.

Velocity vectors (that illustrate flow directions) between the NCRT and WWTP are presented for the following stress periods (see Table 8-1 for stresses in each stress period) as follows:

- Figure 8-16: Layer 1, WWTP Dewatering and BRW-01W Dewatering (Stress Period 5)
- Figure 8-17 Layer 3, WWTP Dewatering and BRW-01W Dewatering (Stress Period 5)
  Figure 8-18: Layer 1, WWTP Dewatering with no BRW-01W Dewatering (Stress Period 9)
- Figure 8-19: Layer 3, WWTP Dewatering with no BRW-01W Dewatering (Stress Period 9)
- Figure 8-20: Layer 1, WWTP Dewatering with Trench Flooding (Stress Period 19)
- Figure 8-21: Layer 3, WWTP Dewatering with Trench Flooding (Stress Period 19)

These figures can be compared with each other and also can be compared with similar figures for the simulated steady-state conditions before the Phase 1 dewatering (Figures 8-14 and 8-15). Observations regarding these figures include the following:

- Stress Period 5 (WWTP Dewatering plus BRW-01W Dewatering) – In layer 1, flow patterns near the NCRT are not substantially changed by the dewatering, but near the HCC groundwater now flows under the HCC from south to north toward the WWTP extraction (rather than converging toward the HCC without dewatering). There is a more substantial change in flow patterns in layer 3. The capture zone of the WWTP extraction extends well south of Silver Bow Creek, to the second power pole. The southernmost power pole is the “first” power pole for this discussion. The simulated flow directions from the power poles toward the WWTP, for this period of dewatering at the WWTP and the BRW-01W pond, is extremely consistent with the observed distribution of PCP illustrated on Figure 6-1.

- Stress Period 9 (WWTP Dewatering with no BRW-01W Dewatering) – In layer 1, flow is essentially similar to the case for stress period 5. The termination of BRW dewatering has little or no impact. The capture zone in layer 3 does not extend quite as far south as in period 5. However, based on other simulations performed, this slightly reduced capture zone results because the WWTP extraction rate in stress period 9 is 5 gpm lower than in stress period 5, rather than from a change in the BRW pond dewatering.

- Stress Period 19 (WWTP Dewatering plus Trench Flooding) – In layer 1, there is a significant impact from the trench flooding. The trench flooding creates a flow divide, such that flow in layer 1 north of the flooded trench is toward the north (rather than toward the NCRT as in stress periods 5 and 9). However, no such flow divide is created in layer 3, and the capture zone of the WWTP in stress period 19 again extends south to the second power pole in layer 3.

The WWTP dewatering significantly alters the capture zone of the NCRT in model layer 3. This alteration is clear when Figure 8-15 (no dewatering) is compared with Figures 8-17 and 8-19 (with dewatering). The WWTP dewatering allows PCP-contaminated groundwater in layer 3 to be drawn beyond the capture zone of the NCRT to the north, which potentially creates a problem when dewatering is terminated. The model results suggest that PCP-contaminated groundwater pulled north of the NCRT capture zone in layer 3 (from the WWTP dewatering) will not subsequently be captured by the NCRT and treated. Some of the PCP-contaminated groundwater may flow up and into the HCC, and some may flow to the west in groundwater as a secondary plume, when the dewatering is terminated and the flow system returns to a pattern similar to Figure 8-15 (for the deeper alluvium).

Simulated drawdown for these same stress periods for model layers 1 and 3 are presented as follows:

- Figure 8-22: Layer 1, WWTP Dewatering and BRW-01W Dewatering (Stress Period 5)
- Figure 8-23 Layer 3, WWTP Dewatering and BRW-01W Dewatering (Stress Period 5)
  Figure 8-24: Layer 1, WWTP Dewatering with no BRW-01W Dewatering (Stress Period 9)
- Figure 8-25: Layer 3, WWTP Dewatering with no BRW-01W Dewatering (Stress Period 9)
- Figure 8-26: Layer 1, WWTP Dewatering with Trench Flooding (Stress Period 19)
- Figure 8-27: Layer 3, WWTP Dewatering with Trench Flooding (Stress Period 19)

These figures illustrate the complex pattern of drawdown caused by different stresses over time (such as BRW pond dewatering or trench flooding), coupled with the interaction of groundwater with surface water features. Note that although it appears on some of these figures that there is additional drawdown in layer 1 centered around the NCRT, it is not caused by changes in extraction rates at the NCRT. Instead, it results from drawdown propagating from model layer 3 coupled with the system geometry (which causes drawdown in model layer 1 to be tempered near Silver Bow Creek).

8.9 DISCUSSION OF MODEL CALIBRATION AND SENSITIVITY ANALYSIS

Additional observations regarding the calibration simulations and additional simulations performed by Tetra Tech include the following:

- A zone of high hydraulic conductivity near the trench was needed in model layers 1 and 3 to achieve the correct distribution of water levels near the NCRT. Without those zones of higher hydraulic conductivity, the model would simulate too steep of a hydraulic gradient toward the trench. Additionally, a zone of lower hydraulic conductivity was assigned in model layer 1 near the remnant portion of Old Silver Bow Creek, which was flooded with treated water during the latter part of the transient calibration period, to improve the match of the aquifer response to that flooding.

- Although the model simulations suggest that WWTP dewatering creates a capture zone that extends to the second power pole in the deeper alluvium, there are no simulation periods before the trench flooding where groundwater flow in model layer 1 (shallow alluvium) is toward the north in the vicinity of the 10-01/10-02/10-15 cluster. Referring to Figure 6-1, shallow monitoring location 10-02 had a high PCP reading of 281 µg/L on March 8, 2010 (prior to trench flooding), with lower concentrations after trench flooding. These results suggest that shallow PCP impacts in that area (near 10-02) are likely from the third power pole, which is just east of that location, rather than the first power pole, given the groundwater flow direction toward the south in that area in model layer 1. Thus, it appears that there is the potential for continuing sources of PCP to exist beneath multiple power poles, and not just the southern power pole.

- The BRW-01W pond was dewatered for construction, but the BRW-01W and BRW-01E pond were kept at a lower elevation (approximately 5427 feet MSL) than previous elevations (approximately 5,430 feet MSL for BRW-01W and 5,432 feet MSL for BRW-01E) after the construction was completed in December 2009. The lower pond elevations caused a widespread long-term decline in water levels across the entire area of interest, as is illustrated on Figure 8-28, which presents the simulated drawdown at selected wells caused only by elevation changes at the BRW ponds. These figures suggest that the changes in BRW pond elevation cause only a small portion of the overall observed drawdown; the rest is caused by the WWTP dewatering. Note that observed water levels did not fully recover to pre-extraction levels after the first period of dewatering (there was still approximately 0.5 feet of drawdown), and these results suggest the likely reason is the lower BRW pond elevations after construction was completed.

- The steady-state calibration period was further evaluated with respect to flow volumes for key boundary conditions. Approximately 3,400 gpm is added to the model at the specified head boundaries at the northern and southern edges of the model (combined) within the model domain. This inflow makes up the water that ultimately discharges to surface water from both the north and the south (which includes the HCC, Metro Storm Drain, Blacktail Creek, and Silver Bow Creek well west of MPTP). This inflow was compared to reported flows in Old Silver Bow Creek at the time of the RI (which was the primary discharge point at that time for groundwater). The RI indicated that, at that time, flow in Old Silver Bow Creek near the MPTP site was on the order of 10 cfs (approximately 4,500 gpm) and farther downstream at the USGS gaging station was approximately 20 cfs (approximately 9,000 gpm). The difference (approximately 4,500 gpm) included discharge from groundwater and flows discharged by the WWTP. It seems that the amount of water simulated in this model entering the valley from the hills (approximately 3,400 gpm) is the correct order of magnitude for this system. The steady-state calibration period also includes 347 gpm discharging to the HCC along its entire length. Of that total, approximately 92 gpm discharges from groundwater upstream of GS-25, and approximately 255 gpm discharges from groundwater downstream of GS-25. The magnitude of these numbers is consistent with overall flows reported for the HCC (i.e., the correct order of magnitude).

- A sensitivity analysis simulation was performed where the extraction rate in stress period 9 (which lasts for 9 days) was increased by 25 percent versus the actual value. The velocity vectors for model layer 3 for that scenario are presented in Figure 8-29 (which can be compared with Figure 8-19). The results show that the capture zone for the WWTP extends just slightly farther south after 9 days.

- Another sensitivity simulation was performed, with 25 percent extra pumping in period 9, with period 9 extended from 9 days (Figure 8-29) to 30 days (Figure 8-30), and then to 365 days (Figure 8-31). In addition to the velocity vectors, the simulated drawdown contours are also included on these figures. The drawdown contours deepen slightly as the period of pumping is extended, but there is little or no change to the velocity vectors. This simulation demonstrates that the flow system responds to stresses relatively quickly, with little subsequent change in the flow system and capture zones until the stresses are once again modified.

- The calibration efforts determined that the simulation of drawdown (and steady-state water levels) is sensitive to the conductance of the HCC and Silver Bow Creek. Increasing the conductance of these features significantly reduces the drawdown in both layer 1 and layer 3.

- The calibration efforts also determined that the simulation of drawdown (and steady-state water levels) is sensitive to the vertical hydraulic conductivity of the aquitard. Increasing the value causes too little drawdown in layer 3.

- The calibrated base values for horizontal hydraulic conductivity of 125 ft/day in layer 1 and 120 ft/day in layer 3 are consistent with the representative value of 100 ft/day estimated from previous aquifer tests (see Section 3.2). Similarly, the calibrated values for storage properties are consistent with expected values discussed in Section 3.2.

- Several sensitivity simulations were performed to assess the simplified representation of the hills north and south of the site. As detailed in Section 8.3, a combination of specified head boundaries and parameter assignments was used to provide a source of groundwater in the hills north and south of the valley (primarily bedrock), which then serves as a source of water to the alluvial valley. In the base model, the amount of groundwater added in the hills (combined north and south) was approximately 3,419 gpm. The goal of these sensitivity runs was to decrease and increase the amount of water provided from the specified boundaries in the hills north and south of the valley and then adjust hydraulic conductivity values to re-establish a reasonable match between simulated and observed values for both the steady-state and transient calibration. A summary of these simulations is provided below:

    - *Run 6a (less water added to hills)* – Achieved by using lower hydraulic conductivity adjacent to the constant head boundaries versus the base run (3.6 ft/day rather than 4.5 ft/day). Less water is added at the specified head boundaries (2,904 gpm versus 3,419 gpm). Values of hydraulic conductivity were modified (increased to 150 ft/day as base value in valley) to re-establish a reasonable match in the area of primary interest. The steady-state calibration statistics change as follows: mean error changes from 0.03 feet to 0.34 feet; and absolute residual mean changes from 0.84 feet to 0.86 feet. This match is not quite as good as the base case. The transient match to observed drawdown at key locations (Figure 8-32) is good.

    - *Run 6b (even less water added to hills)* – Achieved by using lower hydraulic conductivity adjacent to the constant head boundaries versus the base run (2.25 ft/day rather than 4.5 ft/day). Less water is added at the specified head boundaries (2,261 gpm versus 3,419 gpm). Values of hydraulic conductivity were modified in the valley (increased to 200 ft/day) and hydraulic conductivity in the foothills was also increased in an attempt to re-establish a reasonable match in the area of primary interest. The steady-state calibration statistics change as follows: mean error changes from 0.03 feet to 0.58 feet; and absolute residual mean changes from 0.84 feet to 1.08 feet. This match is not as a good as the base case. The transient match to observed drawdown at key locations (Figure 8-33) is poor. It appears that it is hard to match the steady and transient targets well with this little water added to the hills.

    - *Run 6c (more water added to hills)* – Achieved by using higher hydraulic conductivity adjacent to the constant head boundaries versus the base run (6.0 ft/day rather than 4.5 ft/day). More water is added at the specified head boundaries (3,591 gpm versus 3,419 gpm). Values of hydraulic conductivity were unchanged in the valley and hydraulic conductivity in the foothills was decreased to re-establish a reasonable match in area of primary interest. The steady-state calibration statistics change as follows: mean error changes from 0.03 foot to 0.01 feet; and absolute residual mean is unchanged from 0.84 feet to 0.84 feet. This match is essentially the same as the base case. Transient match to observed drawdown at key locations (Figure 8-34) is good.

These simulations can then be used to indicate how changes in the amount of flow entering the alluvium from the hills north and south alter the simulated results for drawdown caused by WWTP dewatering and the resulting impacts on the flow system. Results are illustrated on the following figures:

- Drawdown caused by WWTP dewatering, model layer 3, stress period 5:

Figure 8-23:	Base Run
Figure 8-35:	Run 6a (less water added to hills)
Figure 8-36:	Run 6b (even less water added to hills)
Figure 8-37:	Run 6c (more water added to hills)

- Flow Vectors between NCRT and WWTP with WWTP dewatering, model layer 3, stress period 5:

Figure 8-17:	Base Run
Figure 8-38:	Run 6a (less water added to hills)
Figure 8-39:	Run 6b (even less water added to hills)
Figure 8-40:	Run 6c (more water added to hills)

These figures for runs 6a and 6c (versus the base case) illustrate that the amount of water added to the hills north and south of the valley, using the simplified representation described in Section 8.3, has only a minor impact on the simulated drawdown and flow vectors that result from the WWTP dewatering. The drawdown pattern remains generally radial, and the extent the capture zone of the WWTP extraction extends toward the NCRT is similar to the base run. These results confirm that use of this simplified boundary representation for the hills does not significantly affect the modeling results and does not alter the modeling conclusions. The drawdown and flow vector results for run 6b are not as important because that run does not yield a good match between simulated and observed conditions. The fact that it was difficult to re-establish a good match for the steady-state and transient targets for sensitivity run 6b (even less water added to the hills than run 6a) suggests that the amount of water added to the hills in run 6b is too low.

- The numerical modeling started with the assumption that net recharge is accounted for in the flow that enters the model domain from upgradient boundaries (no net recharge was applied). It appears that net recharge from precipitation was not significant over the period modeled. It is possible that there was net recharge in the months before August 2009 and that some observed drawdown during the period modeled could result because background water levels decreased during this drier period. Some simulations were performed with a small amount of net recharge specified in the steady-state period, but discontinued in the transient period. The results were mixed; some transient hydrographs matched better, and some matched worse. However, the results presented in this report assume no net recharge for the entire simulation.

- The modeling illustrates that WWTP dewatering and the lowering the BRW pond elevations both contributed to drawdown near the NHRT. The modeling cannot determine if these contributions are the cause of the decrease in concentrations observed at the NHRT, though there is certainly a correlation, and it makes sense that water levels may have been drawn down below the elevation where the highest concentrations of residual PCP in soil are located.

8.10 SIMULATIONS FOR POTENTIAL MITIGATION STRATEGIES

Simulations were performed to evaluate two potential mitigation approaches to future WWTP dewatering. These approaches involve increased extraction of water by MPTP during WWTP dewatering to extend the capture zone of the MPTP remedy farther north and reduce the extent of WWTP capture to the south. The two approaches are as follows:

- Add one or more new extraction wells north of the NCRT and extract water from these wells during periods of WWTP dewatering (compare with Figure 8-17 for the case without mitigation):

  Figure 8-41: Flow vectors with new well at 50 gpm (layer 3, stress period 5)
  Figure 8-42: Flow vectors with new well at 100 gpm (layer 3, stress period 5)

- Increase extraction at the NCRT during periods of WWTP dewatering (compare with Figure 8-17):

  Figure 8-43: Flow vectors with 50 gpm additional at NCRT(layer 3, stress period 5)
  Figure 8-44: Flow vectors with 100 gpm additional at NCRT(layer 3, stress period 5)

In either case, the additional water that would be extracted would be treated by the MPTP treatment plant. Comparison of these figures to Figure 8-17 (the equivalent figure without mitigation) indicates that either strategy is potentially viable for reducing the southern extent of capture of the WWTP dewatering. Without mitigation (Figure 8-17), the capture zone of the WWTP during dewatering extends well to the south of Silver Bow Creek and location 10-2, approximately as far south as location MW-87-3. Adding one well at 50 gpm (Figure 8-41) keeps the capture zone of the WWTP north of Silver Bow Creek near location 10-2, and adding one well at 100 gpm (Figure 8-42) keeps the capture zone of the WWTP even farther north. If one well cannot produce the simulated amount of water, multiple wells could be installed near each other. For the simulation with 50 gpm added at the NCRT (Figure 8-43) the capture zone of the WWTP is pushed further to the north versus the case with no mitigation, but not enough to keep the capture zone of the WWTP from extending the vicinity of 10-02. However, for the simulation with 100 gpm added at the NCRT (Figure 8-44) the capture zone of the WWTP is pushed to the approximate location of Silver Bow Creek (i.e., near location 10-02) and includes the third power pole.

The MPTP operator indicated the following regarding these potential mitigation approaches:

- Additional flow of 100 gpm (or slightly more) could likely be accommodated at the MPTP treatment plant with relatively simple modifications (which might include an additional mobile carbon treatment unit).

- The biggest complications in drilling one or more new wells north of the NCRT will be the terrain for drilling (currently under water because of a beaver dam) and the difficulty of piping the water to the south posed by the railroad tracks.

- It is possible to use a larger 10-horsepower or 15-horsepower pump at the NCRT (versus the current 5-horsepower pump) to extract an additional 100 gpm or more. The pump works off a variable frequency drive such that additional extraction could be achieved during periods of WWTP dewatering and throttled back for normal operation without too much inefficiency with respect to electricity use.

The simulations illustrate that additional extraction from the NCRT is needed to provide equivalent mitigation from a new pumping well located close to location 10-02 because the NCRT is located farther south than the potential new well. However, the logistics of increasing the extraction at the NCRT are likely much more simple than adding one or more new wells and associated piping north of the NCRT.

9.0 RECOMMENDATIONS

The following recommendations are offered:

- The conceptual modeling effort, coupled with the numerical simulations, suggest the potential for a continuing source of PCP beneath the power poles located north of the NCRT. It is recommended that these potential source areas be investigated. If they are determined to be a continuing source of PCP impacts, some form of remediation may be appropriate. Investigation might be performed with soil cores or a backhoe (as logistics allow) around each power pole, with observations of soil staining and odor, presence of carrier oil, and chemical analysis of soil for total petroleum hydrocarbons and PCP. The details of an investigation are beyond the scope of this report and would be developed in a work plan. If the investigation confirms that a source of PCP exists under one or more poles, remedial approaches could include excavation (which would likely require relocation of the poles) or in situ techniques such as bioventing (which might not require relocation of the poles).

- The trench flooding appears to provide limited benefit because it does not mitigate the potential for the WWTP to capture PCP migrating in model layer 3. If there are continuing sources of PCP beneath power poles north of the flooded trench, flooding the trench may cause transport of these impacts to the north toward the HCC, rather than toward the NCRT. Although initiation of trench flooding was reasonable given the circumstances at the time, discontinuing the trench flooding should be considered.

- Two potential approaches were evaluated with the simulation model to mitigate the extent of capture of WWTP extraction wells during future construction dewatering at the WWTP. One approach is to extract water from one or more new wells near location 10-2 (north of the NCRT) during WWTP dewatering. The other is to extract more water from the NCRT during WWTP dewatering. In either case, the additional water that would be extracted would be treated by the MPTP treatment plant. The logistics of the extracting more water from the NCRT appear to be simpler. It is recommended that a detailed feasibility analysis and cost estimate be prepared for potential modifications to the MPTP treatment plant that might be required for these mitigation strategies to be implemented. It is also recommended that a short-term test of approximately 1 week be performed with additional extraction of 50 to 100 gpm at the NCRT (such that the capture zone of the NCRT is not diminished during the test). Changes in water levels during this test could be obtained from existing transducers at monitoring wells located near the NCRT, and these observed changes in water level could be compared with simulated changes predicted by the model to validate the model (or perhaps to improve the model). This comparison will add confidence that this mitigation measure would be successful.

- The regulators should assess the need to treat water extracted at the WWTP during future dewatering. Implementation of one of the mitigation measures suggested above should keep extracted PCP concentrations at the WWTP extraction wells lower than they would be without the mitigation measures, ideally precluding the need for treatment of extracted water at the WWTP extraction wells.

- Even if water extracted at the WWTP is treated, the model results suggest that PCP-contaminated groundwater pulled north of the NCRT capture zone in layer 3 (because of the WWTP dewatering) will not subsequently be captured by the NCRT and treated after dewatering is terminated. When dewatering is terminated, some of the PCP-contaminated groundwater pulled beyond the capture zone of the NCRT may flow up and into the HCC, and some may flow to the west in groundwater as a secondary plume. Thus, treating water extracted at the WWTP during future dewatering is not a completely effective strategy. The evaluation presented here is based on flow directions, and transport modeling was not performed to predict potential future concentrations of a secondary PCP plume that could flow to the west. The existing monitoring well network north of Silver Bow Creek would not likely provide a sufficient density of data to adequately generate a PCP isocontour map of the migration of residual contamination as a result of pumping during construction dewatering at the WWTP. However, data collected from the existing monitoring well network could document changes in water quality in an area of concern between the MPTP site and the WWTP. In addition, several monitoring wells that currently exhibit concentrations of PCP below 2 µg/L could be used as "sentinel" wells to monitor potential migration of contaminants (north of Silver Bow Creek) to the west. These monitoring wells include 10-06, 10-07, 10-12, and GW-06R. However, there are no monitoring wells immediately west of well BMW-13B. The potential ramifications of this outcome from the first phase of dewatering should be addressed from a regulatory perspective.

- It is hoped that addressing the potential ongoing sources of PCP impacts (at the power poles) will mitigate impacts from WWTP dewatering in the long-term.

- The numerical modeling presented in this report is a useful tool that could be improved with additional effort. Some improvements might include a more realistic representation of the regional stratigraphy to the north and south, additional calibration efforts regarding surface water conductance terms, and more heterogeneous representation of hydraulic conductivity (horizontal and vertical) and storage terms. These improvements would be recommended only if there is a perceived benefit of improving the tool beyond its current state.

Dewatering at the WWTP appears to cause flow conditions that lead to expansion of the PCP impacts north of the HCC. It causes the overall footprint of the area affected by PCP to be increased. There are plans for additional dewatering at the WWTP, perhaps for up to a year, related to ongoing construction. The recommendations above highlight issues that should be addressed prior to the next phase of dewatering. Addressing any remaining sources of PCP beneath the power poles (if confirmed) is a long-term solution that is recommended. Two approaches to mitigate the extent of capture of WWTP extraction wells during future construction dewatering at the WWTP were simulated, and further evaluation of one of those approaches (increased extraction at the NCRT during future dewatering) is recommended. Finally, the potential to contribute to a secondary groundwater plume of PCP when the dewatering is terminated (because PCP-contaminated water is pulled beyond the capture zone of the NCRT during dewatering), and the need to treat water that is extracted at the WWTP during future dewatering, should be considered further from a regulatory perspective.